

Award of the 2.3 and 3.4 GHz spectrum bands

Annexes to the statement

Publication date:

11 July 2017

Figure A9.1 header row
updated 25 July 2017

Contents

Annex		Page
1	Current state of the UK mobile market	2
2	Parameters of retail mobile competition	67
3	Mobile spectrum bands	78
4	International benchmark of spectrum holdings	97
5	Current network performance	125
6	Network investment and capacity growth	140
7	Commercial responses to managing data growth	157
8	Future credibility of MNOs	159
9	Responses on likelihood of strategic investment in the Auction	186
10	Likelihood of strategic investment in the Auction	261
11	Summary of other responses to our November 2016 competition assessment and Ofcom's comments	290
12	Additional analysis	323
13	Illustrative auction procedures	328
14	Glossary of terms	351

Annex 1

Current state of the UK mobile market

Introduction

- A1.1 In this annex we provide factual information on the current state of the UK mobile market. We include subscriber growth, market shares and pricing trends. Having considered the latest evidence and the responses to the November 2016 consultation, we consider that competition is generally working well, with strong competition between suppliers, commercial wholesale access and continued investment in new services. Compared to our November 2016 consultation we believe that the evidence on retail pricing is more mixed, but there is also some evidence of improved performance in the retail market from some MVNOs.
- A1.2 Specifically, in the pricing section of this annex we discuss the issues with the pricing analysis submitted by Frontier Economics on behalf of H3G, and why we consider it does not provide reliable evidence of overall price increases in the market. Nonetheless, we accept that the evidence provided in the Frontier Economics report questions whether we were right to suggest in the November 2016 consultation that price increases for some plans with handsets might be accounted for by rising handset costs. Our revised view in light of the evidence now available to us is that in recent years there have been price reductions for some types of tariff as well as price increases for others.
- A1.3 The updated 2016 market data¹ shows that market concentration indices have also continued to decrease, albeit at a slower pace.² This has been driven by the increased subscriber market share of H3G, which had the highest number of net additions for the second half of 2016. There is some evidence of increased competition at the retail level as a result of improved performance by some MVNOs.
- A1.4 This annex is structured as follows:
- Summary of November 2016 consultation
 - Summary of responses
 - General state of the UK market
 - Recent changes to the structure of the market
 - Retail mobile market
 - Wholesale mobile market
 - Evolution of UK mobile pricing
 - Mobile revenues
 - Effects of spectrum shares on competition
 - International comparison of network quality
 - Additional competition considerations

¹ Updated to December 2016, where available.

² In our consultation, we estimated the Herfindahl-Hirschman Index (HHI, a measure of market concentration; the higher its value, up to a maximum of 10,000, the greater the market concentration) for Q1 2016 to be 1,990 while the HHI for Q4 2016 was 1,977.

- A1.5 Annex 2 considers the evidence on the key parameters that are important to consumers when they choose provider, and annex 5 considers the available evidence comparing the network quality of the MNOs.

Summary of November 2016 consultation

- A1.6 In annex 7 of our November 2016 consultation we presented a general overview of how the UK mobile market was performing, focusing on aspects such as subscriber growth, market shares, pricing trends and the current state of the UK mobile networks, among others. We based that annex on information provided by MNOs, our own basket-based pricing analysis, other Ofcom reports as well as reports by external parties (e.g. Enders Analysis and the European Commission).
- A1.7 That annex aimed to provide factual information about the current state of the UK mobile market and was not intended to be an exhaustive description of the current state of competition in the mobile sector in the UK.
- A1.8 Based on that evidence we argued that the UK mobile market was currently working well for consumers and businesses, with strong competition between the different MNOs. We considered that the UK enjoyed relatively low prices when compared to other countries, whilst seeing significant levels of investment in new products and services.
- A1.9 As evidence of the strong competition between MNOs we argued that O2 and H3G had continued to increase their market share over the years (despite having much smaller shares of spectrum than the other MNOs) while market concentration indices had continued to decrease since the merger between 2010 Orange and T-Mobile.
- A1.10 We also showed that prices of most SIM-only baskets decreased over the 2013-2016 period. One notable exception was the highest usage SIM-only basket, which reflected H3G's price increases for its plans with unlimited data allowance. For plans with handsets the evidence was mixed with some baskets experiencing price increases followed by price decreases. We argued that these variations could be due to increased prices for some handsets as well as additional costs for 4G packages.
- A1.11 We also argued that both our own international pricing benchmarks as well as those of the EC show that prices in the UK are lower than other comparable countries.

Summary of responses

- A1.12 BT/EE argued that the UK mobile market was “highly competitive”³ despite asymmetric spectrum holdings. BT/EE argued that this was not surprising as spectrum is only one factor amongst many that determine an MNO's competitive strength⁴.
- A1.13 BT/EE also argued that H3G's suggestion that current market prices are not sustainable could be a reflection of some operators' prices being based on short-run rather than long-run costs. If an MNO prices according to short-term costs, it may be able to reduce its price after capacity investments have taken place,

³ See pages 8 and 9 of BT/EE's response

⁴ We discuss different parameters of retail mobile competition in annex 2.

reflecting low short-run marginal costs. However, it may be forced to increase prices again when it requires additional investment to increase capacity. In contrast, low prices would be sustainable if they are based on long-run costs, which are less sensitive to the cost of adding capacity.⁵

- A1.14 In its response Vodafone also highlighted the fact that both H3G and O2, which were the operators with the lowest spectrum shares, had been able to increase their market share over recent years.⁶
- A1.15 In the NERA report submitted as part of O2's response, NERA agreed at a high level with Ofcom's conclusion that the market was working well for consumers, but warned that the fact that competition had worked well until now was no guarantee that it would continue to be effective in the future. The NERA report also stated that < [REDACTED] . Finally, the NERA report also argued that there is evidence of a softening of competition from H3G, as evidenced by the increase in prices in the unlimited plans that Ofcom discussed in the November 2016 consultation. However, NERA considered that it may be that these price levels were unsustainable.⁷
- A1.16 H3G argued that UK consumers are already suffering the consequences of concentration of useable spectrum, with significant price increases between 2015 and 2016, poor network quality and performance⁸ compared to other European countries, spectrum hoarding,⁹ not-spots as a result of concentration of sub-1 GHz spectrum and concerns about competition in the wholesale market.¹⁰
- A1.17 H3G provided a pricing analysis report by Frontier Economics (FE) which it said provided evidence that overall prices in the UK have increased between 2014 and 2016 once plans with handsets are included. In the report the pricing analysis is carried out using a revised basket approach as well as using econometrics. This analysis claims to show that there has been an overall increase in prices when handset plans are considered over the 2014 to 2016 period, and even after taking account of handset costs.
- A1.18 In this annex, we present the data that we included in annex 7 of our November 2016 consultation and update it where possible (e.g. using full year figures for 2016 where available). We have merged the 2016 figures from BT and EE when we discuss retail subscribers. We have also expanded the evidence on the evolution of the wholesale market and have included a section on the international comparison of network quality as well as a discussion of FE's pricing report. We also briefly discuss current spectrum holdings in the UK market, as covered in section 3 of the November 2016 consultation.

⁵ See paragraph 58 of BT/EE's response.

⁶ See page 13 of Vodafone's response.

⁷ See NERA report, pages 107-109.

⁸ We discuss network performance in annex 5.

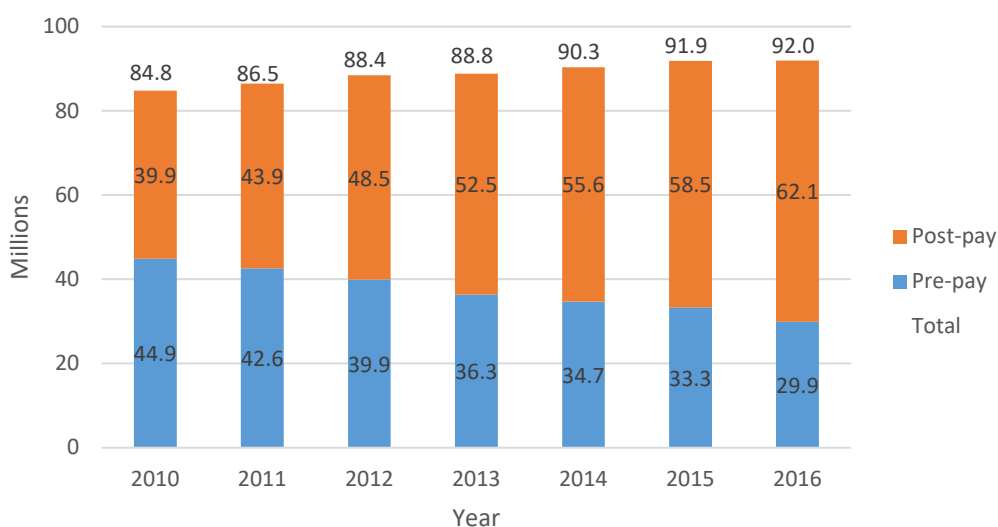
⁹ We discuss this in annex 11.

¹⁰ See page 78 of H3G's response.

General state of the market

A1.19 The number of mobile subscriptions in the UK has grown continuously in recent years, from 84.8 million in 2010 to 92.0 million by 2016.

Figure A1.1. Mobile subscriptions, by pre-pay and post-pay¹¹



Source: Ofcom/operators

Note: Includes M2M¹²

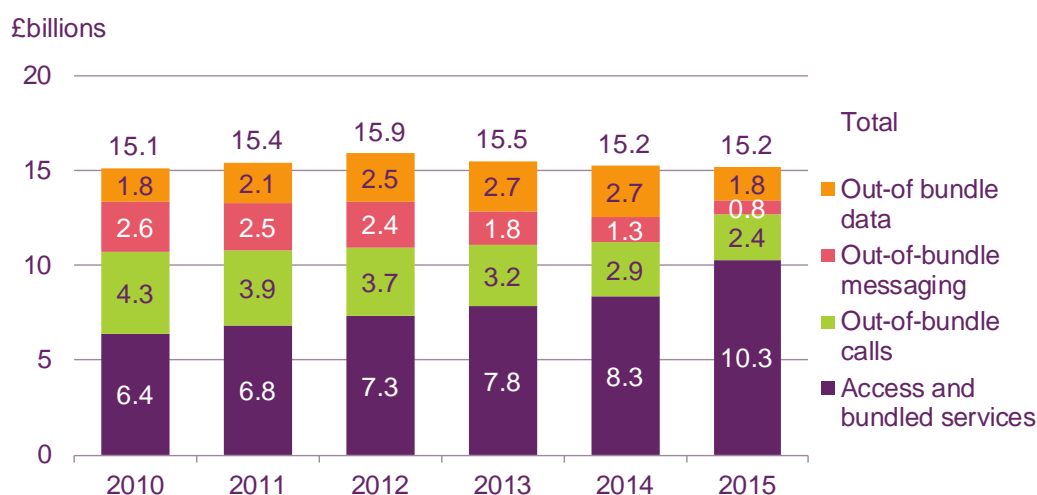
A1.20 As the figure above shows, there has been a significant change in the pre-pay / post-pay split.¹³ Whereas in 2010, 53% of subscriptions were pre-pay, by 2016 this proportion had fallen to 32%. The fall of approximately 3.5 million pre-pay subscriptions between end of 2015 and end of 2016 was offset by a growth in post-pay subscribers of ca. 3.5 million in that same period, with a small rise in the total number of subscriptions.

A1.21 Mobile retail revenue remained stable in nominal terms between 2014 and 2015, having experienced a decrease between 2012 and 2014.

¹¹ Updated from consultation with new 2016 data.

¹² Machine to Machine. This involves the connection of devices to the network so that they can receive or relay information. One such example is smart energy meters, which use a mobile network to relay usage readings back to the energy provider. M2M connections are considered as post-pay.

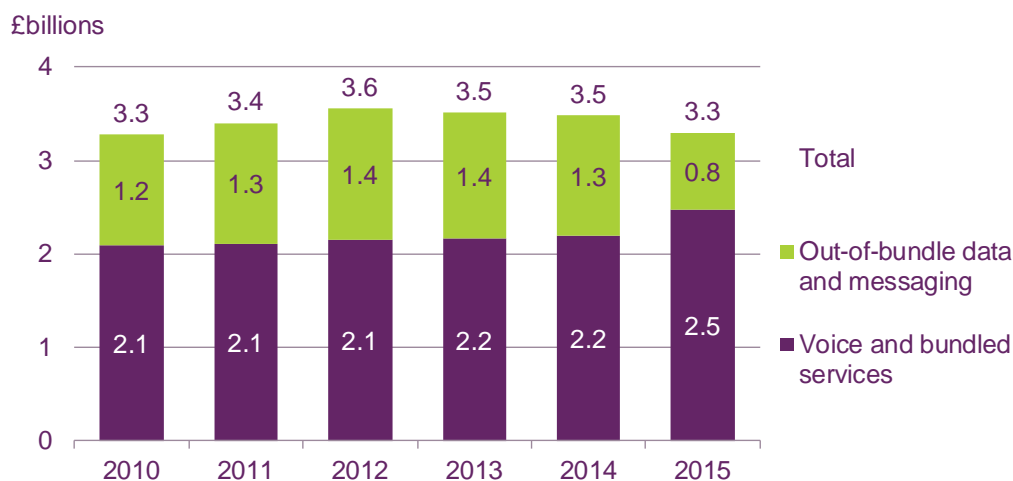
¹³ The distinction between post-pay and pre-pay tariffs may not always be strong. For example, some pre-pay tariffs involve subscribers making regular monthly payments for minutes and data that must be used in the following month, which are similar in form to post pay tariffs. There are also some post-pay tariffs with very short termination periods that are not unlike some pre-pay tariffs. For more on the blurring of the distinction between pre-pay and post-pay see paragraphs 14 to 18 of Appendix B of the CMA's decision on BT/EE merger, https://assets.publishing.service.gov.uk/media/56991ae4ed915d468c00002b/FR-Appendices_and_Glossary.pdf

Figure A1.2. Mobile retail revenue by service

Source: Ofcom CMR 2016

Note: Data is in nominal terms

A1.22 On the other hand, total business mobile revenues have been declining since 2012 after an increase in the period between 2010 and 2012. Between 2014 and 2015 there was a significant increase in the revenues from voice and bundled services. Nonetheless, for business revenue this increase was more than offset by a sharp drop in the out-of-bundle revenues.

Figure A1.3. Business mobile revenues

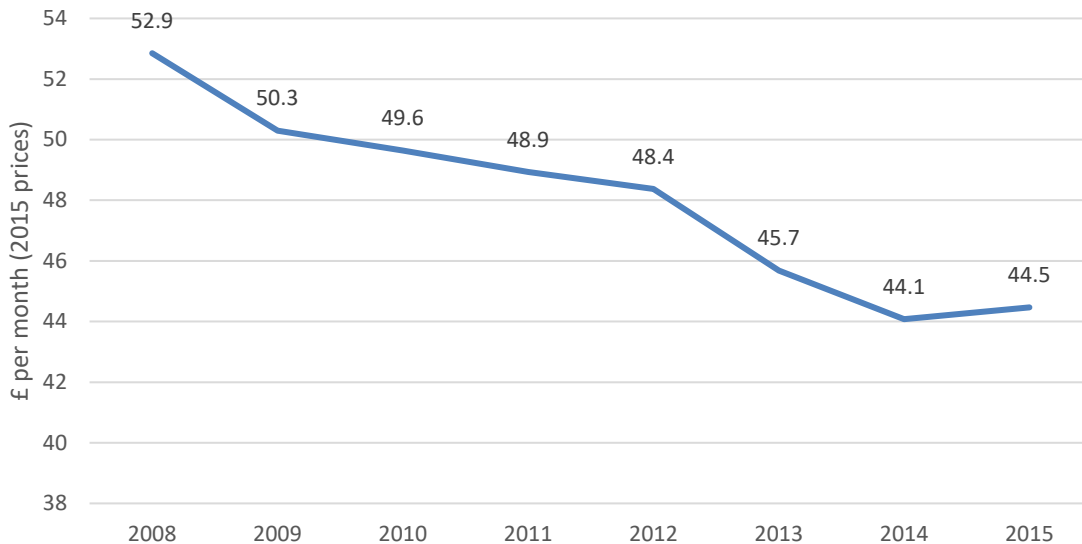
Source: Ofcom CMR 2016

A1.23 Total mobile retail revenue fell slightly by £63.9m (0.4%) in 2015 (although still at £15.2bn when rounded, as in 2014 – see Figure A1.2) in contrast to the 0.1% average annual growth rate over the five years to 2015. Along with prices and declining SMS and MMS use, a key reason for falling average revenues may be the migration of higher-use pre-pay customers onto post-pay services during the year.¹⁴

¹⁴ Source: Ofcom CMR 2016

A1.24 Average monthly spend on mobile services had decreased continuously until 2014. In 2015 there was an increase in household spend on mobile of ca. £0.40 per month.

Figure A1.4. Average monthly spend on mobile services

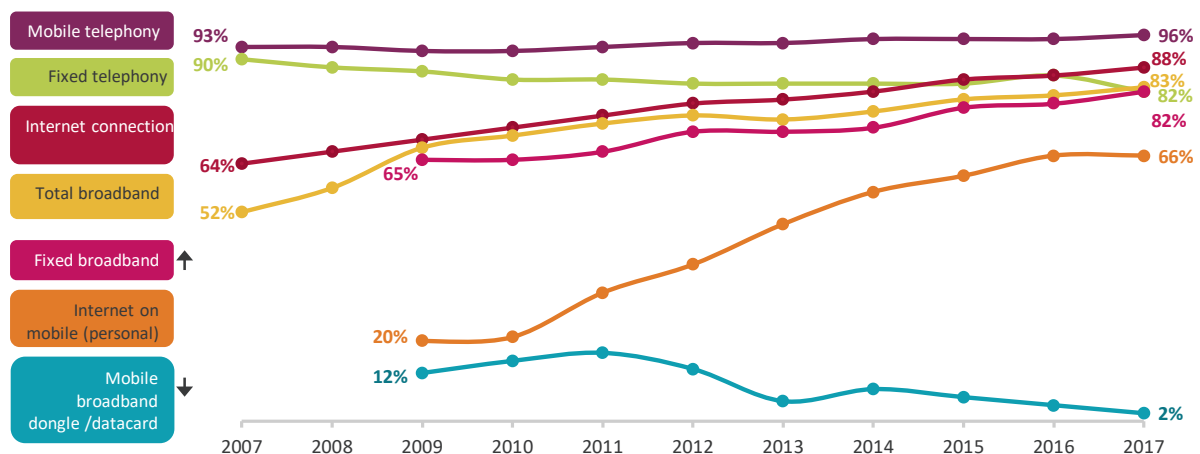


Source: Ofcom CMR 2016

A1.25 Data usage, including internet on mobile devices has increased rapidly in recent years. Whereas in 2010 only 21% of adults had access to the internet on their mobile, by 2016 this figure had increased to 66%.

Figure A1.5. Household take-up of key telecoms technologies

Proportion of households/adults (%)



Source: Ofcom Technology Tracker. Data from Quarter 1 of each year 2007-2014, then Half 1 2015-2017

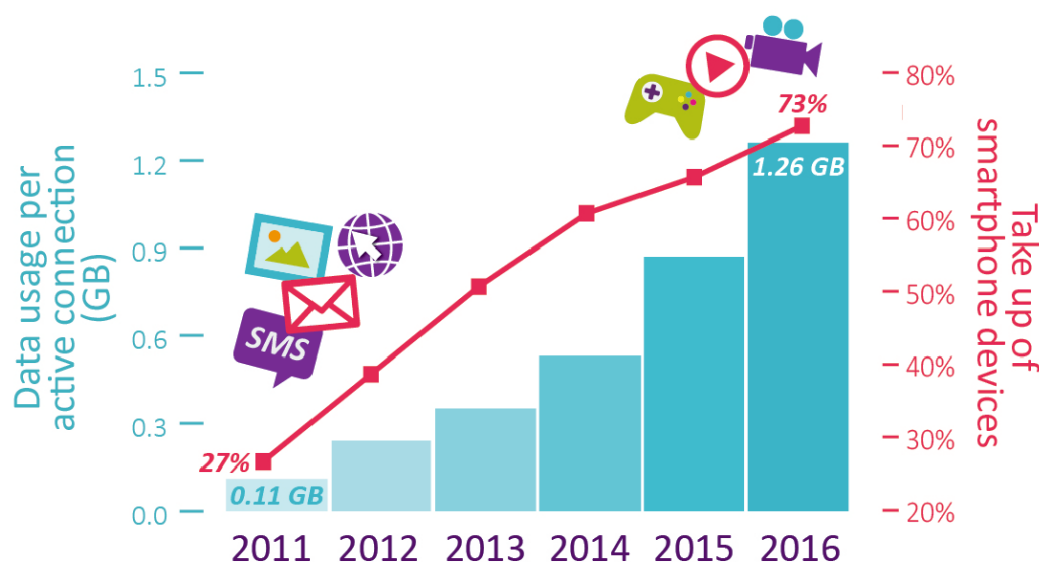
A1.26 Access to mobile broadband using dongles and datacards has decreased from a peak of 17% in 2011 to just 2% by 2017.

A1.27 The increased internet access on phones reflects the increased penetration of smartphones in the UK, which is among the highest in Europe. For example, in

2016, 71% of adults in the UK owned a smartphone up from 66% in 2015.¹⁵ This is higher than penetration rates in other European countries such as France, Germany and Italy, which had rates of 49%, 60% and 60% respectively in spring 2015.¹⁶

- A1.28 4G has experienced rapid growth in the UK. In Q4 2015 4G accounted for almost half of all mobile subscriptions (46%), and 4G take-up increased across all ages, genders and socio-economic groups in 2016. The availability of 4G mobile services has also increased, with the UK having 97.8% outdoor premises coverage by at least one operator in May 2016.¹⁷ 4G subscriptions have grown from just 1.3 million in Q3 2013 to 50 million by Q3 2016.¹⁸
- A1.29 The number of M2M connections has also been growing (up 7% to 6.7 million in 2015), as Internet of Things (IoT) devices begin to enter the market.
- A1.30 In our 2017 5G update on 5G spectrum in the UK,¹⁹ we showed that average monthly data use per customer had increased from around 110 MB in Q1 2011 to 1.26 GB by H1 2016. Over that same period smartphone penetration had increased from 27% to 73%.

Figure A1.6. Average monthly data use and smartphone penetration, 2011-2016



Source: Ofcom Connected Nations 2016 Reports and Ofcom Technology Tracker from Q1 of each year 2011-2014, then H1 2015-2016

- A1.31 In our 2016 connected nations report,²⁰ we also showed that by June 2016, total monthly data traffic in the UK had reached 105.5 PB,²¹ an increase of almost 45%

¹⁵ Source: Ofcom CMR 2016

¹⁶ See <http://www.pewglobal.org/2016/02/22/smartphone-ownership-and-internet-usage-continues-to-climb-in-emerging-economies/>. the UK smartphone penetration rate for this period was 68% in this survey

¹⁷ Source: Ofcom CMR 2016

¹⁸ Source: CMR 2016 and updated data from operators / Ofcom

¹⁹ See https://www.ofcom.org.uk/data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

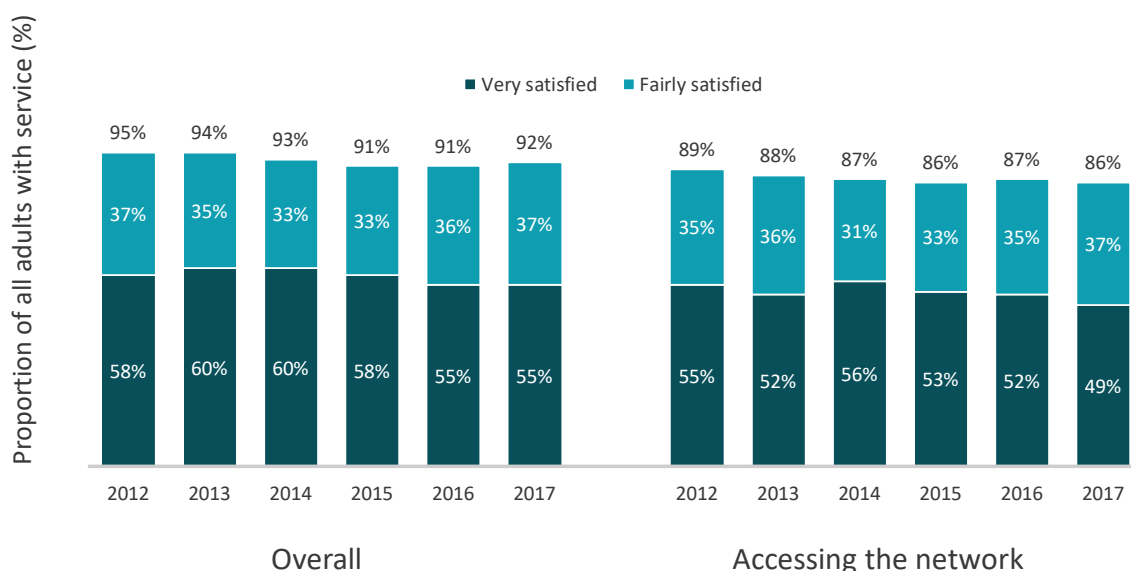
²⁰ See https://www.ofcom.org.uk/data/assets/pdf_file/0035/95876/CN-Report-2016.pdf

²¹ Petabytes, i.e. millions of GB

compared to the same period in 2015 (72.9 PB) and more than a ten-fold increase since March 2011 (9 PB).

- A1.32 Consumer satisfaction with mobile services has remained fairly stable with 92% of subscribers expressing that they are fairly or very satisfied with their service.

Figure A1.7: Satisfaction of aspects with mobile service



Source: Ofcom Technology Tracker. Data from Quarter 1 2009-2014, then Half 1 2015-2017

- A1.33 As part of the Digital Communications Review (DCR), we commissioned a study by WIK to assess the drivers of investment and consumer welfare in mobile communications. This WIK study found there was no general relationship between competition and investment that can be expected to hold across all markets. It also found that over the last decade, the UK's capex to revenue ratio was broadly comparable to those in a number of other EU and international mobile markets.²²

Recent changes to the structure of the market

- A1.34 In 2010 Deutsche Telekom (T-Mobile) and France Telecom (Orange) agreed to merge their UK mobile operations into Everything Everywhere (now EE), thereby reducing the number of MNO's in the UK market from five to four.
- A1.35 In 2012 Vodafone acquired Cable and Wireless' (C&W) global operations including those in the UK.²³
- A1.36 In 2015 BT agreed to acquire EE, with the merger being completed in 2016 after receiving clearance from the CMA.²⁴

²² WIK-Consult, *Competition & investment: An analysis of the drivers of investment and consumer welfare in mobile telecommunications*, July 2015, p.41:

http://stakeholders.ofcom.org.uk/binaries/consultations/dcr_discussion/annexes/Competition_and_investment_mobile.pdf

²³ http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=2_M_6584

²⁴ <https://www.gov.uk/cma-cases/bt-ee-merger-inquiry>

- A1.37 Before the BT/EE merger, there was an expectation that BT was going to use its own spectrum to launch its own mobile service, albeit one largely reliant for national coverage on wholesale access as an MVNO.
- A1.38 In 2015 H3G agreed to acquire O2's UK mobile operation, which would have reduced the number of MNOs in the UK to three. However, this proposed merger was blocked by the European Commission in 2016.²⁵
- A1.39 In 2017 H3G acquired UK Broadband which currently provides Fixed Wireless services to approximately 15,000 subscribers²⁶ in the central London area.

Retail mobile market

- A1.40 In principle, market shares can be measured in a range of ways based on subscriber numbers, revenue, volume of (data) traffic etc. Most of the evidence set out below is for shares of subscribers (which is the information most easily obtained on a comparable basis across operators). Later in this annex we also include some evidence on shares of data traffic.
- A1.41 We have not included revenue market share comparisons because of the difficulties in making such comparisons meaningful and accurate, for example due to the effect of handset revenues, potential differences in accounting treatment (e.g. potential inclusion of non-mobile related revenues), and challenges in the treatment of MVNOs.
- A1.42 < [REDACTED] ²⁷ .
- A1.43 < [REDACTED] ²⁸ . In Figure A1.16, we show evidence on net contract additions from Enders Analysis. This shows positive net contract additions for H3G in the four quarters from Q1 2016 to Q2 2017.
- A1.44 Furthermore, between 2011 and 2016 H3G,²⁹ O2 and MVNOs increased their retail market subscriber shares, while EE and Vodafone experienced decreases in market shares. < [REDACTED] .

Figure A1.8: Total mobile subscription market share by retail operator³⁰

< [REDACTED]

- A1.45 The difference between the market shares in the figure above and those presented later in this annex highlights the effect of hosting MVNOs. For example, when hosted MVNOs are taken into account, O2's market share is similar to EE's at ca. 35% as shown in Figure A1.17b.
- A1.46 Of these MVNOs only Virgin Mobile and Tesco have acquired a subscriber market share of more than 3% of the retail market.

²⁵ http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=2_M_7612

²⁶ <http://www.threemediacentre.co.uk/news/2016/ukbroadband-news.aspx>

²⁷ See page 67

²⁸ Including hosted MVNOs but excluding M2M subscriptions

²⁹ In Figure A1.8 and other charts below, H3G is shown as "Three".

³⁰ BT subscribers are included in EE number for 2016.

- A1.47 A common measure of the level of market concentration is the Herfindahl-Hirschman Index (HHI). This index is estimated by taking the absolute value of the market share of each firm in the industry (e.g. 25 if the market share is 25%) and then squaring this number. The sum of these values for all firms is the HHI and can theoretically range from close to zero for a market with a very large number of small firms, all with little market share (e.g. less than 1%), to 10,000 for a market with one operator with 100% market share. If all firms in a market with four competitors had the same market share, the HHI would be 2,500, i.e. $4 \times (25\% \times 100)^2$.
- A1.48 Using the HHI, the market is still relatively concentrated, particularly since the merger of T-Mobile and Orange, before which the HHI for the market was ca. 1,750. After the T-Mobile and Orange merger this concentration index increased to 2,317 but the rising market share of H3G and other MVNOs has led to a decrease in this concentration indicator as illustrated in the table below.

Figure A1.9: HHI index for the UK retail mobile market³¹

	2009	2010	2011	2012	2013	2014	2015	2016	Change 2010- 2016
HHI	1,749	2,317	2,237	2,141	2,088	2,071	2,032	2,021 ³²	- 296

- A1.49 As shown in Figure A1.10 below, in the pre-pay segment, Vodafone and EE have lost a significant number of subscribers since 2011. Only H3G has seen growth in the number of pre-pay subscribers since 2011.

Figure A1.10: Total pre-pay subscribers by operator³³

✂ [REDACTED]

Figure A1.11: Pre-pay subscription share by retail operator³⁴

✂ [REDACTED]

- A1.50 In the post-pay segment, shares have remained relatively stable with variations of 1-4 percentage points in shares for each MNO over the last five-year period.

³¹ Unlike the HHI presented in Annex 6, this table takes into account the market shares of MVNOs as well as MNOs. The MVNOs taken into account are: Virgin, Tesco Mobile, Lycamobile and Lebara Mobile. Tesco and O2 are treated separately. For the estimation of the HHI, each of the MVNOs included in the calculation is treated separately. We have updated the numbers for 2011 to 2016 from the consultation with amended data as submitted by stakeholders.

³² BT subscriber numbers have been included in EE numbers for 2016. If BT and EE are kept separate then the HHI would be 1,961 for 2016.

³³ BT is included in EE numbers for 2016. We have amended the data as per verified data received from MNOs.

³⁴ BT is included in EE numbers for 2016. We have amended the data as per verified data received from MNOs.

Nonetheless, all MNOs and MVNOs who offer post-pay plans have seen significant growth in their absolute numbers of post-pay subscribers.

Figure A1.12: Total post-pay subscribers by operator³⁵

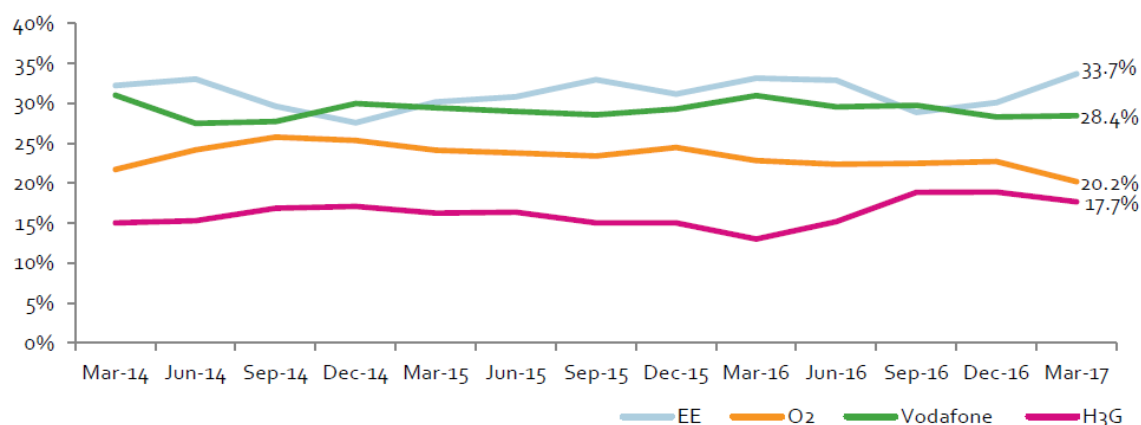
⌘ [REDACTED]

Figure A1.13: Post-pay subscription share by retail operator³⁶

⌘ [REDACTED]

A1.51 According to Enders Analysis, EE had the highest share of gross contract additions while H3G had the lowest share. However, when these shares are compared to normalised retail MNO market shares,³⁷ EE's share of gross additions is comparable to its market share, O2's is below its market share and Vodafone's and H3G's are above their market share.

Figure A1.14: Share of gross contract additions



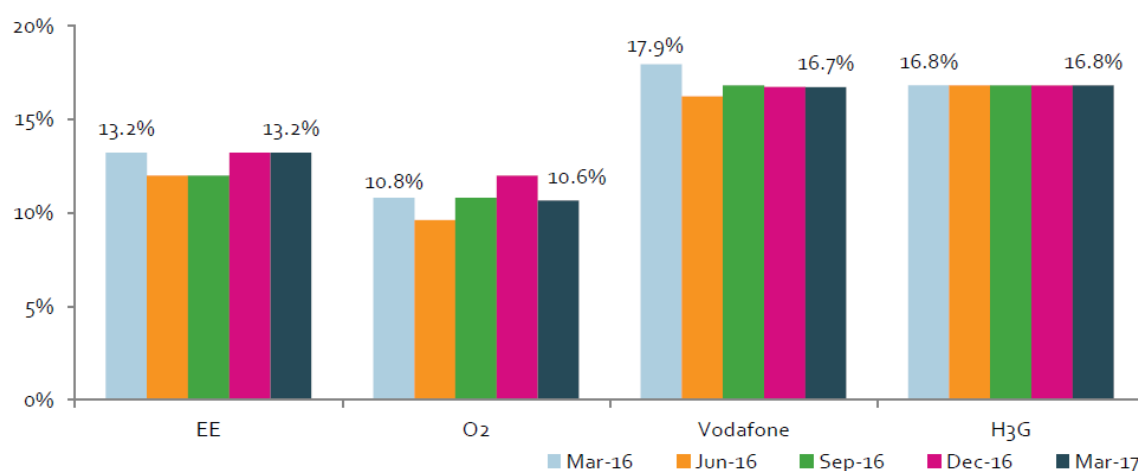
Source: Enders Analysis

A1.52 According to Enders Analysis, O2 has the lowest contract churn rates, followed by EE, while H3G and Vodafone have comparable, higher churn rates.

³⁵ BT is included in EE numbers for 2016. We have amended the data as per verified data received from MNOs. ⌘ [REDACTED] .

³⁶ BT is included in EE numbers for 2016. Data has been updated since our consultation.

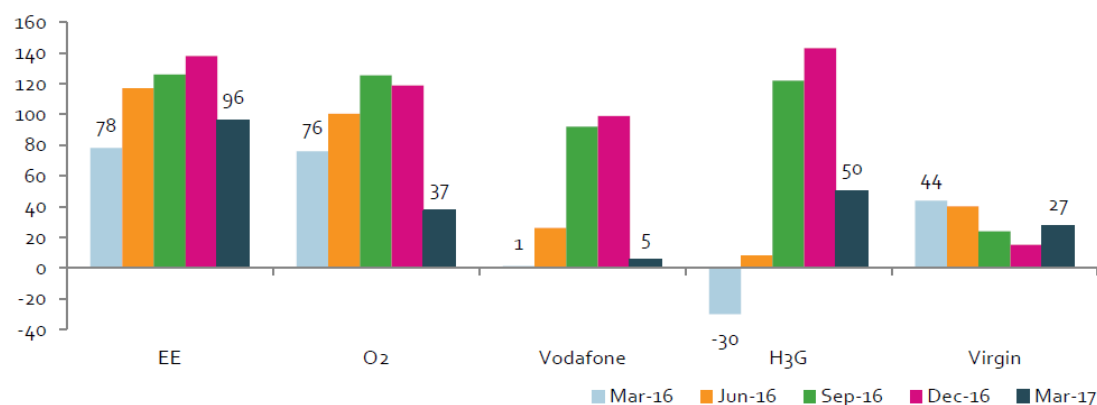
³⁷ Market shares calculated without taking into account MVNOs, i.e. total market shares of the four MNOs add up to 100%.

Figure A1.15: Annualised contract churn

Source: Enders Analysis

A1.53 These churn rates would explain why O2 has been able to increase its market share while having a share of gross additions below its own market share. O2 has been more successful at retaining its existing subscribers, even if it has been less effective at acquiring new customers than Vodafone or H3G, for example.

A1.54 All MNOs experienced a decline in contract net additions in Q1 2017 while one MVNO - Virgin - showed an increase in net additions over the same period. EE had the highest number of net additions for Q1 2017, overtaking H3G which had the most net additions in Q4 2016.

Figure A1.16: Contract net additions (thousands)

Source: Enders Analysis

A1.55 We do not have complete Q1 2017 subscriber information for all MNOs and MVNOs to include in the charts above. However, we have been able to extract some information from the recent quarterly and annual reports of some of the MNOs, which we list below.

- a) In its Q1 2017 report, Telefónica (O2) reported an overall decrease in mobile subscribers of ca. 450,000 between December 2016 and March 2017. This includes the disconnection of 228,000 inactive accounts during

the first quarter of 2017. The decrease in subscriber numbers includes a decrease of 127,000 post-pay subscribers.³⁸

- b) BT/EE reported that group level post-pay net additions for the last quarter of the year ending March 2017 were 192,000, with a reduction in the pre-pay subscriber base of 388,000.³⁹
- c) For the last quarter of the year ending March 2017, Vodafone reported 5,000 net contract additions, a significant decrease from the 99,000 of the previous quarter. However, the latter figure excludes the effect of a one-off adjustment, which reduced the base by 125,000 subscribers.⁴⁰
- d) Finally, we understand that H3G's parent company only reports half yearly. Therefore, its next report is likely to be published in August/September of 2017.

A1.56 As we discussed in our 2016 Consumer Switching consultation document,⁴¹ about 6.6 million subscribers had switched mobile phone provider in the 18 months prior to the consultation. Therefore, on average, ca. 5% of total subscribers switched mobile phone providers per year.

Wholesale mobile market

A1.57 Retail competition in mobile services today is characterised by competition between both MNOs and MVNOs. There are currently four UK MNOs: BT/EE, H3G, O2 and Vodafone. Competition at the wholesale level between these MNOs enables MVNOs to obtain wholesale access commercially, without regulation.

A1.58 Currently all MNOs host MVNO operators. For example, EE hosts Virgin Mobile, O2 hosts Sky, Vodafone hosts Lebara and H3G hosts iD. Wholesale market shares of MNOs, including both the MNOs' own retail subscribers and the subscribers of hosted MVNOs, differ from those of just their own retail subscribers. For example, O2 is currently the operator with 3% [REDACTED] subscribers at the wholesale level, whereas it had 3% [REDACTED] market share at the retail level.⁴²

Figure A1.17a: Subscriber market shares by network (including own subscribers and hosted MVNOs' subscribers) – Operator data

3% [REDACTED]

³⁸ See page 22 of <https://www.telefonica.com/documents/162467/138879215/rdos17t1-eng.pdf/ccb1826a-f588-4232-b8db-398e444e428b?version=1.1>

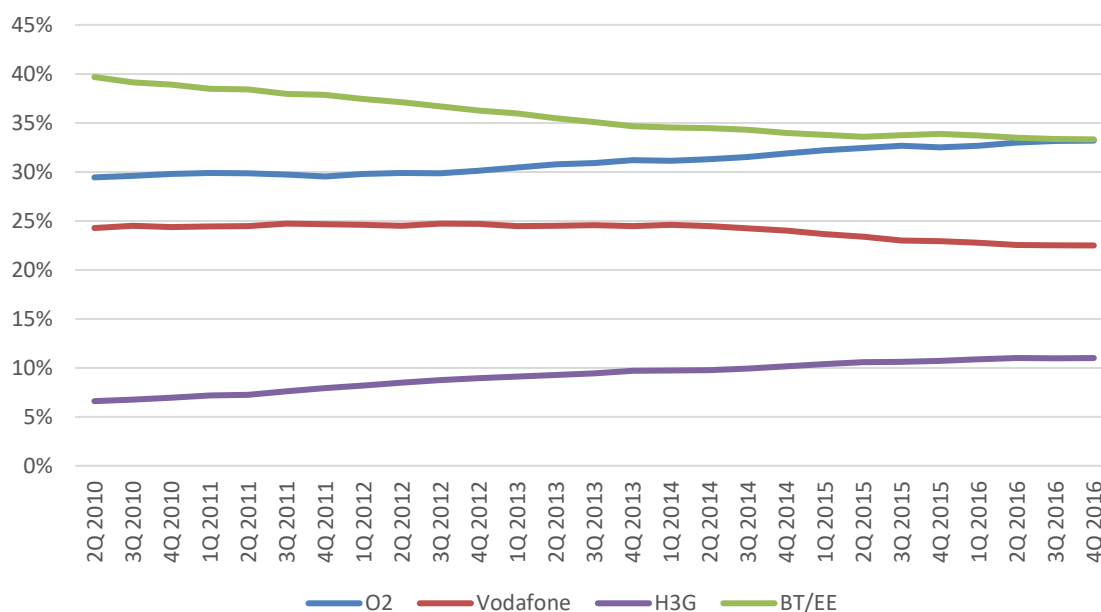
³⁹ See page 12 of <http://www.btplc.com/Sharesandperformance/Quarterlyresults/2016-2017/Q4/Downloads/Slides/q417-slides.pdf>

⁴⁰ See slide 45 of http://www.vodafone.com/content/dam/vodafone/investors/financial_results_feeds/preliminary_results_31march2017/p_prelim2017.pdf

⁴¹ See paragraph 4.9 of https://ofcom-build.squiz.co.uk/_data/assets/pdf_file/0025/82636/consumer-switching-mobile-consultation.pdf.

⁴² Our analysis for this statement is based on data provided by the operators to Ofcom as part of their regular information submissions to us. However, as we do not publish this information, we are also including market share data based on published Analysys Mason data. We have checked and these two sources are broadly similar.

Figure A1.17b: Subscriber market shares by network (including own subscribers and hosted MVNOs' subscribers) – Analysys Mason data



Source: Analysys Mason

- A1.59 In section 3 of our November 2016 consultation, we stated that the UK mobile market is working well, “with four credible MNOs and a range of MVNOs supporting strong retail competition”.⁴³
- A1.60 However, in its response H3G argued that in recent publications such as Ofcom’s Phase 2 submission to the CMA for the BT’s acquisition of EE, Ofcom had become more pessimistic about the state of competition in the wholesale market and MVNOs’ reduced ability to compete at the retail level, and that this was a contradiction to Ofcom’s current view of the retail market.
- A1.61 H3G also referred to the EC’s decision on the proposed H3G/O2 merger, where the EC found that UK MVNOs’ ability to compete has decreased since 2009 to the level that they “are unable to meaningfully constrain the competitive behaviour of MNOs on the retail market for mobile telecommunications services today”.⁴⁴ Both 3< [REDACTED] and 3< [REDACTED] also referred to this judgement from the EC as evidence that MVNOs are not a competitive constraint on MNOs.⁴⁵
- A1.62 H3G commented that in its Phase I submission to the EC on the H3G/O2 merger Ofcom argued that:
- “MVNOs are increasingly becoming less relevant as consumers become more data orientated”;
 - “the proportion of mobile data used by MVNO customers has fallen considerably from 14% in 2011 to 7% now”;

⁴³ November 2016 consultation, para 3.17.

⁴⁴ p. 85-86 Three response.

⁴⁵ 3< [REDACTED] response, p. 5; 3< [REDACTED] response, p. 9.

- “the only MVNOs with a subscriber share above 2% are Tesco Mobile and Virgin Media, and no MVNO has achieved a 5% share”;
- MVNOs “make a limited contribution to retail competition compared to MNOs” and cannot compete for high value customers with high data tariffs due to per unit pricing from MNOs, which Ofcom said prevented MVNOs growing their market share;
- MVNOs have limited market power “as evidenced by the difficulty that some MVNOs have had in negotiating the supply of 4G” and are often not given the latest technologies until years after they are launched by MNOs.

A1.63 BT/EE pointed out that one indicator of O2 performing well currently is that it has won MVNO contracts with TalkTalk and Sky. TalkTalk’s MVNO contract with O2 was agreed in November 2014⁴⁶ and Sky’s in January 2015.⁴⁷

A1.64 & [REDACTED] ⁴⁸

A1.65 The FCS said the market is not working well, arguing that there was no free market allowing MVNOs equivalence with MNOs, and that the former must follow the rules of the latter.⁴⁹

A1.66 BT/EE stated that both the wholesale and retail markets work well, noting the “many MVNOs driving good outcomes for consumers”. As well as agreeing with Ofcom’s evidence in the consultation that operators with smaller spectrum holdings are gaining market share, BT/EE also pointed out Ofcom’s positive assessment of the retail market in Ofcom’s Strategic Review of Digital Communications.⁵⁰

A1.67 Recent developments indicate signs of increasing competitive activity among MVNOs. Since we published our November 2016 consultation, Sky has launched its own MVNO service using O2’s network. Furthermore, Carphone Warehouse’s MVNO – iD – had managed to acquire more than 600,000 subscribers by the end of FY 2016-2017, doubling its subscriber base within one year.⁵¹ This is consistent with the data on wholesale and retail subscribers submitted by & [REDACTED] .

⁴⁶ We understand that TalkTalk’s customers have not yet been moved to O2.

⁴⁷ We agree that O2 has performed well to date in terms of winning retail customers and wholesale customers. However, we summarise our assessment of O2’s ability to add capacity in the future in section 5.

⁴⁸ p. 6-7, [REDACTED] response.

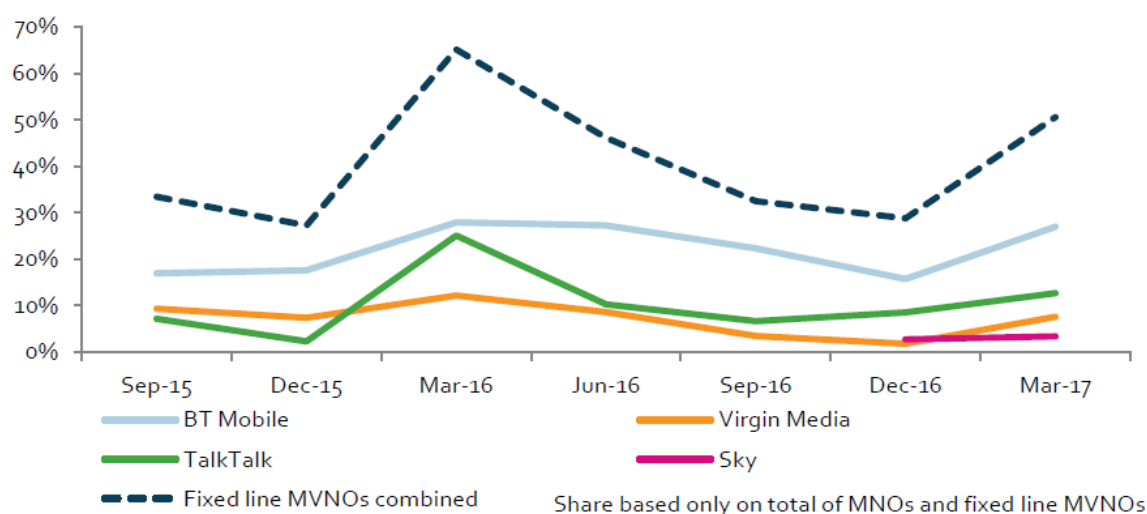
⁴⁹ FCS response, p. 3-4.

⁵⁰ DCR Consultation, July 2015, paragraphs 1.49 and 4.11

⁵¹ See pages 11 and 21 of <http://www.dixonscarphone.com/~media/Files/D/Dixons-Carphone/documents/preliminary-results-201617-and-strategy-update-final.pdf>.

- A1.68 Furthermore, 3< [REDACTED] , and 3< [REDACTED] were the only retail providers with positive total net additions⁵² between 2015 and 2016⁵³, 3< [REDACTED]⁵⁴
- A1.69 We consider that some MVNOs have been able to gain subscribers in the post-pay segment. For example, according to the data submitted by operators, 3< [REDACTED]⁵⁵
- A1.70 According to Enders Analysis, fixed line MVNOs (including BT⁵⁶) had around 50% of the contract net additions in Q1 2017. Enders notes that there is generally a seasonality effect which causes net additions for MVNOs to increase relative to MNOs during the first quarter of the year. However, net contract additions by MVNOs in Q1 2017 were below those of MNOs, unlike in Q1 2016.

Figure A1.18: Fixed line MVNO contract net additions share



Source: Enders Analysis

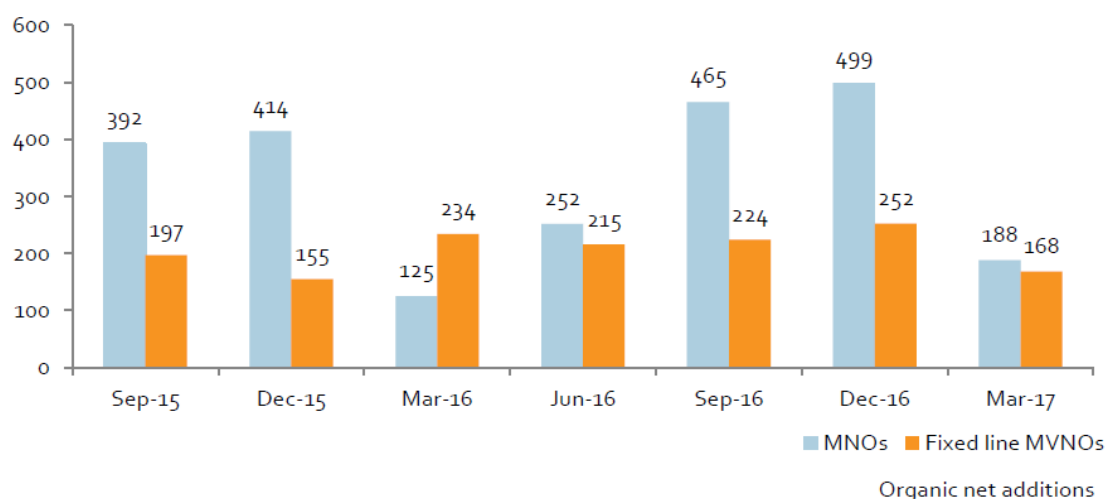
⁵² The net additions figure by Enders Analysis above only covers post-pay net additions.

⁵³ We have collected information from MNOs on their total retail subscribers as well as total wholesale subscribers, i.e. their own retail subscribers plus those of hosted MVNOs. We have also collected data from some MVNOs on their total retail subscribers. The difference in the MNO data between retail and wholesale subscribers should be consistent with the total number of MVNO subscribers in the country. However, when the subscriber data collected from MVNOs is compared to the implied MVNO subscribers derived from the MNO data, it would appear as if reported MVNO subscribers are greater than they should be. This may be the result of different definitions of active user between the data submitted by MNOs and that submitted by MVNOs. However, the difference between the retail and wholesale subscriber data submitted by MNOs should still provide a reasonable reflection of total MVNO subscribers.

⁵⁴ BT Mobile's net additions excluded from MVNO figures.

⁵⁵ The growth rate of 3< [REDACTED] .

⁵⁶ Telecommunications operators who provide a fixed line service as well as mobile services as an MVNO, e.g. Virgin, TalkTalk, Sky and BT.

Figure A1.19: Contract net additions (thousands)

Source: Enders Analysis

- A1.71 MVNOs tend to account for a larger share of voice minutes than data. In our Strategic Review of Digital Communications discussion document, we described how the proportion of voice minutes used by MVNO customers has not changed since 2011, at 16% of total mobile voice minutes (calculated including Tesco mobile). However, the proportion of total mobile data used by MVNO customers has fallen to 7% (from 14% in 2011). In our November 2016 consultation, we said that this suggests that MVNO networks are more targeted at voice call markets, or that their service propositions lead to a higher proportion of such. We explained that this may be influenced by the terms available from mobile operators for MVNOs (e.g. whether 4G services are made available) or availability of high end, data focussed handsets.⁵⁷
- A1.72 However, the offerings of some of the newer MVNOs (e.g. Sky, iD) are comparable in terms of data allowances to those of MNOs. For example as of 1st June 2017, Sky offered packages with up to 5GB of data allowance per month, iD's largest data allowance plan included 10GB per month, while Virgin offered a package with 20GB of data allowance.⁵⁸
- A1.73 Overall, we still consider that MVNOs make a limited contribution to retail competition compared to MNOs and it remains the case that no MVNO has a subscriber share of 5% or more. However, some of the most recent evidence suggests there may be a more positive picture of competitive activity by MVNOs than the earlier evidence on which we based our comments in the H3G/O2 and BT/EE mergers.

⁵⁷ Ofcom, Strategic Review of Digital Communications: Discussion document, 16 July 2015, paragraph 4.29, http://stakeholders.ofcom.org.uk/binaries/consultations/dcr_discussion/summary/digital-comms-review.pdf.

⁵⁸ As of 27 June 2017.

Evolution of UK mobile pricing

Introduction

- A1.74 In this section we discuss the evolution of mobile pricing in the UK, where possible updating and expanding on the data that we presented in our November 2016 consultation. We also discuss Frontier Economics' (FE) pricing analysis report.
- A1.75 In annex 7 of our November 2016 consultation, we showed how prices had changed from 2013 to 2016 based on our International Communications Market Report (ICMR) basket methodology. We found that for baskets with handsets there was a mixed picture with some baskets increasing in price, others decreasing and some with no clear trend. We said it was likely that the increase in tariffs over the 2013-2015 period was a reflection of the increase in the price of premium handsets as well as the additional cost of 4G packages shortly after they were launched.
- A1.76 In order to control for changes in handset prices, we focussed on SIM-only plans. We found that prices had generally decreased for SIM-only plans, with the exception of the highest usage basket which had shown significant increases in recent years. We said that this was likely driven by H3G's increases in prices for high data allowance packages, including its unlimited packages. However, we also showed that H3G's high data allowance packages were still competitively priced when compared to the offerings of other MNOs. We also showed that H3G's benchmark handset plans (as per Enders Analysis) compared well with those of other MNOs, including sales through Carphone Warehouse.
- A1.77 Finally, we noted that both our own international comparison, and that carried out by the EC, showed that UK mobile prices are generally lower than those in other comparable countries.
- A1.78 In its response to the consultation, H3G provided a pricing analysis report by Frontier Economics which it said provided evidence that prices in the UK have increased once plans with handsets are included. In the report the pricing analysis is carried out using a revised basket approach as well as using econometrics. This analysis claims to show that there has been an overall increase in prices when handset plans are considered over the 2014 to 2016 period, even after taking account of handset costs.
- A1.79 In the rest of this section we explore the available evidence on price trends in the UK, including reviewing FE's report on pricing. Our assessment is structured as follows:
- pricing context;
 - basket approach discussing both Ofcom's basket approach as well as Frontier Economics' revised approach;
 - econometric analysis;
 - international pricing comparison;
 - update on some of the pricing observations that we included in the consultation;
 - conclusion on pricing.

A1.80 The analysis presented in this chapter uses nominal prices and focuses on price changes in the period from 2014 to 2016. For reference, we include yearly inflation rates (CPI) as reported by the ONS.⁵⁹

Figure A1.20: Year on year inflation (CPI)

	2014	2015	2016
Inflation (CPI)	0.5%	0.2%	1.6%

Source: ONS

Pricing context

A1.81 Mobile service plans can be divided into three broad categories:

1. Pre-pay plans, where users do not have a monthly contract with their provider but must “top-up” their credit before they can make calls or browse the internet. There are no minimum-term limits to pre-pay plans and the subscribers generally have to provide their own handset or purchase it outright from the provider.
2. Post-pay SIM-only plans where consumers provide their own handset and sign a contract with the provider to grant them a specific monthly voice, SMS and/or data allowance at a set price per month. These tend to be rolling contracts of one or twelve months.
3. Post-pay handset plans where the mobile operator provides the consumer with the handset as well as the allowance to make calls, send texts or use data services. These plans may charge an upfront fee for the phone as well as a monthly charge⁶⁰ and they generally have a duration of 24 months.

A1.82 As shown in Figures A1.1 and A1.10, pre-pay subscriptions have been decreasing both in absolute numbers and as a share of total subscriptions, decreasing from 53% (45 million) of all subscriptions in 2010 to 33% (30 million) in 2016.⁶¹

A1.83 Data collected from MNOs and leading MVNOs suggests that 34%⁶² of existing post-pay connections were SIM-only in Q2 2016. There are some indications that this segment is growing in importance. According to GfK data, 47% of new post-pay

⁵⁹ See <https://www.ons.gov.uk/economy/inflationandpriceindices/timeseries/d7bt/mm23> . Using December CPI figures.

⁶⁰ O2 has an O2 refresh plan where the payment for the phone and for airtime are separate, thereby allowing the user to upgrade their phone before the end of the contract.

⁶¹ Includes M2M

⁶² This figure was calculated based on data collected from MNOs and MVNOs below.

EE response dated 9 December 2016 to question 1 of the s.135/s.136 request.

Vodafone response dated 9 December 2016 to question 1 of the s.135/s.136 request.

H3G response dated 20 December 2016 to question 1 of the s.135/s.136 request.

O2 response dated 17 January 2017 to question 1 of the s.135/s.136 request.

BT response dated 13 January 2017 to question 4 of the s.135/s.136 request.

Tesco Mobile response dated 14 December 2016 to question 1 of the s.135/s.136 request.

Virgin Mobile response dated 19 December 2016 to question 4 of the s.135/s.136 request.

TalkTalk response dated 11 January 2017 to question 4 of the s.135/s.136 request.

contracts sold in the year ending March 2017 had a duration of 12 months or less, up from 30% in the year to March 2013. We have reviewed the plans available on the websites of MNOs and MVNOs (including Carphone Warehouse) and only found handset plans that are 24 months in length. This would suggest that post-pay plans of 12 months or less⁶³ correspond to SIM-only plans.

- A1.84 The increase in importance of SIM-only plans is consistent with the findings of the EC in for the O2/H3G merger case, based on information provided by H3G, in which it finds that there has been a shift from handset contracts to SIM-only contracts in recent years in the UK.⁶⁴ Specifically, the EC stated that *“According to the Notifying Party [H3G], there has been a 12% increase in sales of SIMO contracts between January 2014 and January 2015 in the United Kingdom: the increase in SIMO contracts has been consistent since 2012 when SIMO contracts took up approximately 28% of the overall postpaid segment and increasing to 39% in 2014. A number of competitors responding to the market investigation also stated that they expect a growth of the volume of the SIMO contracts sold.”*
- A1.85 Therefore, the UK market is made up of a sizeable but declining number of pre-pay subscriptions, while post-pay subscriptions, of which a significant and growing share is made up of SIM-only users, comprise the majority of subscriptions.
- A1.86 In competing for post-pay subscriptions, MNOs’ pricing strategies are relatively complex compared to those of firms in many other industries. Operators vary their offerings along many dimensions, given the diverse tastes of consumers; and prices vary depending on the make-up of individual plans. Below is a snapshot (on 15 June 2017) of a selection of some of the key dimensions of current tariffs taken from the four MNOs’ websites.

⁶³ We have conservatively used 12 months or less. This ensures that 18 month contracts are not classified as SIM-only in the GFK data.

⁶⁴ See paragraph 52, http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6415_10.pdf.

Figure A1.21: Examples of post-paid plans including handsets offered by MNOs

	EE		O2		H3G		Vodafone	
Handset	Apple iPhone 7 32GB		Apple iPhone SE 32GB		Samsung Galaxy S8 64GB		Apple iPhone 7 32GB	
	Plan 1	Plan 2	Plan 1	Plan 2	Plan 1	Plan 2	Plan 1	Plan 2
Contract length (months)	24	24	24	24	24	24	24	24
Upfront cost	£49.99	£9.99	£0.00	£69.99	£129.00	£99.00	£200.00	£20.00
Monthly cost	£42.99	£52.99	£31.00	£28.00	£40.00	£45.00	£40.00	£50.00
Minutes	Unltd	Unltd	Unltd	Unltd	Unltd	Unltd	500	Unltd
Texts	Unltd	Unltd	Unltd	Unltd	Unltd	Unltd	Unltd	Unltd
Data	1GB	5GB	1GB	1GB	1GB	2GB	500MB	4GB

Source: Operator websites as of 15/06/2017

Note: We have abbreviated unlimited allowances to “Unltd”. Some of these plans offer promotions that are not reflected in the table.

- A1.87 Like-for-like price comparisons between tariffs are complicated due to the number of dimensions by which tariffs, services and handsets can differ. Price differences between MNOs with differentiated offerings or between different tariff plans of the same MNO may reflect differences in the quantity or quality of services or handsets. Moreover, even for an equal bundle allowance, such as O2 in Figure A1.21, comparison may be complicated due to differing upfront costs paid towards the handset, which in turn affect the monthly cost.
- A1.88 The previous discussion refers to complexities involved with comparisons at a single point in time. This is compounded when considering how prices evolve over time, since we need to control for changing bundle allowances and handsets over time. The table below is based on the detailed raw pricing data used by FE in its analysis. This considers the trends in average prices for given data allowances. The values highlighted in red correspond to increases in prices with respect to the previous year while those in green correspond to price decreases.
- A1.89 As can be observed from Figure A1.22, the average monthly prices by year and data allowance from FE's raw pricing data suggest a mixed picture with some average prices by data allowance rising and others falling over this period. However, while this shows the changes in the average prices of plans with the same data allowance, there are other characteristics that could be changing over time that are not considered here.⁶⁵ Therefore, conclusions on the overall pricing behaviour of the market based only on this comparison might not be reliable.

⁶⁵ Figure A1.22 does not take into account other dimensions such as contract length, device included, provider of the service and minutes and SMS allowances, among others. Furthermore, for each data

Figure A1.22: Average monthly prices (in £) by year and data allowance⁶⁶

Data allowance (GB per month)	2013	2014	2015	2016
0		7.73		
0.05	8.76	10.59	9.58	
0.1	15.38	14.94	12.80	11.07
0.25	16.34	19.05	18.56	12.60
0.3		12.70	13.38	12.96
0.5	23.64	20.30	20.00	19.66
0.75	22.68	20.56		
1	27.49	23.48	24.64	24.73
1.5	28.37			
2	31.05	26.55	27.95	28.58
3	36.26	30.25	28.28	28.54
4	34.84	30.58	31.95	31.11
5	34.85	31.33	31.93	32.57
6	32.33	30.55	33.73	33.66
7		35.68	35.93	33.48
8	39.80	34.95	36.28	33.62
9		41.10		29.30
10	35.31	34.59	37.76	38.46
11				27.63
12	41.52	40.58	37.54	36.03
13		46.10	43.61	
15			44.55	44.88
16				33.75
20	44.80	38.73	42.91	41.18
21				34.74
24				45.25
25			50.39	49.80
26				39.96
30			45.69	43.19
40				53.48
50		66.62	69.65	66.76
100	24.55	27.06	36.35	44.18

Source: Ofcom from Frontier Economics' data

A1.90 To separate price changes on a like-for-like basis from other differences in the bundle, such as the technological standard being used to serve consumers (3G or 4G) or the size of allowances over time, or in the handset, two approaches can be used. The first is a basket analysis where tariff plans are categorised and assessed

allowance the number of observations between different years changes as some plans disappear while new ones are launched.

⁶⁶ Average monthly prices are based on FE's raw pricing data used in its econometric analysis. This data comprises solely post-pay plans with handsets, excluding wholesale handset costs. These average monthly prices do not include post-pay SIM-only plans.

as a group. The second is econometric analysis where all tariff plans are taken into account in an attempt to isolate pure price changes from changes that relate to other differences at a point in time and over time. Each of these different approaches has advantages and disadvantages, which can affect the analysis and the appropriate interpretation of the results.

- A1.91 We have carried out our own basket approach based on the methodology used for our own ICMR and which we discuss next. As mentioned, FE carried out an analysis based on a revised basket approach as well as an econometric analysis, which is discussed later in this section.

Basket approach

Ofcom's basket approach

- A1.92 In our November 2016 consultation, we presented the evolution of prices for what we labelled as “weighted average of best prices available from all operators” and “lowest available stand-alone mobile pricing (SIM-Only)”.
- A1.93 The basket approach defines eight hypothetical usage baskets, consisting of a combination of mobile voice, SMS and data usage volumes, to broadly represent mobile service usage across different types of consumers. To analyse the prices of these baskets, we used a bespoke pricing model commissioned from pricing consultancy Teligen. The model is populated with tariff data available on the websites of leading mobile service providers in the UK and identifies the tariffs that offer the lowest price for meeting the requirements of each usage basket. The model also identifies 'weighted average' prices for each basket, calculated as the average of the lowest tariff from each of the providers for that basket, weighted by the market share of the service provider. All sales taxes and surcharges have also been included, in order to reflect the prices that consumers actually pay.
- A1.94 To assess pricing trends, we have compared the tariffs of the different UK operators based on the representative usage baskets or connections shown in Figure A1.23, which follow the same methodology that we used in our 2015 ICMR.⁶⁷
- A1.95 We consider that the basket approach is a useful way to compare pricing of communications services. However, there are limitations to our methodology, which are discussed in detail in our 2016 ICMR.⁶⁸ For example, the pricing model assumes a rational consumer who shops around for the best value tariff. However, in reality, many consumers do not act in this way and only a proportion will be on the best plan for their usage profile. Further, to calculate the 'weighted average' price, the model uses operators' overall retail customer market share and not the subscriber base for the particular tariff as those figures are not available to us.

⁶⁷ See http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/icmr15/icmr_2015.pdf for a detailed explanation of the determination of the baskets. For the pricing analysis, we have not updated the basket selection to use the 2016 ICMR baskets because usage, especially consumption of data services, has changed over time and the tariff plans that were available in earlier years do not always provide sound results. For example, the 2016 basket in connection 8 includes 15GB of data volume. In earlier years, such as 2013 and 2014, there were few packages that offered such high data allowances. As a result, the pricing models calculated an out of bundle data price for these packages to meet the required allowance, causing the resultant prices to be very high in the earlier years. Consequently, to make the baskets more comparable across the period of our analysis, we use the 2015 basket criteria. We have also corrected the Teligen model for some errors in 2015 and 2016.

⁶⁸ https://www.ofcom.org.uk/data/assets/pdf_file/0026/95642/ICMR-Full.pdf

Figure A1.23: Composition of service baskets

	Handset type	Outbound voice minutes per month	Outbound SMS per month	Data use per month
Connection 1	Basic	50	None	None
Connection 2	Basic	50	25	100MB
Connection 3	Intermediate	150	200	300MB
Connection 4	Intermediate	250	100	400MB
Connection 5	Premium	200	50	500MB
Connection 6	Intermediate	100	250	2GB
Connection 7	Premium	300	150	1GB
Connection 8	Premium	500	200	5GB

Source: Ofcom

A1.96 Using the basket approach, we compare five types of plan:

- i. All plans with handset prices, in which we compare the evolution of all plans, including handsets. When a plan does not include a handset (e.g. it is SIM-only or pre-pay) the retail price of a handset is added⁶⁹ to make it comparable.
- ii. All plans excluding handset prices, in which the retail price of handsets is removed from those plans that include a handset.
- iii. SIM-only plans, in which we only look at SIM-only plans within each basket category.
- iv. Post-pay handset plans excluding handset prices, i.e. only post-pay plans that include a handset but where the price of the handset is removed.
- v. Pre-pay plans.

A1.97 We also look at two sets of results for the prices in each of the baskets and each of the categories listed above:

- a. **Weighted average:** This set of results involves, for the usage profile in each basket, identifying the best price available from each provider (MNO or MVNO⁷⁰) from all of the plans it offers, and then deriving a weighted average price for each basket using those providers' retail market shares as the weights.
- b. **Lowest available:** This set of results involves, for the usage profile in each basket, identifying the single best price plan available from all the MNOs and MVNOs.

⁶⁹ As sourced from amazon.com and other retailers

⁷⁰ The MVNOs included in the Teligen model are GiffGaff, Virgin, Tesco, Lebara and Lycamobile for 2014 and these plus TalkTalk, Talkmobile and BT Mobile for 2015 and 2016.

- A1.98 For each of the alternatives we discuss below we also calculate the overall price change, i.e. taking the sum of all baskets, similarly to the estimation we carried out in our ICMR. It is important to note that these calculations assume that all baskets have equal weighting, which may not be an accurate reflection of how subscribers are distributed among the different baskets.
- A1.99 In our November 2016 consultation, we presented the evolution of prices from 2013 to 2016. However, since we published our consultation we have found some issues with the 2013 data. Firstly, some baskets as defined in the ICMR 2015 require a 4G connection. However, in 2013, EE was the only provider offering 4G service and, therefore, the 2013 data reflects the prices from only one provider. Moreover, the 'weighted average' and cheapest tariff are the same as both represent the best available pricing from EE for basket. Secondly, in 2013 there were very few plans with a data allowance of 5GB or more. In the absence of such plans, the Teligen model will pick up plans with a lower data allowance and will calculate out-of-bundle usage until the 5GB data allowance is reached. When attempting a like-for-like comparison, this can distort the price trends. Therefore, in this statement we have focused our analysis on the price trends from 2014 to 2016, thereby excluding 2013.
- A1.100 It is important to mention that in our November 2016 consultation, as well as the 2015 ICMR, we presented the price evolution of the weighted average of plans with handsets (i.e. i. and a.) and the lowest available 'standalone'⁷¹ plans (i.e. ii. and b.). However, we incorrectly labelled the latter as "SIM-only", which is not the case as it also includes handset plans that have had the price of the handset removed as well as pre-pay and SIM-only plans.⁷²
- A1.101 Furthermore, unlike the 2015 ICMR, the 2016 ICMR (which we discuss in the international pricing comparison section) does not look at plans with handsets but only at the weighted average of plans excluding handsets (i.e. ii. and a.) and the lowest available plans (i.e. ii. and b.).
- A1.102 There are also some methodological differences as well as differences in the dataset between the results that we present in this section and those in our 2017 report "Pricing trends for communications services in the UK".⁷³ For example, in the pricing report, the 'weighted average' mobile prices excluded tariff plans that were more than 300% of the lowest tariff from any provider for a basket. However, all prices calculated by the pricing model have been included here. Further, since the publication of the pricing report, some changes have been made to the Teligen pricing models to correct issues that were identified with certain SIM-only price calculations which are likely to impact the latest prices.
- A1.103 The methodology outlined in this sub-section tries to assess the pricing alternatives from the perspective of consumers who have the option of acquiring pre-pay or post-pay plans and either acquire their own phone from a retailer or have it provided by the mobile operator as part of the price plan.

⁷¹ 'Standalone' refers to tariffs where the mobile plan was not purchased as part of a bundle (e.g. quad-play).

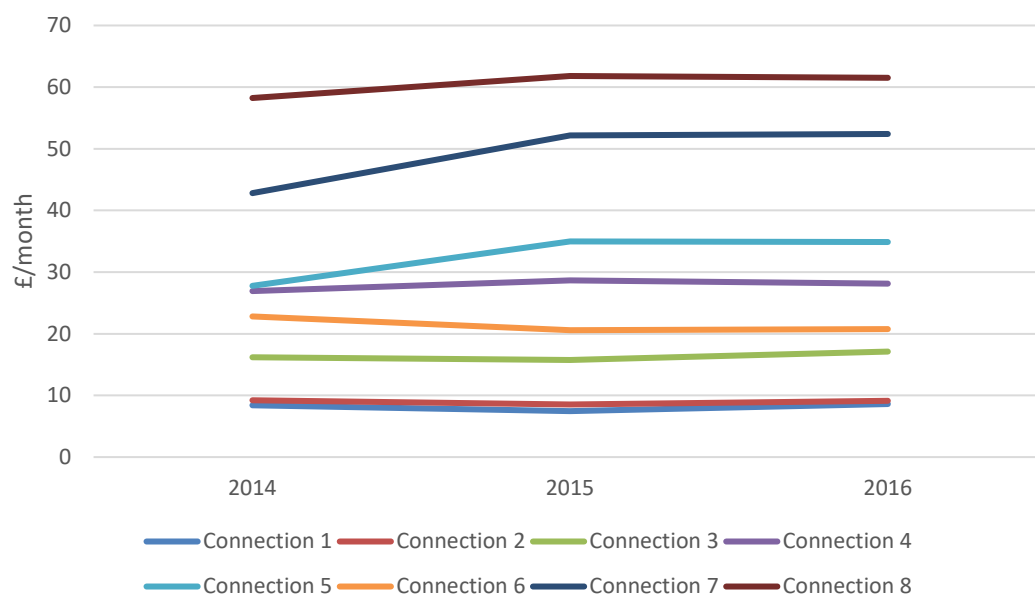
⁷² In our November 2016 consultation we presented Figure A7.16 as "SIM-Only". We now understand that the Teligen model was identifying the lowest available tariff, taking into account all tariffs (not just SIM-only) and removing the retail price of the handset for handset plans.

⁷³ See https://www.ofcom.org.uk/_data/assets/pdf_file/0028/98605/Pricing-report-2017.pdf.

All plans with handset prices (i.)

A1.104 We start by comparing the weighted average of the best prices available from all operators for all plans with handsets (i.e. i. and a.). Baskets 1, 2 and 3 were relatively flat in terms of price, basket 4 experienced a slight increase, basket 6 experienced a decline while baskets 5, 7 and 8 experienced increases from 2014 to 2015, then remaining broadly flat from 2015 to 2016.

Figure A1.24: Weighted average of best prices available from all providers for all plans with handset prices



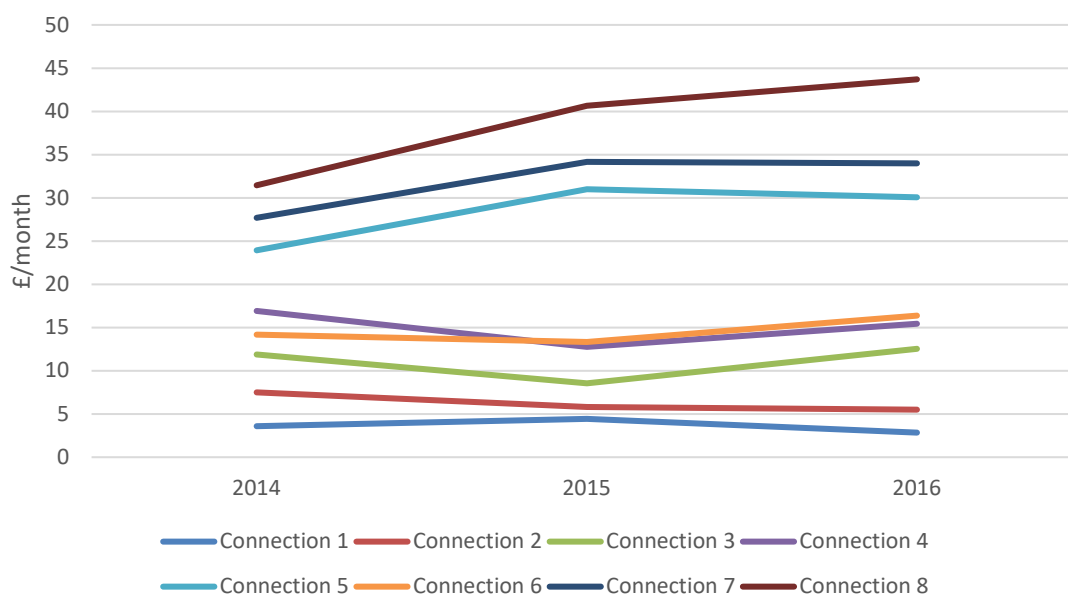
Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.105 The (unweighted) overall price increase between 2014 and 2016 was 9.5%, and it was 1.2% between 2015 and 2016.

A1.106 We also looked at the evolution of the lowest available price for all plans with handsets (i.e. i. and b.). This differs from the weighted average price by identifying only the lowest-priced plan for each basket across providers. Once again connections 5, 7 and 8, which have the premium handsets, showed a marked increase in price between 2014 and 2015. Baskets 5 and 7 then remained broadly flat while basket 8 continued to rise, albeit at a slower pace. Baskets 1, 2, 3 and 4 were at broadly the same price level in 2016 as in 2014. Basket 6 decreased between 2014 to 2015, rising again between 2015 and 2016.

Figure A1.25. Lowest available prices from all providers for all plans with handset prices



Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

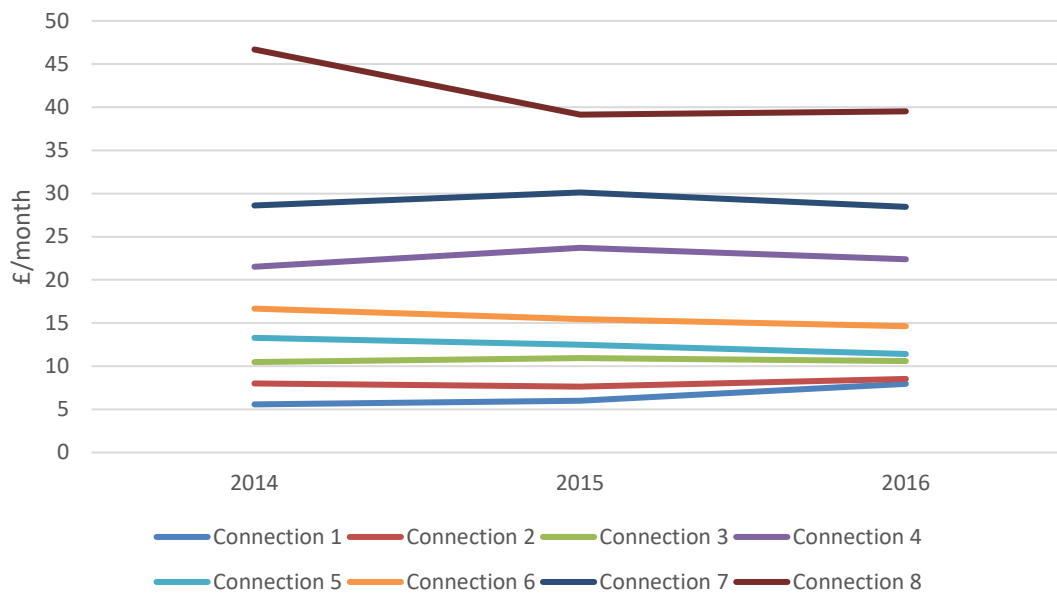
A1.107 The overall price increase between 2014 and 2016 was 17%, and 6.5% between 2015 and 2016.

All plans excluding handset prices (ii.)

A1.108 We now turn our attention to the sample including all plans but where the retail price of the handset has been removed from the tariff if the plan included a handset.

A1.109 Looking at the weighted average of these plans (i.e. ii. and a.), prices have been relatively flat in the 2014 to 2016 period, with the exception of basket 8, which experienced a significant price decrease between 2014 and 2015 and connection 1, with a significant increase in price between 2015 and 2016. Connections 4 and 7 experienced price increases between 2014 and 2015, followed by price decreases between 2015 and 2016.

Figure A1.26: Weighted average of best prices available for all plans excluding handset prices



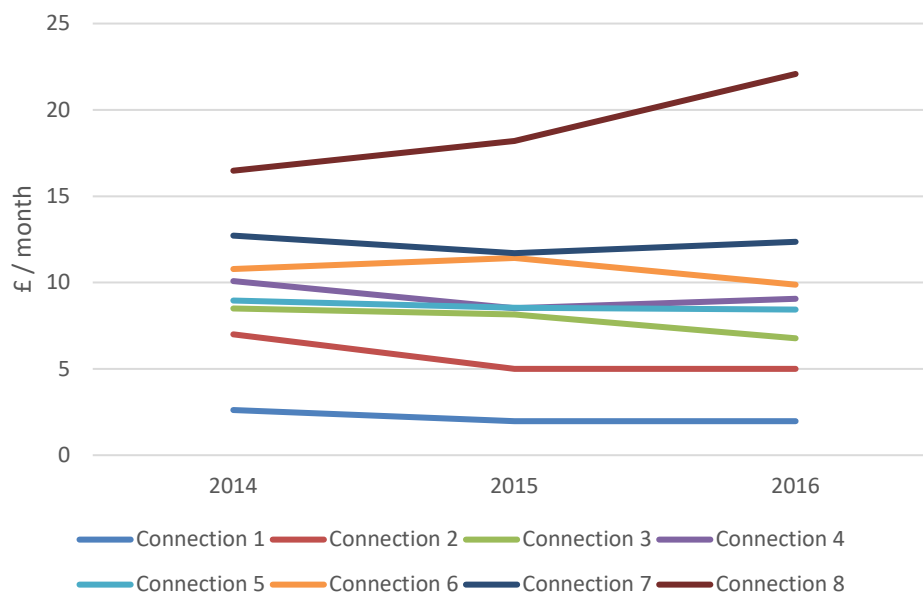
Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.110 There was an overall price decrease between 2014 and 2015 of 4.9%, but only 1.4% between 2015 and 2016.

A1.111 Looking at the lowest available price (i.e. ii. and b.) there has been a continuous and significant increase in the price of basket 8. On the other hand, between 2014 and 2016 all other baskets have experienced price decreases.

Figure A1.27. Lowest available prices for all plans excluding handset prices



Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

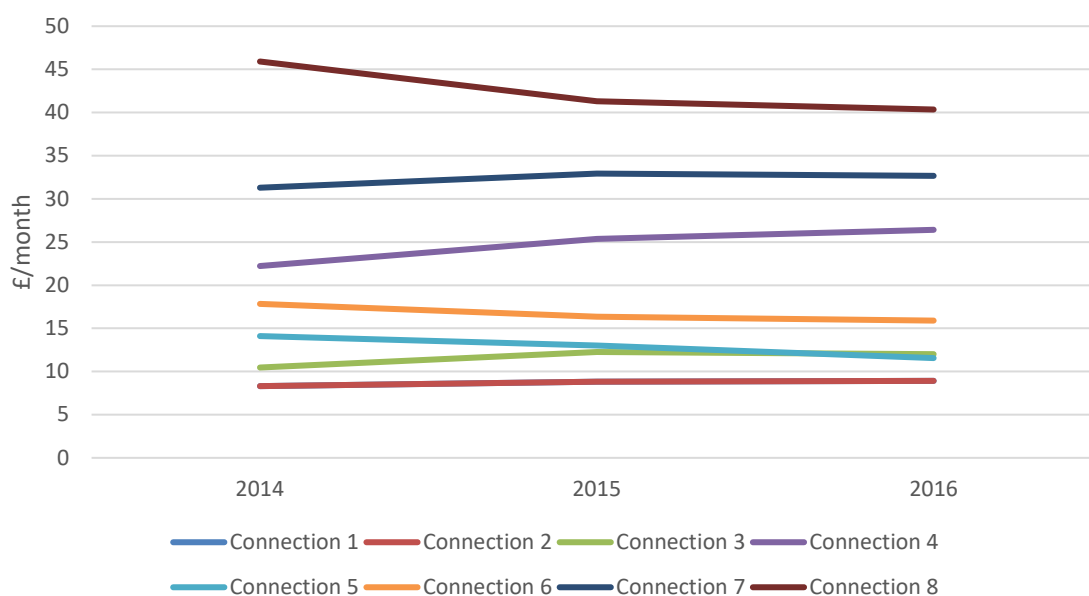
A1.112 There was an overall price decrease of 2% between 2014 and 2016 but a price increase of 2.8% between 2015 and 2016 (driven by the price increase for basket 8).

SIM-only plans (iii.)

A1.113 We have also separated the available plans included in the previous two sub-sections (i.e. i. and ii.) between the three broad categories of post-pay SIM-only, post-pay with handset and pre-pay.

A1.114 For the weighted average of SIM-only post-pay plans (i.e. iii. and a.) there has been an overall downward trend driven by decreases in baskets 3, 5, 6, 7 and 8, offsetting price increases in baskets 4 and 7, especially between 2014 and 2015, and a marginal increase for baskets 1, 2 and 3.

Figure A1.28: Weighted average of best prices available for SIM-only plans

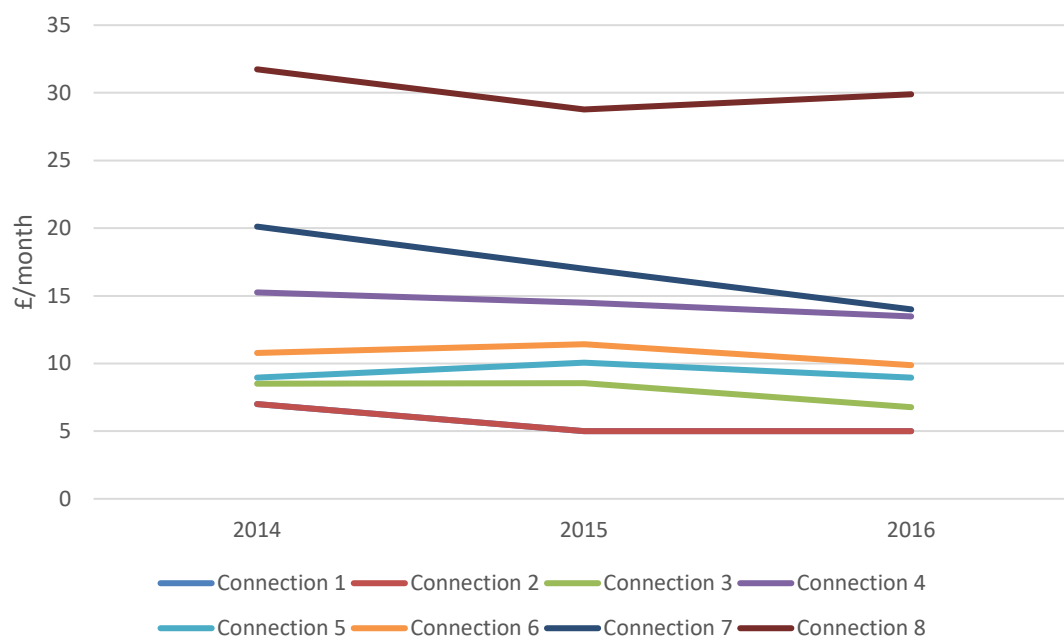


Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.115 There was an overall decrease in these prices of 1.1% between 2014 and 2016 and a decrease of 1.4% between 2015 and 2016.

A1.116 With regards to the lowest available SIM-only plan (i.e. iii. and b.), over the past year only connection 8 increased in price, with other connection types either decreasing or remaining stable.

Figure A1.29. Lowest available' prices for SIM-only plans

Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

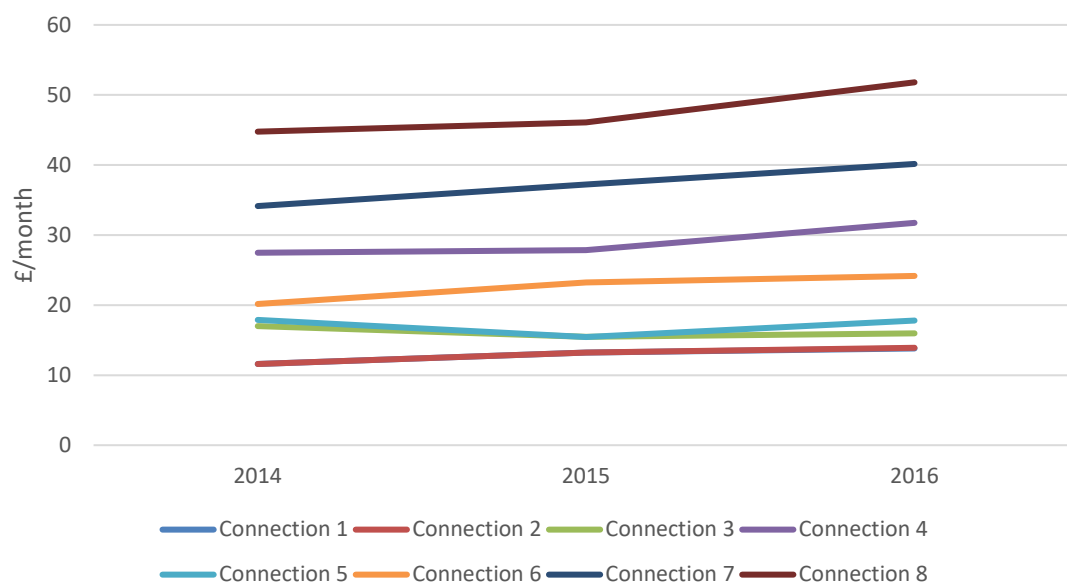
A1.117 Overall prices decreased by 15% between 2014 and 2016 and 7.3% between 2015 and 2016.

Post-pay excluding handset prices (iv.)

A1.118 We now look at the evolution of prices only for post-pay handset plans, i.e. those plans that include handsets, but where the retail price of the handset has been removed (i.e. iv. and a.).

A1.119 With the exception of baskets 3 and 5 between 2014 and 2015, weighted average prices for these plans have had an overall trend increase in price.

Figure A1.30: Weighted average of best prices available for post-pay handset plans, excluding handset prices



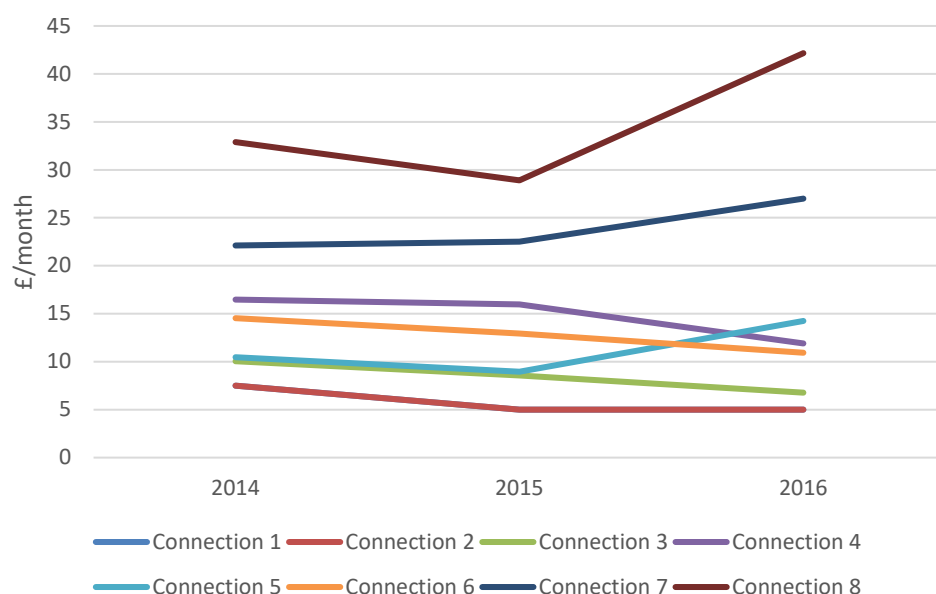
Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.120 The overall price increase between 2014 and 2016 was 13.4% and 9.2% between 2015 and 2016.

A1.121 For the lowest available price (i.e. iv. and b.) the picture is more mixed with price increases for baskets 5, 7 and 8 between 2015 and 2016 while prices for all other baskets either stayed flat or experienced decreases over the same period.

Figure A1.31: Lowest available prices for post-pay handset plans, excluding handset prices



Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

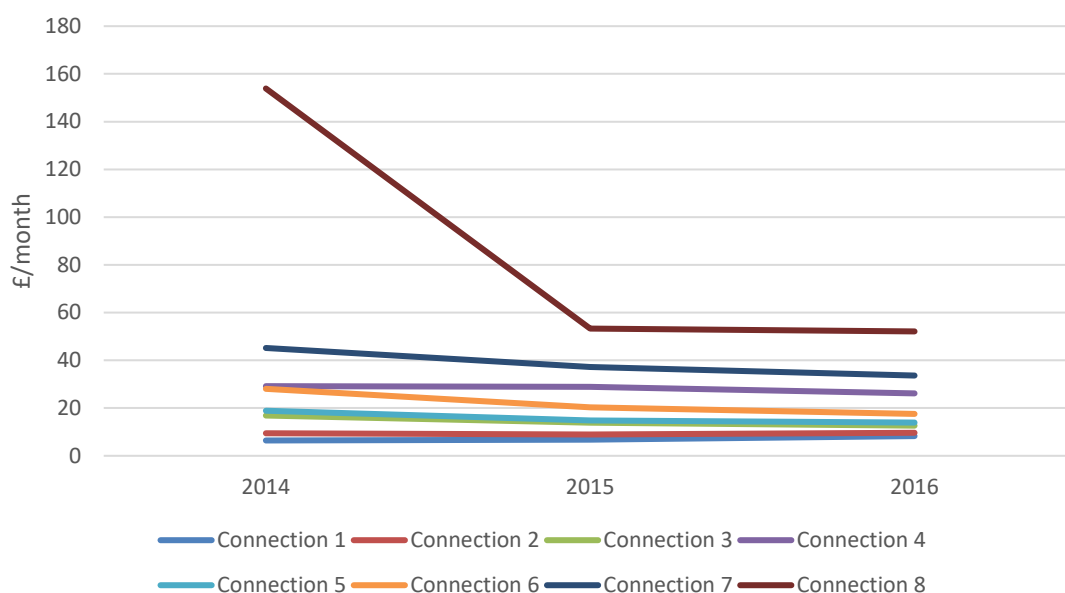
A1.122 The overall price increase between 2013 and 2016 was 1.2% while price increases between 2015 and 2016 were 14.1%.

Pre-Pay (v.)

A1.123 Finally, we look at pre-pay plans.

A1.124 The weighted average of pre-pay plans (i.e. v. and a.) appears to show overall decreasing trend, including a significant fall for basket 8 between 2014 and 2015.

Figure A1.32: Weighted average of best prices available for pre-pay plans



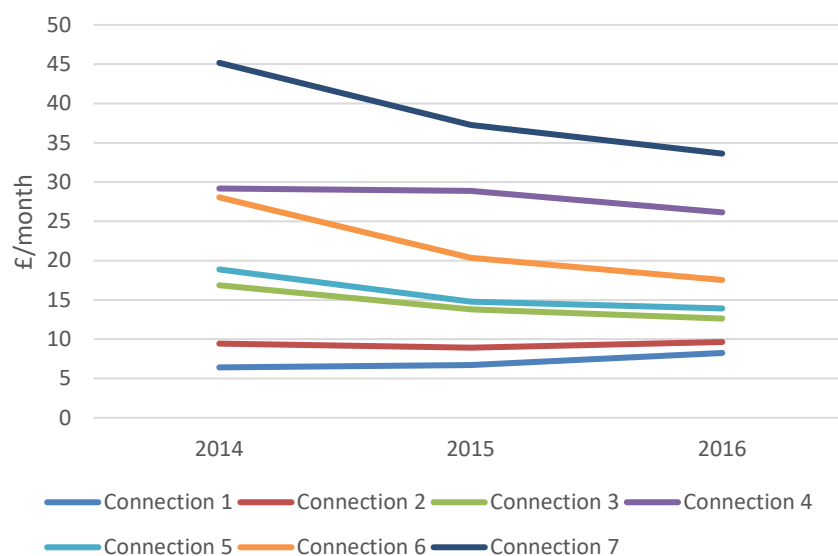
Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.125 Overall prices decreased by 43.5% between 2014 and 2016, although this is likely to be driven by the significant decrease in the price of basket 8 between 2014 and 2015. Between 2015 and 2016 prices decreased by 5.5%.

A1.126 However, in the chart above the model has not removed excessive prices for the 2014 data point for basket 8, resulting in a tariff above £150 per month. Removing basket 8 from the analysis, Figure A1.33 shows more clearly that baskets 1 and 2 experienced price increases while all other baskets 3-7 had consistent price decreases.

Figure A1.33: Weighted average of best prices available for pre-pay plans excluding basket 8



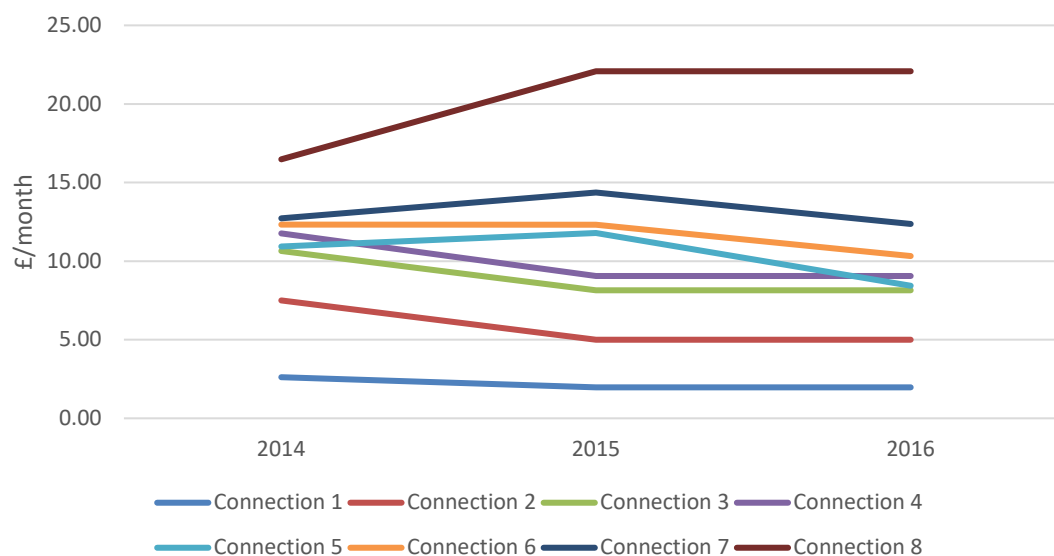
Source: Ofcom, using data supplied by Teligen in July of each year

Note: Nominal prices

A1.127 Excluding basket 8, the overall price decrease between 2014 and 2016 was 20.9% and 6.9% between 2015 and 2016.

A1.128 Looking at the lowest available prices (i.e. v. and b.), there were some price increases, especially in basket 8, but overall prices have been on a downward trend. Unlike the previous two charts, the lowest available price for basket 8 in 2014 produces a reasonable observation and, therefore, we have not removed it from the analysis.

Figure A1.34: Lowest available prices for pre-pay plans



Source: Ofcom, using data supplied by Teligen in July of each year

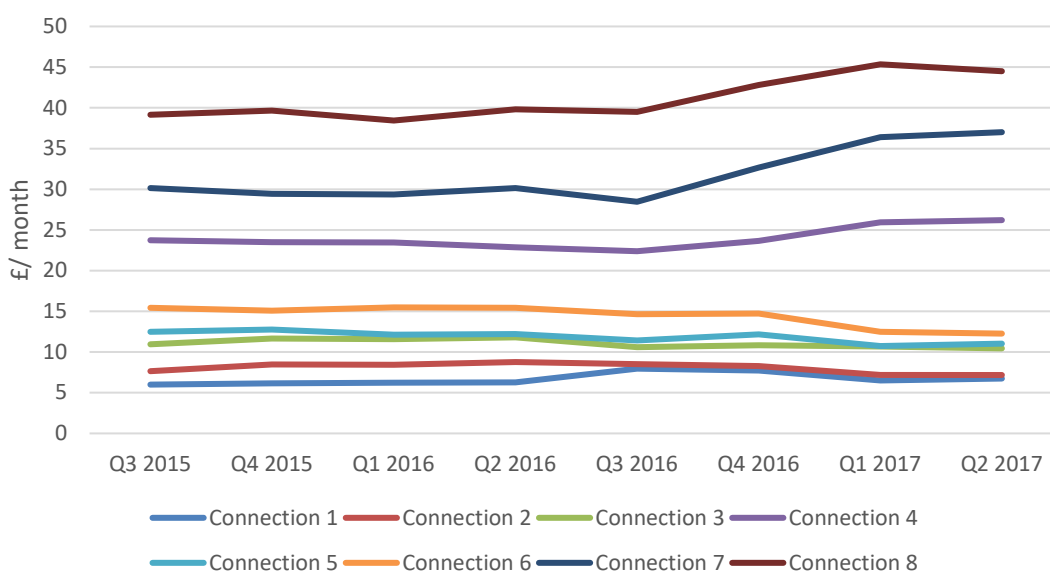
Note: Nominal prices

A1.129 As a result, overall prices decreased by 9% between 2014 and 2016 and 8.7% between 2015 and 2016.

Assessment of variability of basket observations

A1.130 We have also assessed the weighted average prices across all plans excluding handset prices (i.e. ii. and a.) over the last eight quarters to check whether there is significant variability in prices throughout the year, e.g. as a result of temporary promotions. Over this period there have been some price changes, including price increases for baskets 4, 7 and 8 from Q3 2016 while baskets 1, 2, 5 and 6, experienced price decreases over the first two quarters of 2017. Basket 3 has remained fairly stable over this period.

Figure A1.35: Weighted average of best prices available from all operators - quarterly



Source: Ofcom, using data supplied by Teligen

Note: Nominal prices. Sky is excluded in Q1 2017 and Q2 2017; PlusNet is excluded in Q2 2017.

A1.131 While there has been some variability in prices, there does not appear to be significant volatility or abrupt changes in pricing trends.

Summary of Frontier Economics' comments on the basket approach

A1.132 In its report, FE states that our methodology minimises what a mobile subscriber would spend for a given basket of consumption and does not apply weights to the price changes of different baskets. FE also argues that tariffs change all the time so our approach is likely to be sensitive to the exact points in time that are used for the comparison.

A1.133 To arrive at single figure for overall price changes for both the basket and econometric analysis, FE assumes that only 18% of the post-pay contracts are SIM-only. This is based on two sources: Ofcom's "Consumer Experience of 2014" report where Ofcom consumer research conducted in Q2 2014 suggested that 8% of mobile users most often used a SIM-only post-pay contract (i.e. 12% of all post-

pay contracts⁷⁴). The second source is a 2016 YouGov article⁷⁵ which finds that 19% of all mobile subscribers have SIM-only plans (i.e. 23% of all post-pay subscribers). By averaging the two it concludes that 18% of post-pay subscribers use a SIM-only service.

A1.134 FE's revised basket approach claims to have corrected for several of the flaws that it believes are present in Ofcom's approach. For instance, it removes wholesale handset costs, it excludes basket 8 used in the 2016 ICMR report as it considers that there is no evidence of a plan priced at the level shown in the report and it includes weekly tariffs for handset contract baskets and quarterly tariffs for SIM-only baskets (rather than just tariffs in a specific month), among other changes. FE has produced a revised approach for the Ofcom 'weighted average' baskets, but it does not consider 'lowest available' baskets.

A1.135 FE has compared > [REDACTED] ⁷⁶ ⁷⁷

A1.136 In its revised basket analysis, FE finds that handset plans have generally increased in price, while it finds a similar result as Ofcom for SIM-only tariffs. FE found that SIM-only prices decreased by 16% between 2014 and 2016, while prices of contracts with handsets increased by 13% over that same period. Using the 18% SIM-only weight previously mentioned, it finds an overall price increase of 7.8% from 2014 to 2016.

Ofcom's response

A1.137 With regards to the basket approach, FE in its report states that the pricing analysis in ICMR 2015 selects the price offered by the MNOs only. However, our price benchmarking model analyses the prices available from MNOs as well as the largest MVNOs in the UK, where the minimum qualifying price for each provider is weighted by the provider's retail subscriber market share. This is in order to ensure fair representation from the largest providers in the market, including prices offered by MVNOs, which can be lower than those offered by MNOs for certain types of usage. Therefore, FE's basket approach is more limited than our own, in that it excludes MVNOs from its analysis.

A1.138 A key purpose of the ICMR is to benchmark the UK's communications sector against selected international markets. We consider using prices at a specific point during the year to be a practical way to collect and compare pricing of communications services across countries. In an effort to keep the comparisons consistent, we use the prices for the same period across years, i.e. the tariffs across the countries considered in our analysis are collected in July of each year.

A1.139 We agree that the way consumers use mobile services evolves over time, and we assess composition of the hypothetical baskets and adjust these in order to reflect changing usage habits to take this into account. Most recently, we adjusted the baskets in the ICMR 2016 to account of increasing data usage. However, to enable a like-for-like comparison, we use the same usage profiles to analyse prices for both 2015 and 2016. Further, in the *Pricing trends for communications services in*

⁷⁴ See page 112 of

https://www.ofcom.org.uk/_data/assets/pdf_file/0019/63523/tce14_research_report.pdf

⁷⁵ See <https://yougov.co.uk/news/2016/09/02/rise-sim-only-contract-killers-or-start-quadplay-r/>

⁷⁶ Baskets 1, 2, 4, 6, 7.

⁷⁷ Baskets 1 and 2.

the UK report,⁷⁸ which we published in March 2017, we analysed the average prices of mobile services using a basket of services which changed annually to reflect shifting average use of mobile voice, text and data in each year.

- A1.140 In its report, FE also notes that the Ofcom approach does not apply weights to the price changes of different baskets when reporting an overall price change. We agree that our methodology for the overall price change applies the same weight to each usage basket. This is because Ofcom does not have relevant information on the distribution of usage across mobile consumers that can be used to apply different weights to baskets. We believe that, given the absence of information, applying same weight to each usage basket is a reasonable approach. However, it has limitations which are relevant when interpreting the overall price change figures and in seeking to draw implications or conclusions from these figures. The limitations are especially relevant if the prices of different baskets are changing at very different rates or are moving in different directions (as can be the case, as shown in the discussion of basket results above).
- A1.141 FE comments that our basket methodology minimises what a mobile subscriber would spend for a given basket of consumption. In the methodology section of the ICMR, we acknowledge that while our analysis assumes a rational consumer who shops around for the best value tariff, in reality, many consumers do not act in this way. Nevertheless, this approach assesses tariffs that are available in the market.⁷⁹
- A1.142 FE removes wholesale handset costs in its basket analysis. Our basket analysis set out above also considers the impact of handsets, by looking at the prices of plans both with retail handset prices (i.e. i.) and excluding retail handset prices (i.e. ii. and iv.). Consistent with our general approach to baskets, this takes the perspective of consumers choosing between available tariff plans and so uses the retail handset price (whereas FE's approach adopts another reasonable approach of the perspective of MNOs who pay the wholesale handset cost).
- A1.143 With regards to FE's comments on basket 8, the eight hypothetical usage profiles are designed to represent typical usage across different types of consumers. For each provider, our model identifies the lowest-price tariff that meets the requirements of each usage profile, and these prices are then weighted based on the overall market share of each service to calculate a weighted average price for each connection.
- A1.144 The calculation of each provider's lowest price for these connections includes out-of-bundle service charges and, on occasion, this can result in high prices for a provider, where it does not offer a tariff that suits the usage profile in question. In order to avoid such results skewing the weighted averages, the model is designed to exclude tariffs that are excessively high compared to the other tariffs in the basket.
- A1.145 In response to FE's comments regarding the price levels of basket 8 in the 2016 ICMR, we reviewed our findings and found that the model had failed to exclude an excessively high tariff for connection 8 in 2015, resulting in the weighted average price of the connection in 2015, and the fall in prices in the year to July 2016, being overstated. We have corrected for this by excluding this tariff and found that the

⁷⁸ https://www.ofcom.org.uk/_data/assets/pdf_file/0028/98605/Pricing-report-2017.pdf

⁷⁹ For example, it would take into account an attractive new tariff that consumers will switch when they are out of the contract period for their current tariff. As such, it could be a leading indicator of competitive developments.

correct weighted average for basket 8 in 2015 is actually £64 (and not the £113 figure originally published). Therefore, we have addressed FE's comment without needing to drop the basket as the correction shows that this basket is still suitable for our analysis.

A1.146 Using its analysis FE argues that < [REDACTED] ⁸⁰ .

A1.147 We note that, according to FE's data, < [REDACTED] . In the additional evidence that FE provided to Ofcom as support for its report, it also includes a basket analysis that focuses only on MNO's retail prices through their own sales channel (i.e. excluding Carphone Warehouse) as shown in Figure A1.36 below. < [REDACTED] .

A1.148 FE asserted that the evidence < [REDACTED] .

Figure A1.36: Frontier Economics' basket results for MNO contract handsets in 2016 (own sales channels, excluding Carphone Warehouse)

< [REDACTED]

A1.149 In addition, as we discuss later in this section, there is evidence that H3G's high-usage plans are still competitively priced when compared to those offered by the other MNOs.

A1.150 Finally, our evidence suggests that FE has underestimated the importance of SIM-only tariffs in the UK. Recent evidence, including H3G's own submission to the EC, shows that SIM-only is more important than FE has assumed, and it is also a growing segment of post-pay plans in the UK. FE's estimate of the proportion of post-pay plans that are SIM-only (18%) is almost half of the share suggested by our own evidence (34%), which is compiled using data collected from the MNOs and larger MVNOs. Given that FE also finds that SIM-only prices have decreased significantly, its low figure for SIM-only take-up will result in an overestimation of the increase in overall post-pay prices. Correcting the share of SIM-only to 34%, FE's approach results in overall post-pay prices rising by 3.1%, instead of 7.8%.

Econometric analysis

FE's analysis and findings

A1.151 To support its analysis using the basket approach, FE has carried out a piece of econometric analysis to analyse price changes in mobile plans. FE's application of this method considers every post-paid handset plan offered by the four MNOs from 2013 – 2016 (over 160,000 plans). FE's econometric analysis does not include post-pay SIM-only plans nor pre-pay tariffs.

A1.152 To control for the potential of increasing handset prices influencing prices for contracts, FE constructs a dependent price variable that removes the wholesale handset cost from the price. This means that any changes in prices cannot be attributed to changing wholesale handset costs. This monthly price is calculated by taking the initial upfront device payment (spread over 36 months), excluding the wholesale handset cost (also spread over 36 months) and then adding the monthly charge that customers pay, which contributes towards the mobile service, bundle

⁸⁰ See section 5.1 of Frontier Economics' report.

allowances and repayment of the handset price not covered by the upfront device charge.

- A1.153 Using this constructed price variable, FE carries out an econometric analysis based on two regression models. These models use a hedonic pricing approach. This seeks to decompose price differences amongst different plans into price differences that are accounted for by different specified components of the bundle (such as the volume of minutes, texts and data allowances) and operator specific quality differences, and those that are accounted for by changing market conditions. This allows FE to look at how prices have changed across all tariffs, after accounting for changes in operator and/or bundle allowances.
- A1.154 FE's first model is used to compare the trends of mobile prices across time. Controlling for the operator offering different plans and the volume of minutes, texts and data allowances in different plans, FE uses the estimated coefficients of the year dummy variables to calculate the average year-on-year difference in the monthly price. In deriving the average, all tariff plans are given equal weight.
- A1.155 FE's second model is used to assess H3G's prices, relative to other MNOs. FE does this by replacing the individual year and operator dummy variables in its first model with interaction terms between these two variables. This allows FE to look at the relative prices between MNOs across time, controlling for bundle allowances.
- A1.156 FE's first econometric model concludes that prices for handset plans have increased by 15% between 2014 and 2016. Assuming the same weights between handset plans and SIM-only as in its basket approach and the same 16% decrease in price for SIM-only derived in the basket approach, it finds that overall prices have increased by 9.4% over the 2014-2016 period.
- A1.157 FE's second econometric model suggests that < [REDACTED] .
- A1.158 FE concludes that these results provide evidence that overall post-pay prices in the UK have increased between 2014 and 2016; < [REDACTED] .

Ofcom's response

- A1.159 FE's econometric analysis is based on a well-established econometric estimation method called hedonic pricing analysis, which seeks to provide a like-for-like comparison of highly differentiated tariffs. A considerable amount of data is required, comprising firms' prices for their products, pertinent product features and firm-specific characteristics. For example, product and firm-specific features may comprise technological and service features.
- A1.160 For hedonic pricing analysis to allow a robust like-for-like comparison, a number of conditions need to be present: (i) the hedonic pricing analysis needs to be correctly specified; (ii) all important tariff characteristics have to be included in the model; and (iii) there should be independent variation in product characteristics so that all coefficients can be identified. Note though that if some of these conditions are not met because of data limitations then there may still be merit in the analysis but, in this case, caution needs to be exercised and thorough robustness testing of the limitations needs to be conducted to see if it matters for the results and any inference being made.
- A1.161 FE's results are heavily driven by the data used, which means that there are a number of limitations with its analysis. We note that these limitations apply to both

models used in FE's analysis. However, to illustrate the limitations, we only present, where possible, the results from our tests on FE's first model, although we expect that accounting for these limitations is important in both models.

A1.162 Below, we discuss a few of these limitations in more detail.⁸¹

Observations in the FE analysis have equal weight and are assumed to change in the same way over time

A1.163 FE's analysis assumes that all observations (tariff plans) in the hedonic estimation have equal weight and that all tariffs change in the same way over time. We recognise that in the absence of better information, a common assumption with hedonic pricing methods is to assume that all observations enter with equal weight (and we adopt a similar approach to derive an overall figure for price changes in our basket analysis, as discussed above). How much this matters depends on a number of different considerations such as (i) the nature of the dataset and the direction of price trends amongst individual tariffs; and (ii) whether some tariffs are much more popular than others.

A1.164 If prices of different tariffs are moving in different directions over time and some of them are more popular than others, then this limitation is more of a concern, especially if strong conclusions are being drawn about the direction or scale of "overall" price changes (such as the conclusions that FE seeks to draw from its analysis). In other words, if these sources of concern are present (i.e. tariffs with particular characteristics behave differently and particular tariffs are more popular than others), then actual price trends across time and operators could be different to FE's results. FE does not consider this in its analysis.

A1.165 Figure A1.22 above shows that the direction of change in the average prices of plans for each data allowance between 2014 and 2016 is mixed; some average prices have increased across the period, whilst others have fallen.⁸² Most notably, the data suggests that the average prices of plans with unlimited data allowances have increased by approximately £17.00 (63%) between 2014 and 2016.⁸³ Even for those other data allowances experiencing price rises, the increase in average prices is considerably smaller, by comparison. This may suggest that the behaviour of prices of unlimited data plans are distinct from plans without unlimited data offerings.⁸⁴ In other words, it cannot be assumed that all tariffs change in the same way across time.

⁸¹ In the discussion below, we focus on only a few of the limitations we have identified from FE's analysis. Specifically, (i) that FE's analysis assumes that all tariff plans have equal weight and all tariffs change in the same way over time; (ii) that FE's analysis does not consider mobile technology standards; (iii) that the data used in FE's analysis may not cover all plans with differing contract lengths; and (iv) that FE's assumed model specification may not be appropriate. However, in reviewing FE's analysis, we also found that the analysis does not fully take into account the effect on tariffs of differing handset quality and the possibility that mark-ups of price over wholesale cost might change over time or across operators. Additionally, we found that FE's assumption of including bundle allowances of minutes, texts and data as continuous variables was not robust to a test of this assumption where they are measured as categorical variables.

⁸² These average prices exclude wholesale handset costs.

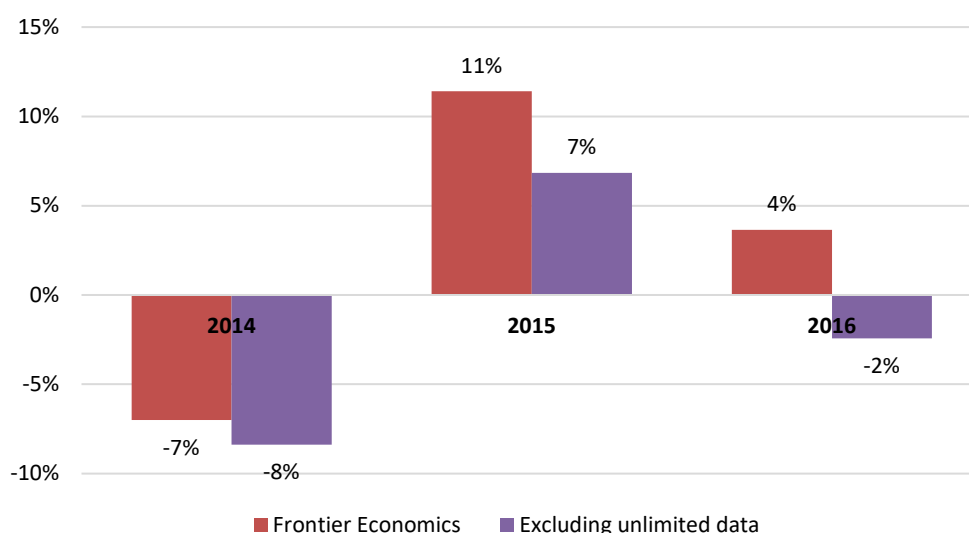
⁸³ In the time period considered, H3G was the only MNO to offer plans with unlimited data allowances. Unlimited data plans account for approximately 5% of all post-pay plans with handsets included in FE's regression analysis.

⁸⁴ The same limitations apply to such comparisons across time.

A1.166 In addition, if demand for these unlimited data packages was low, then the combination of these tariffs behaving differently to others and the equal weighting given to these tariffs could be driving FE's results. As a test of this issue, we carry out FE's first regression model using their dataset but excluding plans with unlimited data allowances. If FE's specification were correct, estimating the model on a subset of observations would not change the results by much. We find, however, that FE's results are sensitive to variations in data points included in the analysis. This means that, depending on what consumers actually demand and whether tariffs behave differently to each other, the actual pattern of prices across time and operators could be materially different to FE's analysis.

A1.167 Figure A1.37 shows the year-on-year price changes, when plans with unlimited data packages are excluded. This shows that the price increase from 2014 to 2016 is 4% compared to 15% in FE's econometric results. Moreover, the direction of the estimated movement in prices in 2016 changes from a price increase in FE's analysis to a price reduction.

Figure A1.37. Year-on-year price changes for FE's reported results compared against excluding unlimited data allowances



Source: Ofcom based on FE's report and dataset

A1.168 Therefore, our test of the sensitivity of FE's results to the assumption of equal weighting of all tariff plans and that all tariffs change in the same way over time resulted in significant changes in the results, both to the overall price change and the pattern of price movements, now showing a price reduction in the latest year, 2016. This raises doubts about the extent to which FE's result for the overall price change provides an accurate and robust picture of price movements.

Mobile technology standards are not considered by the FE analysis

A1.169 As set out above, for a robust hedonic pricing analysis, all important tariff characteristics have to be included in the model. FE's econometric analysis does not distinguish between plans that offer 3G versus 4G technology. This is because the data it uses does not include this information. FE argues that this distinction is unlikely to be important for recent tariffs as the majority of handsets are now 4G enabled and tariffs reflect this.

- A1.170 We would agree this distinction is unlikely to be important for recent tariffs (i.e. those in the latter part of 2015 and 2016) but there is evidence to suggest that this distinction was important in the earlier years (i.e. in 2013 to the early part of 2015). As set out in Ofcom's 2015 Economic Geography report,⁸⁵ 4G coverage was still under development, so some operators offered different tariffs depending on whether they included 4G or relied only on 3G. The importance of this distinction is similarly suggested by a review of the UK data that we used in our cross-country econometric analysis of the effect of disruptive firms on mobile pricing.⁸⁶ While this data is not equivalent to the data used by FE, there is a small overlap in the time-period covered. This data shows that mobile tariffs did differ depending on whether they were using 3G or 4G.
- A1.171 By omitting the distinction between 3G and 4G, FE's analysis neglects the effect of 4G tariffs having higher quality to their equivalent tariff in 3G at a point in time. This effect could be reflected by higher prices and we are aware that some operators were charging a premium for 4G services initially. FE also ignores the impact of improvements in network quality over time. This could be reflected by either higher prices over time since MNOs may charge a premium for improvements in speed or coverage of 4G services or lower prices over time because MNOs are competing to offer better quality services to consumers for less. Ideally, to test for the effect on tariffs of plans being either 3G or 4G, each plan should be identified as either 3G or 4G. However, FE's dataset does not have this information.
- A1.172 To try and account for this effect, we created a variable that measures the percentage of 4G outdoor geographic coverage for each operator in each year. Whilst this does not account for the technology associated with each plan, its inclusion does attempt to crudely account for the changing mobile technology offered by operators across years. Currently, these effects will be incorrectly picked up by FE's econometric analysis.
- A1.173 Figure A1.38 below from our Connected Nations reports shows that 4G was negligible in 2013 and coverage was low in 2014. During the time period covered by this analysis, it is therefore likely that the distinction between 3G and 4G plans would have been important for tariff packages.

Figure A1.38: 4G outdoor geographic coverage between 2013 and 2016 ⁸⁷

% 4G coverage	2013	2014	2015	2016
H3G	-	-	9%	55%
O2	-	9%	26%	52%
EE	-	19%	39%	64%
Vodafone	-	7%	30%	56%

Source: Ofcom, *Connected Nations*

⁸⁵ <https://www.ofcom.org.uk/research-and-data/multi-sector-research/availability-of-communication-services/economic-geography-15>

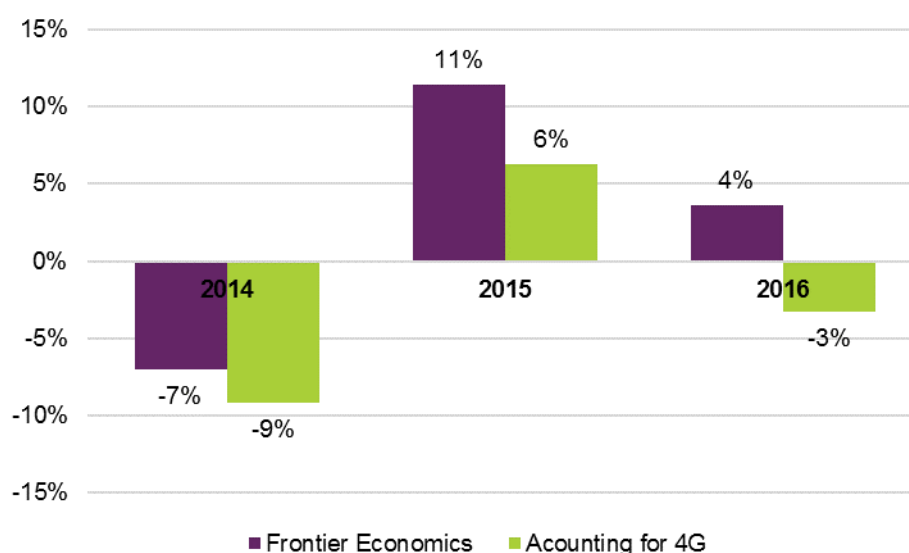
⁸⁶ Based on our review of the data we used in our cross-country econometric analysis of the effect of disruptive firms on mobile pricing, we have identified that over 50 per cent of 2013 tariffs and over 30 per cent of 2014 tariffs were not 4G enabled.

⁸⁷ We use the percentage of 4G outdoor geographic coverage (collected in June), measured by a consistent threshold of -115dBm. The data for 2014 is available in the Infrastructure Report 2014, Figure 59, Page 89. The data for 2015 and 2016 is available in the Connected Nations Report 2016, Figure 20, Page 40. We note that in 2013, 4G coverage was negligible in terms of geographic coverage.

A1.174 If FE's analysis was correct, estimating the model with this additional 4G variable should not produce a materially different result. However, when our measure of 4G coverage is included in the model, the parameter estimate for this variable is positive and statistically significant. This suggests that FE's model, which omits this variable, should be rejected. In particular, adding this variable into the first regression model used in FE's analysis, we find a similar pattern of changes to FE's results to that in our test above to exclude unlimited data plans – see Figure A1.39 below.⁸⁸ In other words, FE's analysis is not robust to small economically reasonable changes in specification. This lack of stability casts doubt on the reliability of the results.

A1.175 The magnitude of the estimated overall price increase across the period 2014 – 2016 is substantially lower at 2% as opposed to the 15% reported by FE; and there is a decrease in the price in 2016 (instead of the price increase in FE's analysis). We acknowledge that the measure of 4G rollout is imperfect as there is a risk that it is correlated with other variables (including the year dummies). Therefore, the impact of including such a measure on the magnitude of price changes across years should be interpreted with caution.

Figure A1.39: Year-on-year percentage change in overall price, accounting for 4G rollout by operator



Source: Ofcom based on FE's report and dataset

A1.176 Notwithstanding this limitation, in our view, the effect of rapid rollout of 4G across the 2015/2016 period and its absence in 2013 should be accounted for separately in FE's analysis. Given the extent of the possible impact of the technology standard affecting tariff plans, FE's analysis is not robust to small economically reasonable changes in specification. We consider therefore that FE's results cannot be relied upon to provide a true picture of price changes and so caution is required in making any inferences based on those estimators.

⁸⁸ We note that in our replication of FE's results, we obtained marginally different mean monthly prices for each year. Using FE's mean monthly prices in each year, as opposed to those found in our replication, does not substantively change our results in testing 4G coverage.

Data used in the analysis may not cover all plans with differing contract lengths

A1.177 Figure A1.40. below indicates the estimated contract length of the data considered by FE in its analysis, rounded to the nearest whole number. We estimate that almost all mobile plans in FE's dataset have a 24-month contract period.⁸⁹

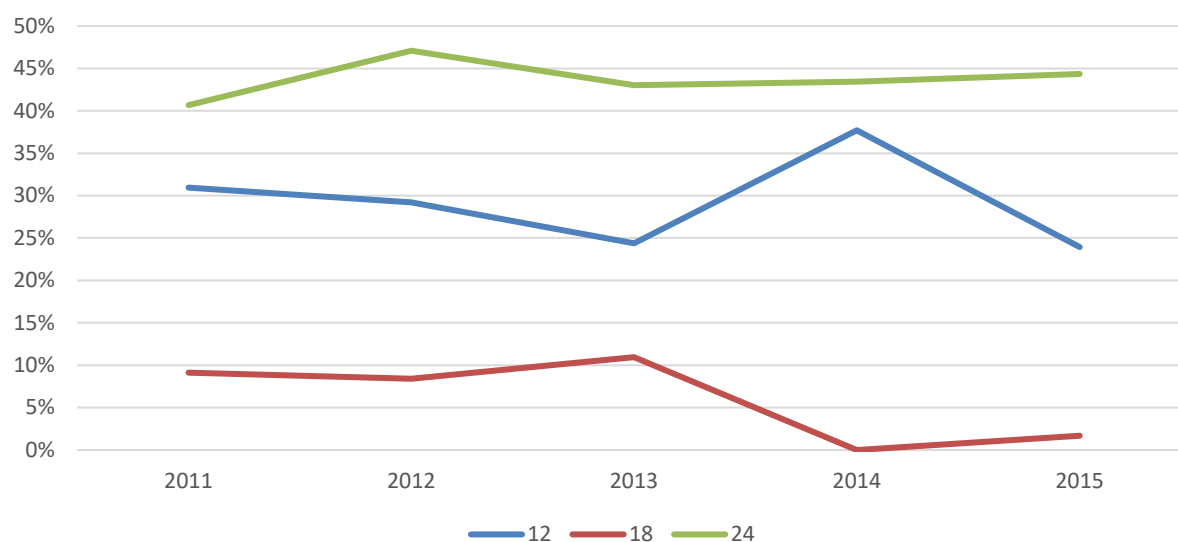
Figure A1.40: Estimated contract length of FE dataset

Estimated contract length (months)	Frequency	Percent
21	2,331	2
24	141,854	98
Other	14	0
Total	144,199	100

Source: Ofcom based on FE's dataset

A1.178 While the dataset provided by FE appears to comprise almost exclusively 24-month contracts, a review of the UK data that we used in our own cross-country econometric analysis of the effect of disruptive firms on mobile pricing shows that many contracts in earlier years were 12 months or 18 months. Figure A1.41. shows the percentage of UK data with differing contract lengths used in our own cross-country econometric analysis.

Figure A1.41: Contract lengths of UK data used by Ofcom cross-country econometric analysis



Source: Ofcom

⁸⁹ FE's dataset includes a variable called "simplecoo". We are unsure of the exact definition of this variable, however, it appears to be the total cost of the mobile plan over the entire contract period given by $\text{simplecoo} = \text{device charge} + (\text{monthly charge} \times \text{contract length})$. From this we estimate the contract length of a given mobile plan. We are able to estimate 89% of the mobile plans included in FE's analysis. The remaining mobile plans had a missing value for the simplecoo variable, which prevents us from estimating the contract length for these plans.

A1.179 We cannot be certain therefore that FE's dataset covers all plans, i.e. those including lower contract lengths. If this is the case, these results may not accurately represent the prices of post-paid contracts with handsets.

Assumed model specification may not be appropriate

A1.180 A key consideration with hedonic analysis is that the relationship between price and the bundle characteristics of the mobile plan may not be linear – prices may increase at an increasing or decreasing rate when characteristics change. FE's analysis does not test for this. It just assumes a linear relationship exists between the average monthly charge and bundle characteristics of the mobile plan.

A1.181 As a test of this assumption, we use a Box-Cox model for each regression model used by FE.⁹⁰ This method reports the value of θ and λ that maximise the likelihood function.⁹¹ Our tests using this approach for both models suggest that in carrying out the hedonic regression analysis, the linear functional form that has been adopted by FE is not a best fit of the data.⁹²

A1.182 Given our concerns set out above, the results from the Box-Cox test are perhaps not surprising and are likely caused by a more fundamental problem with the model.

Our conclusion on FE's econometric analysis

A1.183 In summary, while FE's econometric analysis is based on a well-established econometric estimation method, its results are heavily driven by the data used.

A1.184 We recognise that in the absence of better information, a common assumption is to assume that all tariff plans in the hedonic estimation have equal weight and that all tariffs change in the same way over time. However, if prices of different tariffs are changing at very different rates or moving in different directions, and some of them are more popular than others, then the limitation of FE's equal weight assumption is likely to matter more. FE does not consider this in its analysis.

A1.185 During the time period examined, the average price of plans with unlimited data allowances increased significantly. For other tariff plans, the average monthly prices by year and data allowance from FE's raw pricing data in Figure A1.22 above suggest a mixed picture with some average prices by data allowance rising and others falling over this period. If demand for the unlimited data plans was low, then their significant average price increase could incorrectly skew FE's overall results upwards. Re-running FE's analysis but excluding unlimited data plans shows that FE's results are sensitive to variations in data points included in the analysis. For example, in our illustrative test, not only did the scale of overall price movements

⁹⁰ The Box-Cox model allows an analyst to estimate what non-linear transformation best fits the data. In particular, the Box-Cox model includes two types of transformations: (i) Box-Cox transformation of price = $(\text{price}^\theta - 1) / \theta$; and (ii) Box-Cox transformation of independent variables = $(\text{independent variables}^\lambda - 1) / \lambda$. This method reports the value of θ and λ that maximise the likelihood function.

⁹¹ In statistics, maximum likelihood estimation (MLE) is a method of estimating the parameters (here - θ and λ) of a statistical model given observations (FE's dataset), by finding the parameter values that maximize the likelihood of making the observations given the parameters.

⁹² For FE's model 1, the Box-Cox model suggests a value of $\theta=0.340$ and $\lambda=0.019$ and for model 2, it suggests a value of $\theta=0.336$ and $\lambda=0.020$. This suggests a cube-root transformation of the price variables in both models and a natural-log transformation to the independent variables, minutes, texts and data. Based on these tests, we can infer that the linear functional form FE uses for both models is not a best fit of the data.

change materially, the direction of the price movement in 2016 changed from a price increase to a price reduction. In our view, this sensitivity raises doubts about the extent to which FE's result for the overall price change provides an accurate and robust picture of price movements.

- A1.186 In addition, FE's econometric analysis does not distinguish between 3G and 4G plans. Nor does it account for increasing network quality. Our imperfect test for this (despite its limitations) suggests that FE's results are sensitive to this shortcoming. This suggests that FE's analysis is not robust to small economically reasonable changes in specification and so again this lack of stability casts doubt on the reliability of the results. We are also concerned that FE's dataset does not appear to cover all plans i.e. including those with lower contract lengths. Finally, our tests of FE's assumed model specification suggest that it is not a best fit of the data.
- A1.187 In light of the above issues that we have identified with FE's econometric analysis, we consider that the picture that it paints of pricing trends may be unreliable and hence caution is required in making any inferences from it.
- A1.188 For example, H3G's broader claim is that operators with small spectrum shares (such as H3G) are experiencing increasing capacity constraints which in turn are leading to weaker competition and price increases. In our view, FE's results should not be relied upon, and so fail to provide support for this broader claim.

International pricing comparison

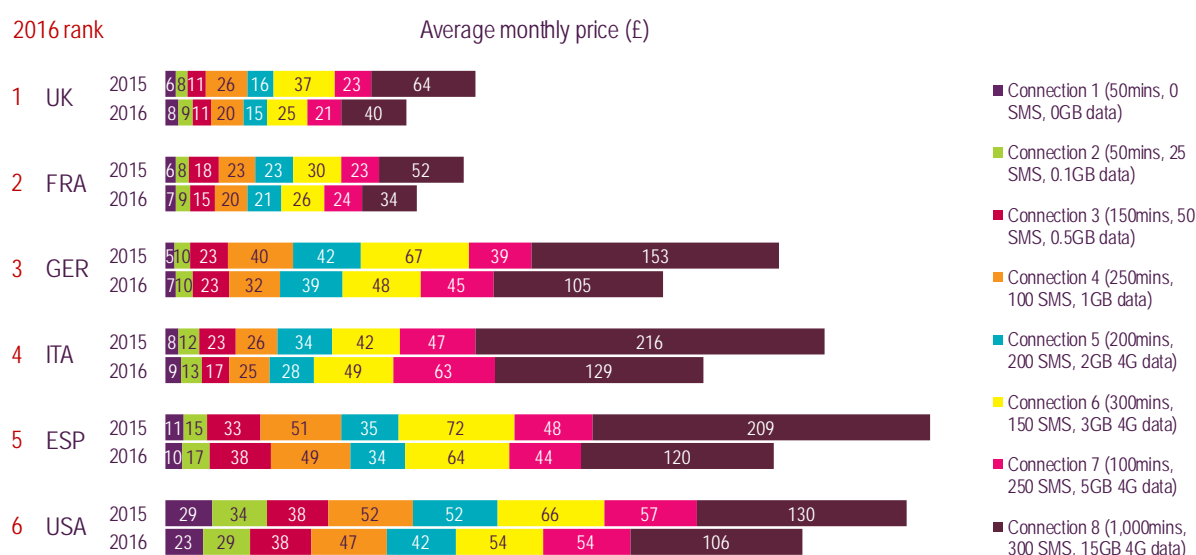
- A1.189 In our November 2016 consultation we included the results from our 2015 ICMR, based on the basket methodology described above. This included the weighted average of plans with handsets (i.e. i. and a.) and the lowest available prices excluding handsets (i.e. ii. and b.).
- A1.190 The 2015 ICMR carried out a comparison of the total price levels of different countries by adding the prices of each of the baskets without taking into account the weight (i.e. share of subscribers) of each basket. For example, we estimated the lowest available prices excluding handsets for each basket in each country. Then for each country we added the values for the eight baskets and compared the result with other countries.
- A1.191 For clarity, in this sub-section on international pricing, "weighted" refers to the use of measure a. as per paragraph A1.97, not to the weighting of the different baskets in order to arrive at a total price. Total prices are always estimated by a simple (i.e. unweighted) addition of the values for each basket.
- A1.192 We concluded that the UK had the lowest total 'weighted average' price (i.e. ii. and a.). However, France, Spain and the UK experienced an increase in this indicator between 2014 and 2015.
- A1.193 We also found that the UK had the cheapest total 'lowest available' prices (i.e. ii. and b.) for eight representative mobile baskets while it had the second cheapest in 2014.
- A1.194 In December 2016, we published our 2016 ICMR (after the November 2016 consultation), in which we updated our international comparison of the UK's mobile pricing⁹³ with other large EU countries and the USA. As discussed in the basket

⁹³ As in Ofcom's 2016 ICMR.

sub-section, the 2016 ICMR only compares prices excluding handsets (i.e. ii.). In this report, we used the term “standalone” to refer to tariffs where the mobile plan was not purchased as part of a bundle (e.g. quad-play).

- A1.195 In the 2016 ICMR we reported that in 2016 the UK had the lowest total ‘weighted average’ price (i.e. ii. and a.) for the eight mobile connections due to a 38% fall in the total price during the year. This fall was largely due to a 64% decline in the ‘weighted average’ price of the highest usage connection (basket 8).
- A1.196 The Frontier Economics report excluded basket 8 from its analysis as it did not find a plan that retailed for £113 nor did it think that any subscriber would take such a plan when there was a £40 plan available somewhere else.
- A1.197 As discussed in the basket sub-section, we have now corrected for this. As a result, the fall in total pricing in 2016 was 22%, not 38%, and the fall in the price of basket 8 was 37%, and not 64%.
- A1.198 In the 2016 ICMR we argued that the total ‘weighted average’ price (i.e. ii. and a.) for all eight connections fell in all six of the comparator countries largely due to falling prices for the highest-use connection, as a result of the increasing availability of tariffs that included larger inclusive data allowances. Despite these declines, the ‘weighted average’ price of Connection 8 remained high in most countries in 2016; the UK and France were the only comparator countries in which it was less than £100 per month.
- A1.199 Most comparator countries showed an increase in the price for the lower-use phone connections, with the exception of the US. In our 2016 ICMR, we stated that we believed that the increase in prices for baskets 1 and 2 in the UK were largely due to operators increasingly focusing on post-pay tariffs on inclusive data allowances, rather than voice (and SMS).

Figure A1.42: ‘Weighted average’ stand-alone mobile pricing



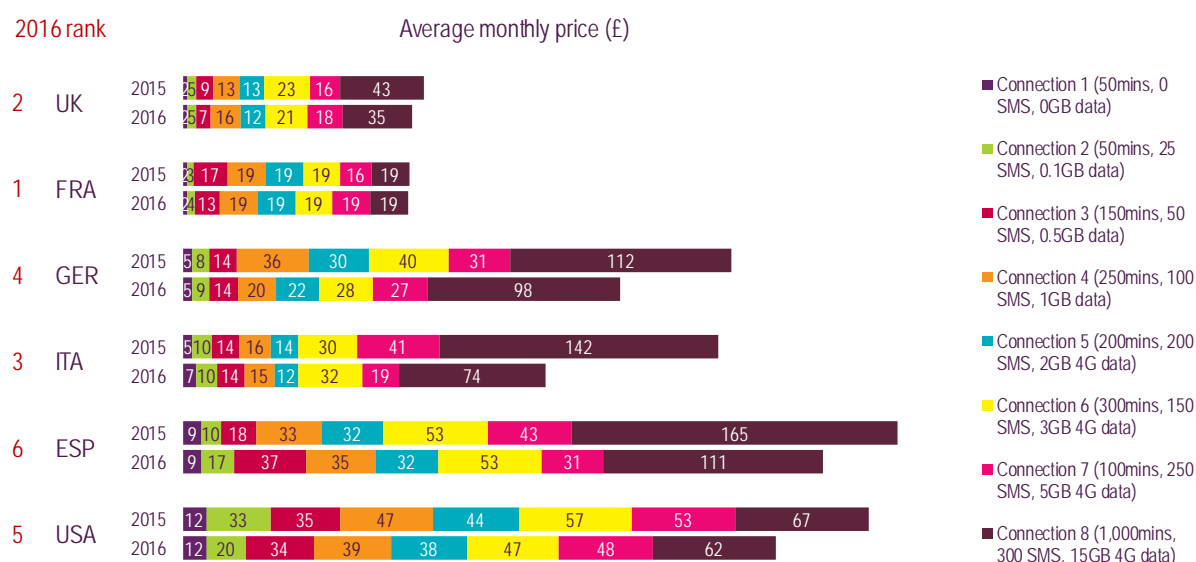
Source: Ofcom using data supplied by Teligen

Note: ‘Weighted average’ of best-value tariff from each of the largest operators by market share in each country; July 2015 and July 2016; PPP adjusted. UK 2015 value for basket 8 has been corrected.

A1.200 Furthermore, in this report we also argued that the UK had the second lowest total 'lowest available' prices for eight representative mobile baskets in 2016, with an overall fall of 5% during the year and the 'lowest available' prices falling for three of the eight connections. The total post-pay UK 'lowest-available' price for our eight connections also fell by 5% during the year, while the total pre-pay 'lowest-available' price fell by 30%. Despite the higher rate of decline in pre-pay prices during the year, the total pre-pay 'lowest-available' price in 2016 was 7% more expensive than the total 'lowest-available' post-pay price.

A1.201 The UK 'lowest-available' prices (i.e. ii. and b.) for the two lowest-use connections (Connections 1 and 2) were unchanged in 2016, while there were increases in the 'lowest-available' prices for Connections 4, 5 and 7. Virgin Mobile, EE and H3G each offered two of the eight UK 'lowest-available' tariffs for our connections in 2016.

Figure A1.43: 'Lowest available' stand-alone mobile pricing



Source: Ofcom using data supplied by Teligen

Note: July 2015 and July 2016; data PPP adjusted.

A1.202 In our 2016 ICMR report we also found that UK 4G users had the highest satisfaction with the price paid for the mobile services among our comparator countries. In the UK, 74% of subscribers were satisfied with the price, followed by Germany, Italy and Australia with 69%, while only 35% of subscribers in Japan were satisfied with their service price.⁹⁴

A1.203 In our November 2016 consultation we presented the results of the Mobile Broadband Prices in Europe 2016 report, which had recently been published by the EC. This report compares mobile broadband prices across the EU's member states as well as non-EU countries including the USA, Japan, South Korea, Norway, Iceland and Turkey.⁹⁵ The report compares handset mobile broadband price plans as well as those for tablets and laptops. There has been no update of this report

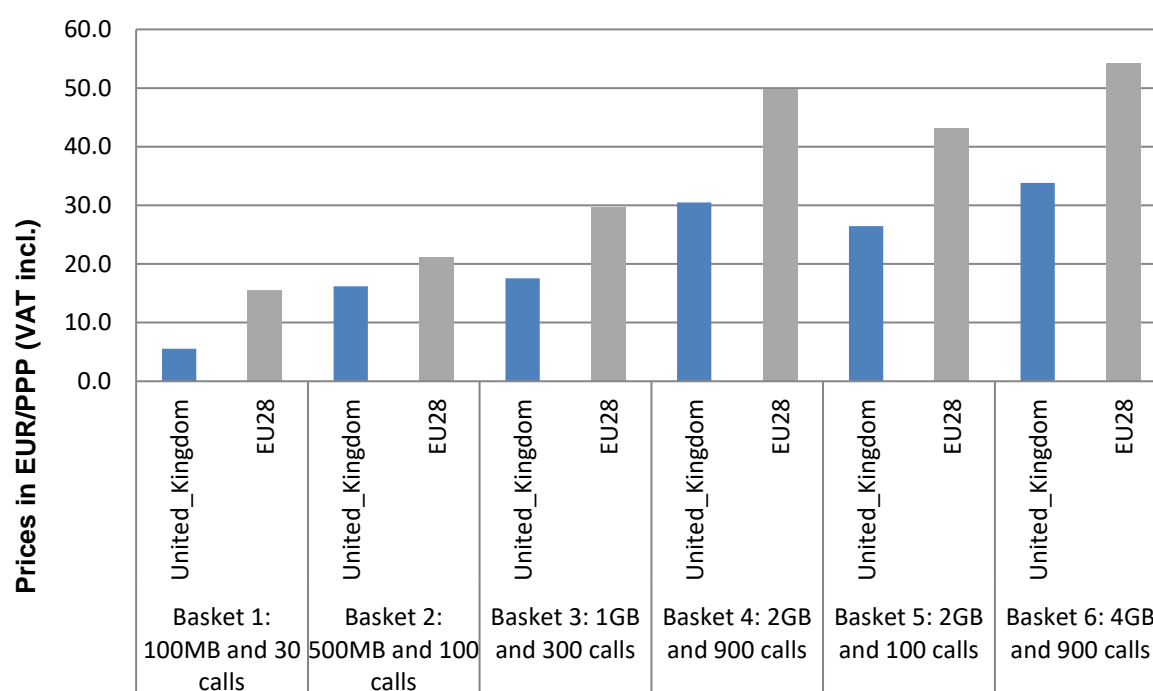
⁹⁴ See figure 3.9 of our 2016 ICMR.

⁹⁵ See <https://ec.europa.eu/digital-single-market/en/news/mobile-broadband-prices-europe-2016>.

since we published our November 2016 consultation and, therefore, we include below what we said at the time for completeness.

- A1.204 The approach used for this report was the 2012 OECD methodology for mobile broadband which calculates the total price of different baskets in order to identify the cheapest offers. It divides the offers into three types of mobile devices (handsets, tablets and laptops) and six usage baskets for each type of device.
- A1.205 The baskets used in the report have relatively low usage allowances. For example, the lowest basket for handset use included 100MB of data plus 30 calls, while the highest basket included 4 GB of data and 900 calls. Laptop allowances ranged from 500 MB and 20 GB and for tablet between 250 MB and 10 GB.
- A1.206 The report finds that the UK performs well compared to other EU countries with regards to handset plans. The UK is in the cluster of countries with the cheapest plans for all but the second basket, where it is in the second cheapest cluster (of four clusters).
- A1.207 Compared to the average of the 28 EU member countries, the UK handset plan prices are between 24% and 64% cheaper.

Figure A1.44: Comparison of the least expensive handset offers UK vs. EU average



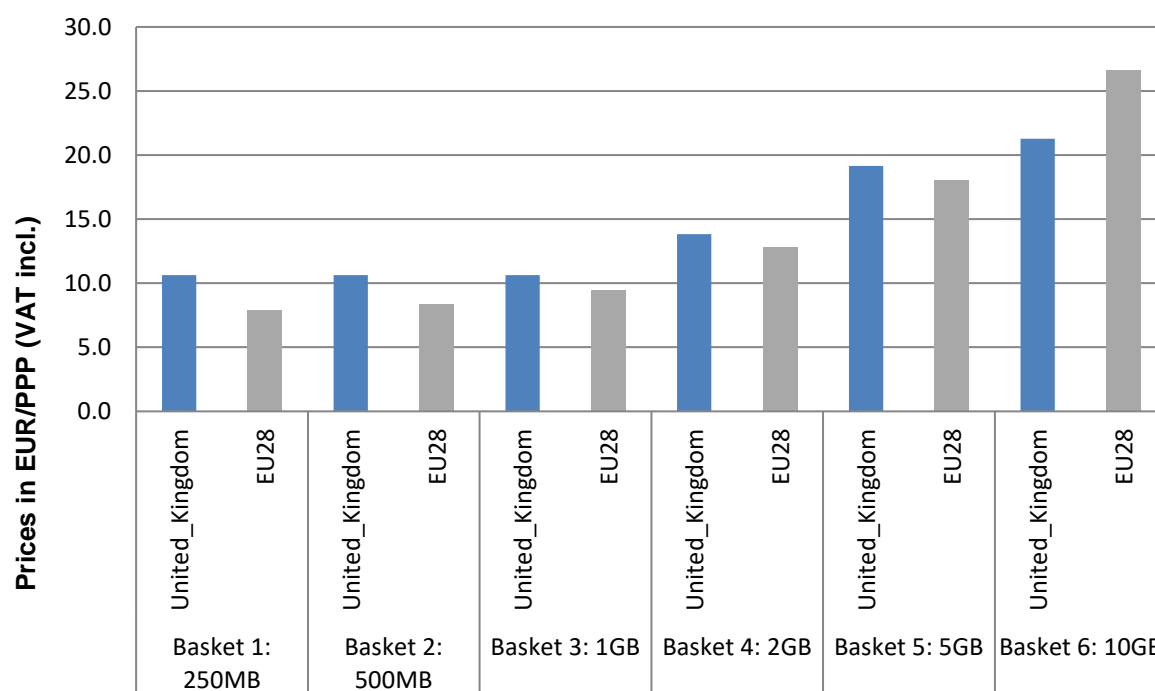
Source: EC Mobile Broadband Prices in Europe 2016 report – Simulation tool⁹⁶

- A1.208 With regards to laptop and tablet plans the UK is in the fourth cluster with the most expensive countries for the baskets with data allowances between 256 MB and 512 MB, in the third cluster for baskets with data allowances between 1 GB and 5 GB and in the second cluster (i.e. second cheapest) for allowances between 10 GB and 20 GB.

⁹⁶ See http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=18584

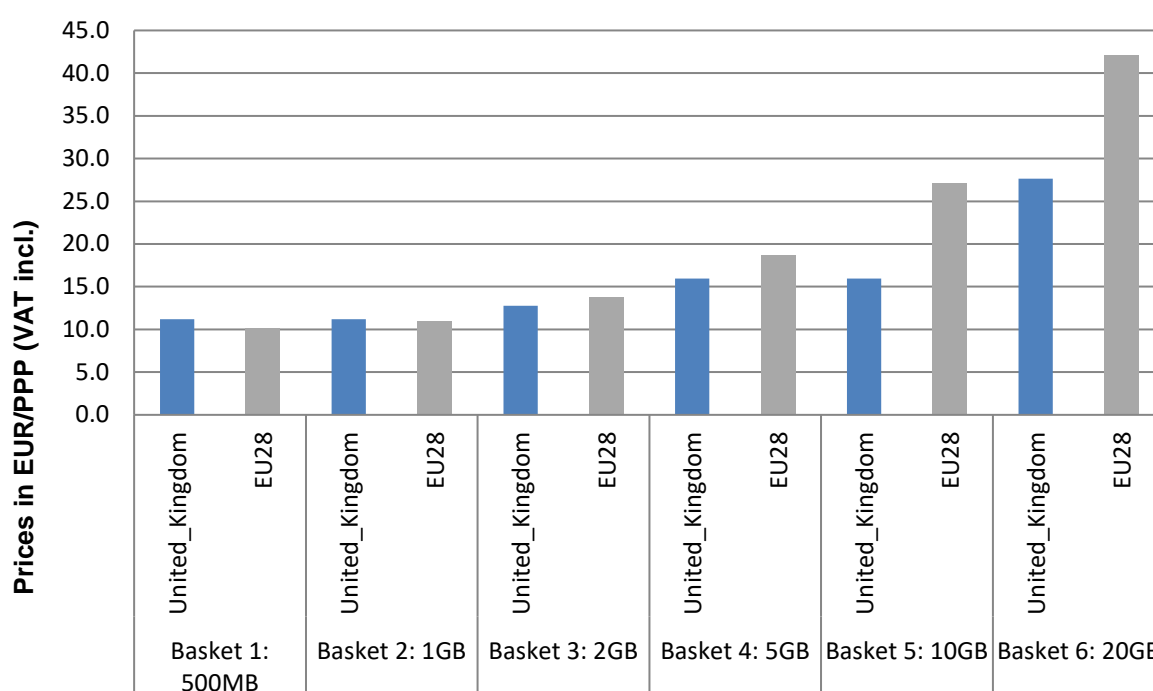
A1.209 For tablet plans, the UK is up to 35% more expensive than the EU average for all baskets except for basket 6, which is 20% cheaper.

Figure A1.45: Comparison of the least expensive tablet offers UK vs. EU average



Source: EC Mobile Broadband Prices in Europe 2016 report – Simulation tool

A1.210 The UK's laptop plans are more expensive for the two baskets with the lowest allowance (between 2%-11%) but cheaper for the other four (between 7%-41%).

Figure A1.46. Comparison of the least expensive laptop offers UK vs. EU average

Source: EC Mobile Broadband Prices in Europe 2016 report – Simulation tool

- A1.211 The report also found that, compared to 2015, prices of UK handset plans have increased by an average of 4% between 2015 and 2016 compared to a 7% decrease on average across EU member countries.
- A1.212 Tablet and laptop plans with low data allowances also increased significantly, with 256MB price plans almost doubling and 512MB and 1GB plans increasing by almost a third between 2015 and 2016. However, higher usage plans had price decreases of 7% on average over the same period. Across the EU, prices of tablet and laptop plans decreased on average by 3%.
- A1.213 The report also compares the proportion of income spent on each of the devices between the different EU countries. It finds that handset plans in the UK are among the cheapest in EU when compared to income. Tablet plans are just above the EU average while laptop plans are below the average.
- A1.214 According to the report, H3G and Vodafone offered the cheapest mobile broadband plans with some significant differences compared to EE. It also found that Vodafone offered the best handset-based plans and it is also the cheapest for laptop plans, except for 20GB where H3G and EE are cheaper. However, it should be noted that the report did not include O2 in the analysis.
- A1.215 Compared with other non-EU countries, the EU's average handset plans are comparable to those of the USA with other countries and baskets being between 18% cheaper and 14% more expensive than the EU average.
- A1.216 For laptop and tablet plans the EU is the cheapest for the baskets with low data allowance but South Korea is cheaper for the plans with higher allowances.

Update on pricing observations included in the consultation

A1.217 In our November 2016 consultation, we also included a discussion on the evolution of pre-pay prices for H3G, the price evolution of H3G's unlimited plans, how H3G's high-usage plans compared to those of other MNOs, and Enders Analysis iPhone 6S "sweet spot" pricing comparison. We have updated all these figures with the latest available data, except for H3G's pre-pay pricing which has not changed. We discuss each of these in turn.

H3G's pre-pay pricing

A1.218 As we said in the November 2016 consultation, in 2013 H3G significantly reduced its pre-pay prices. Figure A1.47. below shows the prices before and after H3G's launch of its '321' pre-pay plan in July 2013. Before this, prices per minute, text and MB had been constant for some time, and have been constant at the reduced prices since July 2013.

Figure A1.47: H3G's pre-pay prices

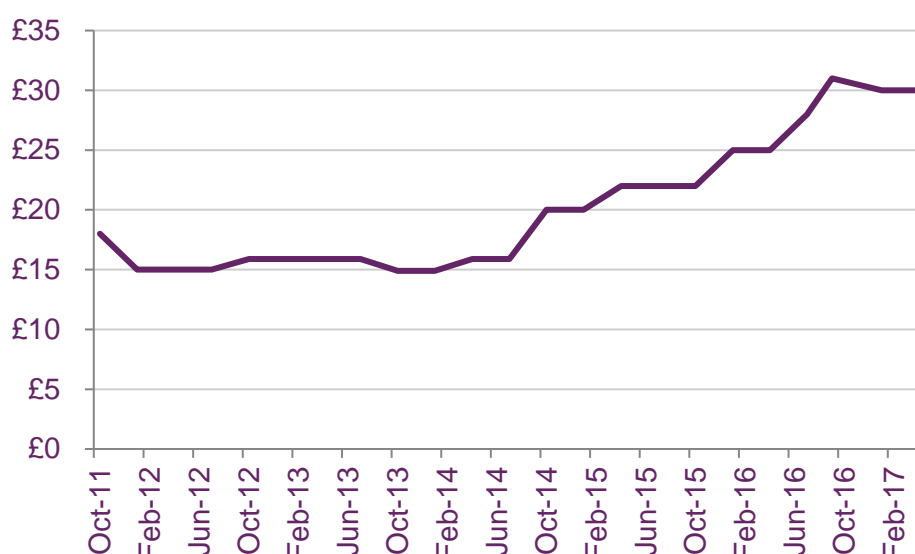
	Before July 2013	Since July 2013
Voice (ppm)	26p	3p
Text	11p	2p
Data (p per MB)	11p	1p

Source: Pure pricing

A1.219 As shown in Figures A1.11 and A1.12 earlier, 3K [REDACTED] .

H3G's high-usage plans

A1.220 There is evidence that some plans, especially high usage plans, have experienced significant increases in prices. Specifically, H3G has increased its prices for some large data packages considerably over the last couple of years. This increase is illustrated in Figure A1.48. below, which shows the price for one unlimited data package offered by H3G.

Figure A1.48: H3G's SIM-only unlimited data, 600 minutes, 12 month contract

Source: Pure pricing

A1.221 H3G has also recently created two tiers of post pay plans called “Essentials” and “Advanced”, with the former not allowing for the use of a personal hotspot and not including the “Feel at home” roaming package. The pricing between the two tiers is materially different. For example, the Advanced 2GB data iPhone 7 32GB memory, unlimited text and voice minutes plan – which Enders Analysis used in its comparison below – is £41 a month, while the Essentials plan with the same allowance is £34 a month. However, the upfront cost of the handset in the Essentials plan is £149 vs. £99 for the Advanced plan.⁹⁷

A1.222 Despite these price increases, H3G appears to still be pricing its high-usage plans generally below other MNOs. For large data users, we have compared the size and price of the largest mobile data packages offered as of December 2016. We have done this for SIM-only offers, to avoid difficulties in comparing different handsets.

A1.223 Figure A1.49 shows a selection of packages with more than 10GB of data allowance offered in June 2017 through the MNOs' own channels and Carphone Warehouse. We recognise that offers change frequently, and that some of the tariffs included in this table were time-limited promotional offers. Figure A1.49 therefore only provides a snapshot of tariffs available at a particular point in time, and is not necessarily representative of what operators offer at other times. Nonetheless, the information shows that H3G prices for large data packages are competitive relative to other operators.

⁹⁷ As listed at

http://www.three.co.uk/iPhone/iPhone_7/plans?memory=32&colour=Black&plans=monthly on 26 April 2017.

Figure A1.49: Largest data packages, SIM-only post-pay offers, June 2017

Operator	£/month	Data (GB)	Minutes	Texts
H3G	£ 32.00	ULTD	ULTD	ULTD
H3G	£ 27.00	ULTD	600	ULTD
H3G	£ 24.00	ULTD	200	ULTD
EE	£ 41.99	30	ULTD	ULTD
TESCO	£ 35.00	30	5000	5000
H3G	£ 26.00	30	ULTD	ULTD
H3G	£ 22.00	30	200	ULTD
H3G	£ 19.00	30	600	ULTD
TESCO	£ 32.00	25	5000	5000
Vodafone*	£ 25.00	25	ULTD	ULTD
O2*	£ 25.00	25	ULTD	ULTD
Vodafone	£ 35.00	20	ULTD	ULTD
TESCO	£ 28.00	20	5000	5000
Virgin	£ 24.00	20	5000	ULTD
EE*	£ 23.99	20	ULTD	ULTD
O2*	£ 21.00	20	ULTD	ULTD
Vodafone*	£ 20.00	20	ULTD	ULTD
O2 (CPW)	£ 36.00	16	ULTD	ULTD
Vodafone	£ 32.00	16	ULTD	ULTD
H3G	£ 26.00	12	ULTD	ULTD
TESCO	£ 23.00	12	5000	5000
H3G	£ 21.00	12	600	ULTD
EE	£ 19.99	12	ULTD	ULTD
H3G*	£ 19.00	12	200	ULTD
O2*	£ 18.00	12	ULTD	ULTD

Source: Ofcom Desk research

Notes: Largest SIM-only data packages offered in June 2017. We do not describe all aspects of the different packages and may not have shown all large SIM-only packages available. Packages are mostly for a 12-month contract (shorter contracts generally being more expensive). Different colour shading used to group specific data allowances

* indicates a promotional offer, and may only have been available for a short period

A1.224 While some other operators have previously offered unlimited data plans, we understand that only H3G still offers unlimited SIM-only post pay packages.⁹⁸

Enders Analysis price comparison

A1.225 In our November 2016 consultation we included the latest comparison by Enders Analysis⁹⁹ for the 'sweet spot' iPhone 6S mobile plan¹⁰⁰. At the time H3G's pricing

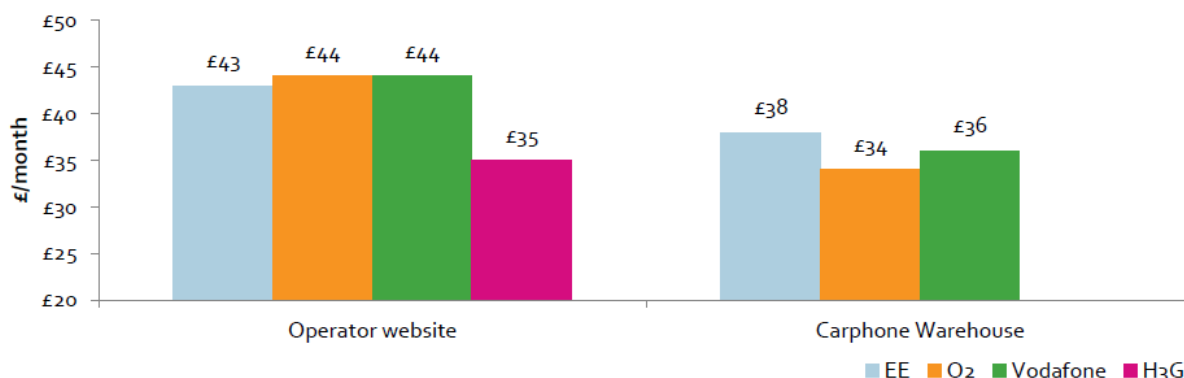
⁹⁸ We note that some pre-pay tariffs are similar in form to post pay tariffs and that GiffGaff (owned by O2) offers unlimited data plans for £20 per month. However, this package is not comparable to the ones in Figure A1.49 as the speed the subscriber receives is reduced to 256 kbps from 8am to midnight after the subscriber uses 6 GB.

⁹⁹ As in its September 2016 report.

¹⁰⁰ 24 month contract with at least 1GB of data, unlimited texts and 2,000 minutes or more per month. One-off handset fee under £100 and 16GB iPhone 6S as handset.

for this plan was lower than for all other MNOs including sales through Carphone Warehouse. In June 2017 Enders Analysis published its latest report on the state of the UK market in which it provides the comparison of the prices for the iPhone 7 'sweet spot' plans.¹⁰¹ In this updated comparison H3G is still cheaper than all other MNOs, including sales through Carphone Warehouse, except for O2's plan sold through Carphone Warehouse, which is £1 a month cheaper than H3G.

Figure A1.50: 'Sweet spot' iPhone 7 32GB pricing by Enders Analysis



Source: Enders Analysis

A1.226 We recognise that there are some limitations to Enders' analysis. One important consideration is that there are different upfront handset fees for different plans, which are likely to have an effect on monthly fees, even if these are all under £100. For example, for this plan O2 has an upfront fee of £19.99, Vodafone of £50, EE of £49.99 and H3G of £99.¹⁰² There can be additional differences to these packages such as, for example, the roaming packages included, if any.

Conclusion on pricing

A1.227 The picture of mobile pricing in the UK is complex. In this section we have discussed different ways to assess the evolution of pricing in the UK mobile market in recent years including using baskets and econometrics. While these approaches may give useful insight, their limitations mean that their results should be treated with care.

A1.228 Specifically, we have identified a number of significant concerns about the analysis Frontier Economics has carried out. For example, our evidence suggests that Frontier Economics has significantly underestimated the importance of SIM-only tariffs in the UK market at present. Even assuming that its findings on overall price changes using the revised basket approach and econometrics are correct, the underestimation of the SIM-only share leads to a significant overestimation of overall price increase.¹⁰³

¹⁰¹ 24 month contract with at least 1GB of data, unlimited texts and 2,000 minutes or more per month. One-off handset fee under £100 and 32GB iPhone 7 as handset.

¹⁰² As retrieved on June 27th 2017 from MNOs websites. H3G's plan includes 2GB of data.

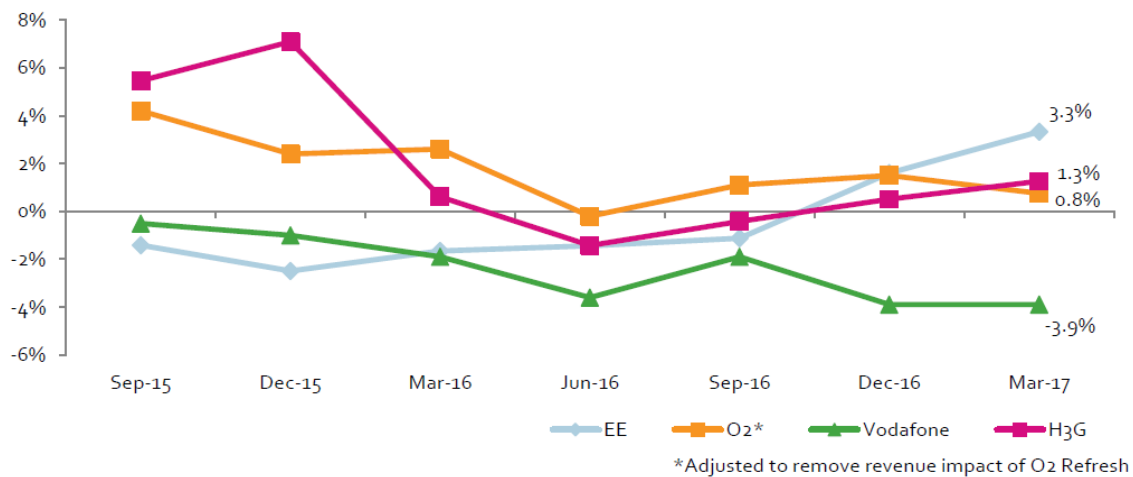
¹⁰³ Using an 18% SIM-only share, FE has estimated an overall price increase from 2014 to 2016 of 7.8% using their updated basket approach and 9.4% using the econometric analysis. Using the 34% SIM-only share as of Q2 2016, these values would be 3.1% and 4.5% respectively.

- A1.229 While we acknowledge that there are limitations to our own basket analysis, we have also identified issues with FE's approach such as not taking into account MVNOs and disregarding high-usage baskets (i.e. basket 8). Moreover, our own basket analysis shows that there is significant variability in price trends between the different baskets and the different types of plan.
- A1.230 Furthermore, the concerns we have identified about the econometric analysis carried out by FE mean that, in our view, the picture of pricing trends that it paints is not reliable.¹⁰⁴
- A1.231 Overall, in light of the concerns we have identified, we consider that the results of FE's basket and econometric analyses fail to provide support for a broader claim that operators with small spectrum shares (such as H3G) are experiencing increasing capacity constraints which in turn are leading to weaker competition and price increases.
- A1.232 Nonetheless, we accept that the evidence provided in the Frontier Economics report questions whether we were right to suggest in the November 2016 consultation that price increases for some plans with handsets might be accounted for just by rising handset costs. Our revised view in light of the evidence now available to us is that in recent years there have been price reductions for some types of tariff as well as price increases for others.
- A1.233 However, we still consider that mobile prices in the UK are relatively low compared to international benchmarks based on our own analysis as well as the international comparison carried out by the EC.

Mobile revenues

- A1.234 According to Enders Analysis, O2, H3G and EE had positive mobile revenue growth in Q1 2017, while Vodafone has experienced continuous revenue decline for all of the past seven quarters. EE has now experienced two consecutive quarters of revenue growth after consistent declines between Q3 2015 and Q3 2016 while O2 has been the only MNO with consistently positive growth, with the exception of a small dip during Q2 2016. H3G is also now in positive territory after decreases in revenue during Q2 and Q3 2016.

¹⁰⁴ As explained above, we conducted some tests of FE's econometric analysis that illustrate its limitations, including re-running FE's analysis excluding unlimited packages. As an illustration, we note that the results derived from this illustrative test, when combined with our estimate of the SIM-only share of 34% and FE's own estimate of the change in SIM-only prices (-16%), would yield an overall price change of -2.8% in post pay plans between 2014-2016, i.e. an overall price reduction. This contrasts with FE's own overall price change of 9.4%. This demonstrates again the instability of FE's results.

Figure A1.51. Reported mobile service revenue growth

Source: Enders Analysis

A1.235 There are differences in the average retail revenue per subscriber between the different operators. 3< [REDACTED] .

Figure A1.52: Average monthly retail revenue per pre-pay subscriber¹⁰⁵

3< [REDACTED]

A1.236 Average post-pay retail revenue per customer¹⁰⁶ trends are different between the different operators. The average revenues of 3< [REDACTED] .

Figure A1.53: Average monthly retail revenue per post-pay subscriber

3< [REDACTED]

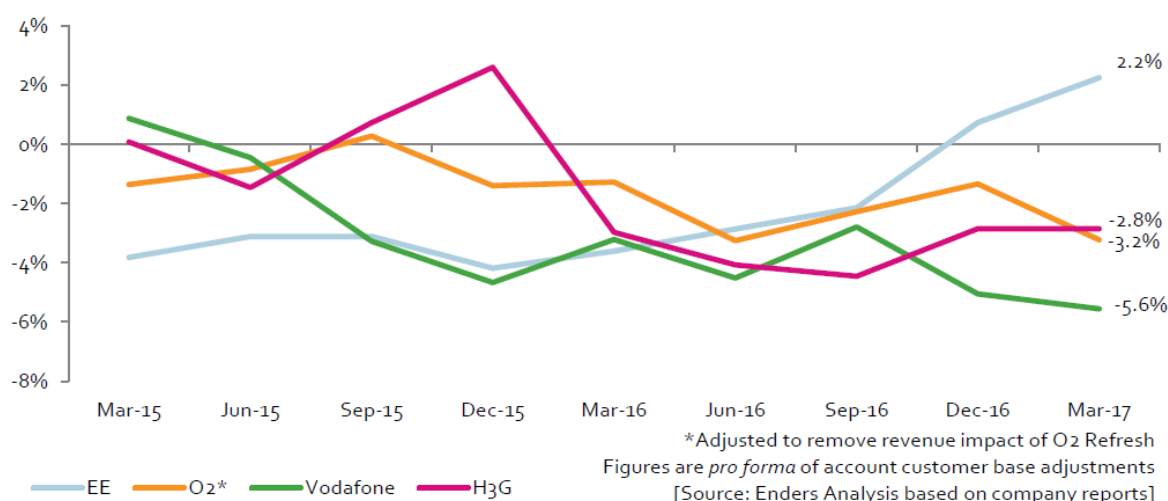
A1.237 The data on average revenue per post-pay subscriber includes revenue from plans which include the provision of handsets as well as SIM-only plans. Therefore, the values in the chart above are likely to be affected by changes in the prices for handsets (and their impact on mobile tariffs) as well as differences in the shares of SIM-only subscribers between the different MNOs.

A1.238 According to Enders Analysis over the past year all MNOs have experienced a contraction in contract ARPU with the exception of EE, which has had positive growth in Q4 2016 and Q1 2017.

¹⁰⁵ 3< [REDACTED] .

¹⁰⁶ These figures include monthly handset revenues but not handset one-off fees.

Figure A1.54: Contract ARPU growth



Source: Enders Analysis

A1.239 Overall, average monthly retail revenue for both prepaid and post-paid customers has continued to decrease with a 3% [REDACTED] .

A1.240 In our 2016 DCR, and the discussion document that came before it, we stated that UK MNOs' earnings before interest, tax, depreciation and amortisation (EBITDA) margins appeared to be low in comparison with those in other international markets. Despite this we considered that the UK mobile sector appeared to be earning returns above the current cost of capital. For example, we estimated EE's ROCE to be 27-28% compared to a 9% cost of capital.¹⁰⁷

A1.241 We also found that the average cash flow margin across the UK MNO's was around 12%, which appeared to be healthy at a time when operators were investing in 4G rollout.

Effects of spectrum shares on competition

A1.242 Although in our consultation we concluded that the UK mobile market was working well, we warned of the risk that the current level of competition could be reduced as demand for mobile services increased. We argued that the current level of spectrum asymmetry could leave some MNOs in a better position to respond to increased demand. However, we noted that, to date, it did not appear that current asymmetric spectrum shares had distorted competition. We noted that both O2 and H3G had continued to increase their subscriber shares despite having the lowest spectrum holdings.

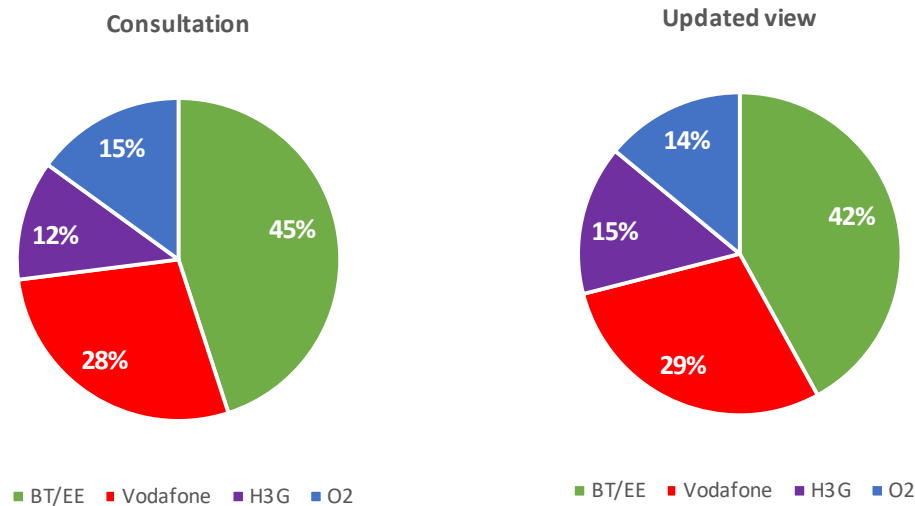
A1.243 At the time we estimated the shares of immediately useable spectrum that had already been allocated, taking into account the 800 MHz, 900 MHz 1800 MHz, 2100 MHz and 2.6 GHz (paired and unpaired) bands.

A1.244 As discussed in section 5 of the main document and annex 3, we now expect the 1400 MHz spectrum to become useable during 2018. Therefore, the resulting shares of immediately useable spectrum taking into account 1400 MHz as well as the bands we considered in our consultation have changed, as illustrated in the chart below. The revised spectrum shares are relevant for our competition

¹⁰⁷ See page 45 of 2016 DCR

assessment during the first transitional period as we now consider that the 1400 MHz band will be useable during this period. However, this band should not have had an effect on the current competitive state of the market as it has not yet been deployed.

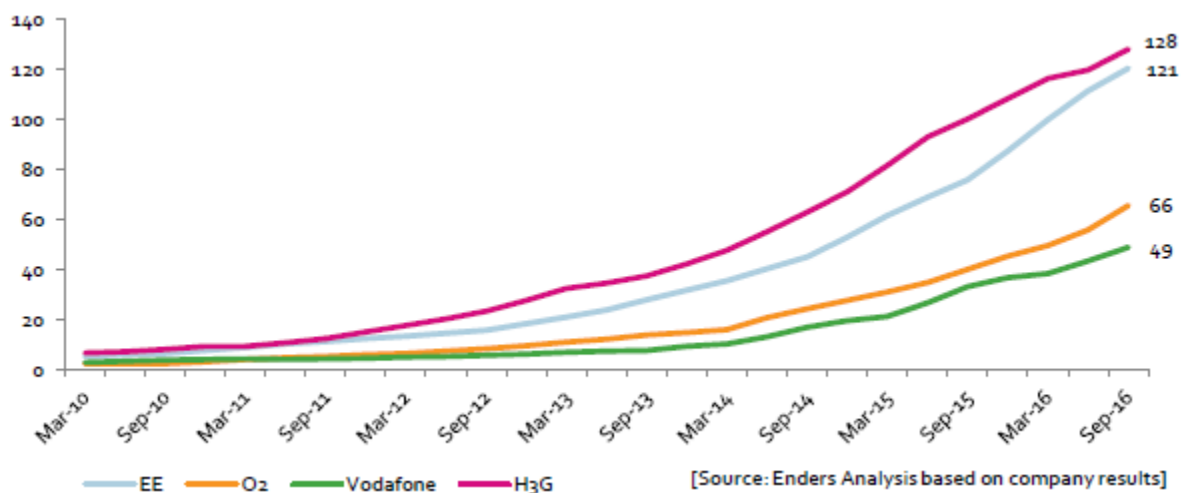
Figure A1.55: Shares of immediately useable spectrum – consultation and updated view



A1.245 We still consider that despite the allocation of mobile spectrum between the four MNOs being very asymmetric, competition is generally working well currently. It appears that the ability of MNOs to compete and to increase their market shares to date has not been driven purely by their share of spectrum holdings. As we discussed earlier in this annex, H3G and O2 are the two MNOs that have generally increased their market share of network subscribers in recent years (including the subscribers of hosted MVNOs). This is illustrated in Figures A1.17a and A1.17b above. In contrast, BT/EE and Vodafone have lost subscribers in recent years.

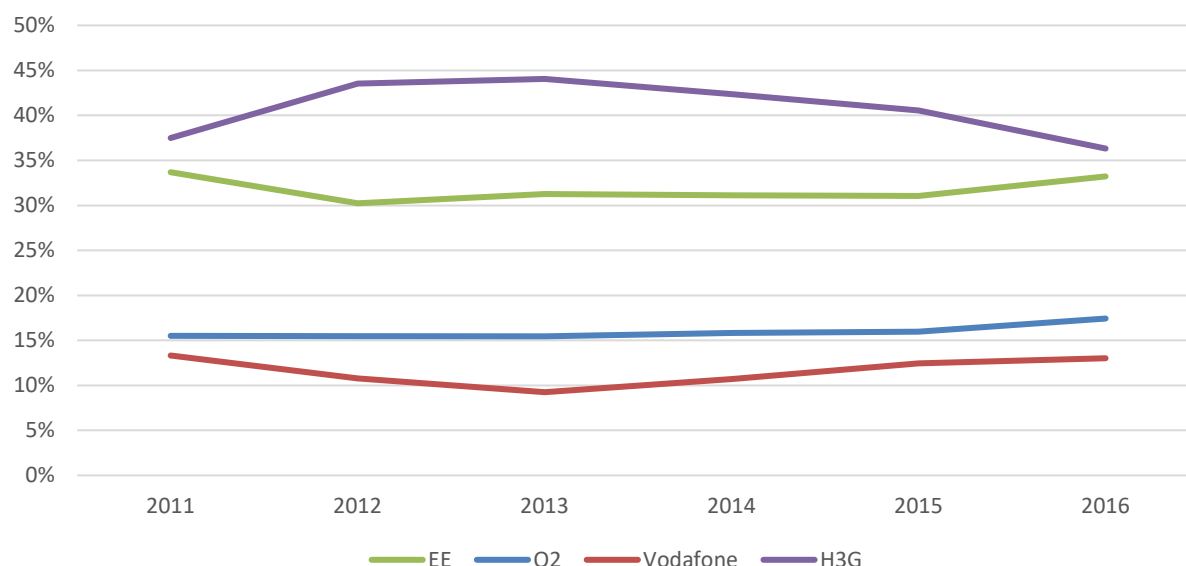
A1.246 The share of data carried by the networks of the four MNO is very different to their subscriber shares. As shown in Figure A1.57., H3G carries the most data (36% of total data), though its share has declined consistently since 2013.

Figure A1.56: Data traffic on MNOs networks (quarterly mobile data traffic, PB)



Source: Enders Analysis

Figure A1.57: Data traffic share on MNOs networks



Source: Enders Analysis

A1.247 According to the latest report by Enders Analysis, in Q1 2017 O2 had the highest data growth of all MNOs (61%) while H3G had the lowest (34%). EE's and Vodafone's data growth stood at 50% and 45% respectively.

A1.248 While H3G has the lowest share of subscribers, it has the highest share of mobile data traffic, as shown in column B of Figures A1.58a and A1.58b¹⁰⁸ below. Column D shows that H3G has higher data traffic per MHz of spectrum than the other operators. Column E shows that O2 has the highest ratio of subscribers per unit of spectrum.¹⁰⁹

Figure A1.58a: Shares of spectrum, data and subscribers, and related normalised ratios – Operator data

✂ [REDACTED]

¹⁰⁸ As mentioned above, we have based our analysis on data provided by operators but also present the same analysis using non-confidential data from Analysys Mason.

¹⁰⁹ The ratios in columns D, E and F are calculated so that the MNO with the smallest ratio is normalised to one. This means that the units in these columns are not meaningful, but the comparison between MNOs can be seen in each column.

Figure A1.58b: Shares of spectrum, data and subscribers, and related normalised ratios – Analysys Mason data

	A	B	C	D	E	F
	Share of spectrum (inc 1400)	Share of mobile data traffic	Share of network subscribers	Data share/spectrum share ratio	Subscriber share/spectrum share ratio	Data share/subscriber share ratio
BT/EE	42%	33%	33%	1.8	1.0	1.8
O2	14%	18%	33%	2.9	2.9	1.0
Vodafone	29%	13%	22%	1.0	1.0	1.0
H3G	15%	36%	11%	5.5	0.9	6.0

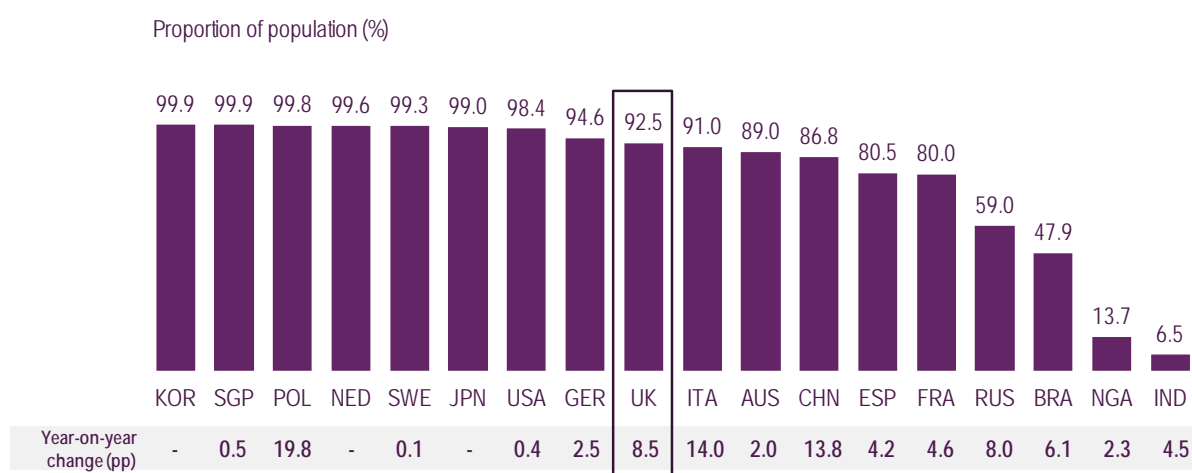
Sources: The shares of mobile data traffic are taken from Enders Analysis' UK mobile market Q4 2016 – Nearly back to growth 13 April 2016 (slide 10). The shares of network subscribers are from Analysys Mason data and include the subscribers of hosted MVNOs, and are for Q3 2016.

International comparison of network quality

A1.249 In our 2016 ICMR we carried out a comparison of UK fixed and mobile networks with those of 17 other countries¹¹⁰.

A1.250 In terms of 4G coverage, we found that the UK ranked ninth out of the 18 countries and second among the EU5 countries, behind Germany, at the end of 2015, at 92.5%, 8.5 percentage points higher than the previous year.

Figure A1.59: 4G population coverage at end 2015



Source: IHS

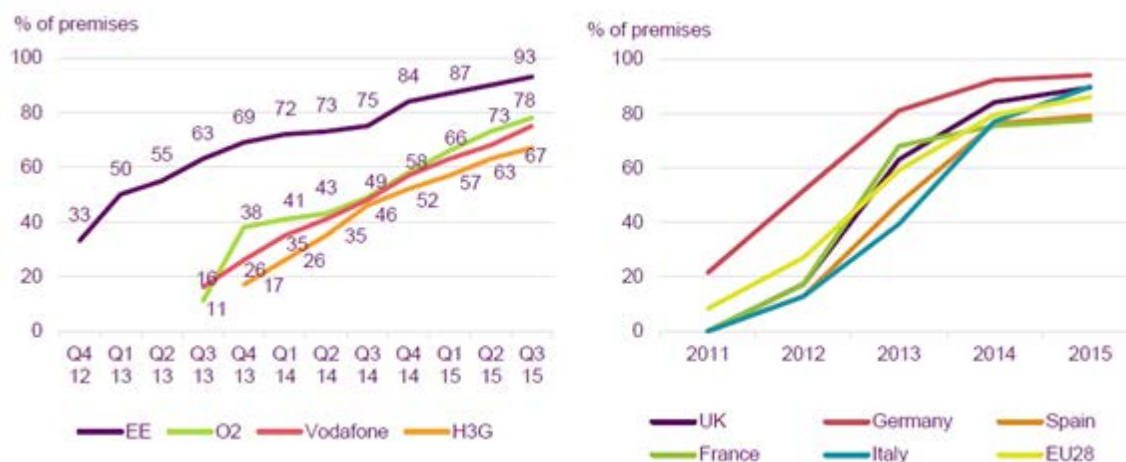
Note: 4G is the fourth generation network technology deployed by cellular operators. The definition is limited to those networks using one of the LTE standards such as FDD-LTE or TD-LTE; HSPA+ networks or WiMAX networks are not included.

A1.251 In our Digital Communications Review we also carried out a comparison of international 4G deployment in which we found that the UK was broadly in line with

¹¹⁰ France, Germany, Italy, USA, Japan, Australia, Spain, the Netherlands, Sweden, Poland, Singapore, South Korea, Brazil, Russia, India, China and Nigeria.

its EU5 peers. However, the UK was lagging behind leading nations such as South Korea, and the US in 4G coverage, both of which reached 99% coverage for premises in 2013¹¹¹.

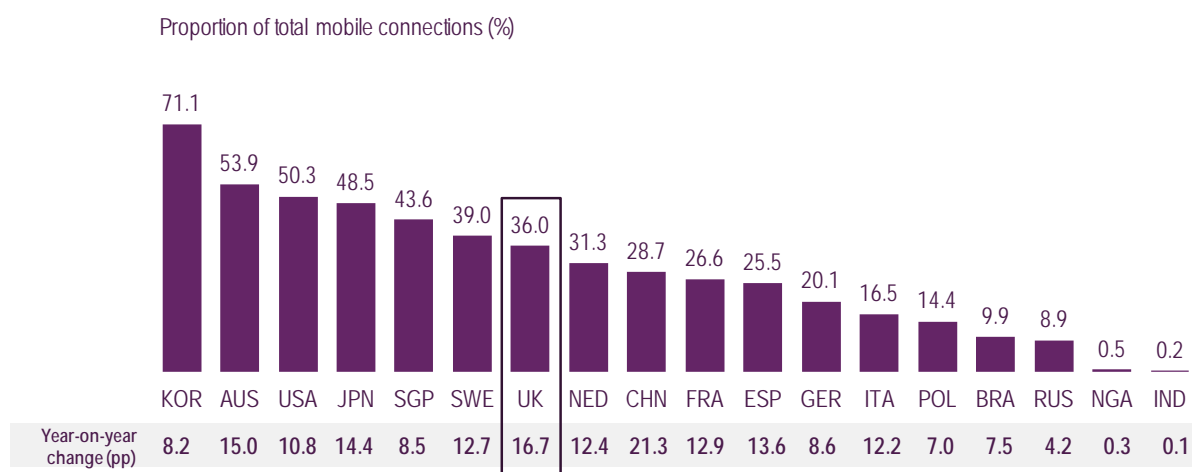
Figure A1.60: UK and European 4G network availability



Source: Enders Analysis estimates, EU digital agenda scoreboard.

A1.252 In our 2016 ICMR we also found that at the end of 2015 the UK ranked 7th in terms of 4G connections as a share of total connections with 36% of all connections being 4G. It was also the highest ranked country of the EU5 comparator countries. The UK also experienced the second highest increase in (16.7pp) after China.

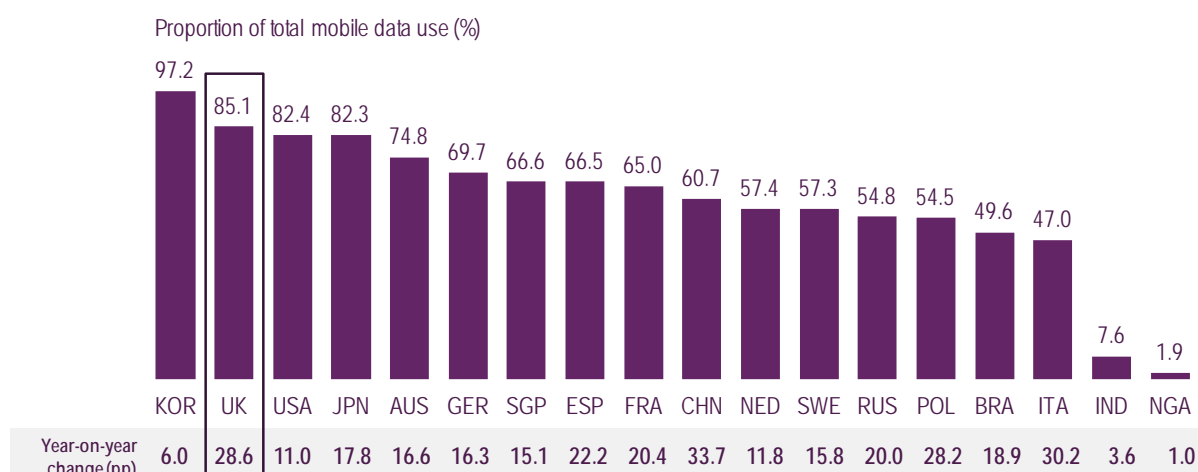
Figure A1.61: 4G mobile connections as a proportion of total mobile connections at end 2015



Source: IHS / industry data / Ofcom

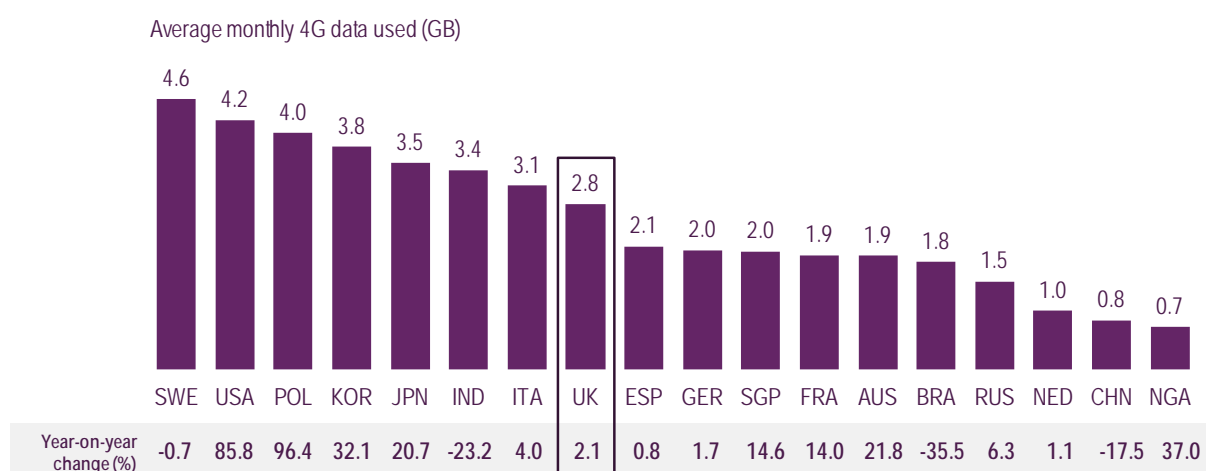
A1.253 The UK ranked second in terms of the proportion of total mobile data carried over 4G behind South Korea. According to the findings in the ICMR, in 2015 85.1% of the total mobile data in the UK was carried over 4G networks, an increase of 28.6 pp over the previous year.

¹¹¹ See page 22 https://www.ofcom.org.uk/_data/assets/pdf_file/0016/50416/dcr-statement.pdf

Figure A1.62: 4G mobile data use as a proportion of total mobile data use: 2015

Source: IHS / industry data / Ofcom

A1.254 Nonetheless, the UK ranked eighth in terms of average monthly data use with an average of 2.8 GB in 2015. This represented a relatively small increase in traffic of 2.1% compared to the previous year.

Figure A1.63. Average monthly 4G data use per 4G connection: 2015

Source: IHS / industry data / Ofcom

A1.255 In the 2016 ICMR we also presented the result of a consumer research study, which compared the responses of a sample of UK subscribers with those of eight other countries.¹¹² This survey showed that the UK subscribers had the second highest overall satisfaction with their 4G mobile phone services with 86% of respondents saying that they were satisfied, just below the USA and tied with Germany.

A1.256 In terms of price paid, UK subscribers were the most satisfied with 74% saying that they were satisfied with the pricing of their mobile service. In terms of ability to access the network and reliability of the internet connection, the UK came sixth among the nine comparator countries with 75% saying that they were satisfied. The

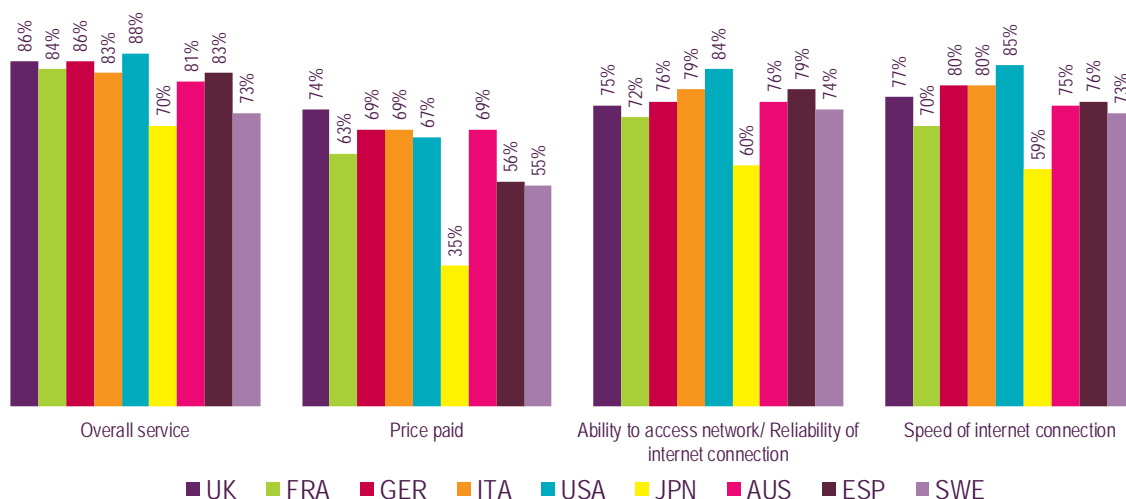
¹¹² France, Germany, Italy, USA, Japan, Australia, Spain and Sweden

highest level of satisfaction with the service's reliability was the US with 84% of respondents saying that they were satisfied.

A1.257 Finally, in terms of satisfaction with the speed of connection, the UK came fourth with 77% of subscribers saying that they were satisfied with the speed of their internet connection. US subscribers were the most satisfied with speeds. The results are summarised in the figure below.

Figure A1.64: Satisfaction with 4G mobile services: 2016

Proportion of those with 4G on their smartphone (%) – net rating 8-10 on aspects of service



Source: Source: Ofcom consumer research, 2016

Base: All respondents with a smartphone who are on a 4G network, UK=455, FRA=454, GER=290, ITA=466, USA=485, JPN=331, AUS=515, ESP=507, SWE=523

A1.258 In its response, H3G argues that UK networks compare poorly against networks in comparable countries as per the P3 network performance index,¹¹³ with only Telefónica Germany and Yoigo in Spain having a worst performance than O2 and H3G UK¹¹⁴. In the chart that H3G provided there is a significant difference between the bottom two MNOs (Telefónica Germany and Yoigo) and the rest. Both Yoigo and Telefónica Germany appear to have a P3 network performance index of ca. 650 while O2 and H3G UK have scores of ca. 750. The median companies in the sample (Telenor and Vodafone Spain) have scores of ca. 800.

A1.259 H3G quotes the 2017 National Infrastructure Commission (NIC) report which argues that the UK is “(...) languishing in the digital slow lane” and that it ranks 54th in the world for 4G coverage.

A1.260 As we outlined in our response to the NIC report, the UK's four mobile operators must each meet a licence obligation to provide 90% geographic coverage of the UK by the end of this year, and the Digital Economy Bill will give us the power to take

¹¹³ P3 is a company that benchmarks mobile networks. A description of P3's test methodology is at <http://www.p3-networkanalytics.com/methodology-2/>. Specifically, P3 described its test approach as follows: “We select typical customer-usage patterns and stretch network capability to its limits. P3 measures smartphone voice and data performance based on extensive drive-tests – from major metropolitan areas to smaller cities, roads and railways. We also perform walk-tests in big cities with special focus on busy intersections, on public transport and in buildings.”

¹¹⁴ Page 95 of H3G's response.

enforcement action against any operator that failed to meet its coverage obligations from the end of 2017. Beyond these existing obligations, we are looking closely at how we can help use our regulatory levers to widen coverage further, working with Government and the industry. In addition, we have committed to examine new coverage obligations when we award the 700 MHz spectrum band for mobile services.

- A1.261 Furthermore, in this response we agreed that mobile connectivity on the main transport networks does not meet consumer expectations but that we expected ongoing 4G network rollout will drive these numbers up, but gaps on segments of major routes and on rural roads may persist.
- A1.262 We agreed that further investment in network infrastructure and systems will be necessary to remedy coverage gaps on roads but, as previously discussed, we are considering what regulatory options are available to help address this, and will look at whether targeted coverage obligations should be associated with future spectrum auctions.
- A1.263 In any case, neither the 2.3 GHz or 3.4 GHz bands are coverage bands nor do their licences include any type of coverage obligation.

Additional competition considerations

- A1.264 One distinctive feature of the UK mobile sector is the significance of large independent specialist retailers such as Carphone Warehouse (and formerly Phones 4U, although it is now defunct). These have played an important role in retail sales of UK mobile services. According to a 2016 report by Enders Analysis, in the year to May 2015 high street retail was still responsible for 56% of post pay handset sales and 79% of pre-pay handset sales. According to this report, over this period specialist retailers (including Carphone Warehouse and Phones 4U) accounted for just under a third of total contract sales in shops.¹¹⁵
- A1.265 There has also been continued innovation in the UK market. This has included innovations by the smallest MNO, H3G, which was also the last MNO to enter the market in 2003. For example, some of the innovations that H3G introduced included being the first operator to offer All You Can Eat data plans, to scrap roaming charges for certain locations and to offer free calls to 0800 numbers from mobiles.
- A1.266 Innovations have not been limited to H3G. For example, to name a few, Vodafone launched the “Rural Open Sure Signal programme”, which provided 100 rural communities in the UK with 3G coverage for the first time and rolled out High Definition voice in 2014.¹¹⁶ EE has introduced services which emphasise data security (in conjunction with MobileIron) and launched EE connect, which offers a platform for M2M services.¹¹⁷ It was also the first MNO to launch Wi-Fi calling,¹¹⁸ which is now offered by all MNOs. O2 offers benefits to its subscribers through its Priority programme including access to concert ticket presale and discounts in

¹¹⁵ According to Enders Analysis, independent specialists (including Carphone Warehouse and Phones 4U) accounted for just under a third of total contract sales in shops in the year to May 2015. According to this same report, over this same period about 20% of all contract handset sales were made through these independent specialists. See Enders Analysis, UK mobile user survey 2015, June 2016, pages 29 and 30.

¹¹⁶ Source: <http://www.vodafone.co.uk/about-us/company-history/>

¹¹⁷ Source: <http://ee.co.uk/business/large/innovation>

¹¹⁸ See <http://newsroom.ee.co.uk/ee-launches-wifi-calling-to-make-calls-and-texts-available-in-every-home/>

selected shops and restaurants. Furthermore, O2 was the first MNO to launch a plan whereby users could upgrade their handsets early if they so wished (O2 Refresh).

Annex 2

Parameters of retail mobile competition

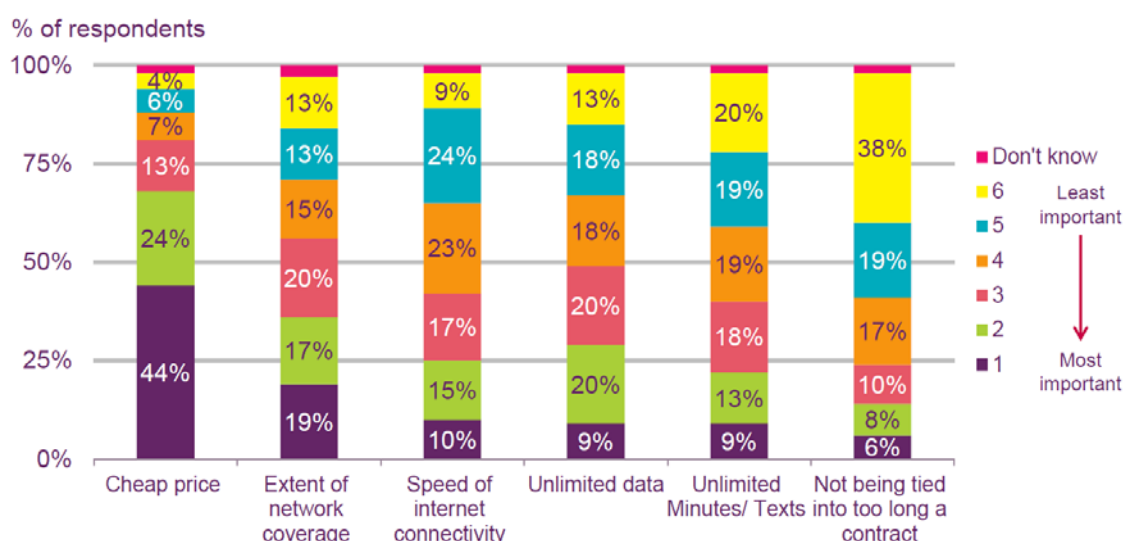
A2.1 This annex considers the relative importance of different parameters of competition in the retail mobile market, focusing on the relative importance of speed in consumers' choices.

Our position in November 2016 consultation

A2.2 In annex 7 of the November 2016 consultation, we said that network performance is one of the factors that a consumer is likely to take into account when choosing a mobile phone service. Other factors include price, customer service, handset choice and contract terms.

A2.3 Figure A2.1 is reproduced from the November 2016 consultation and shows the results of a consumer survey on the importance of different factors in consumers' decisions on whether to take up a 4G plan. Price is most frequently reported as the most important factor. Other factors include coverage, speed and contract terms. This seems consistent with network performance being an important factor in consumers' choices, even if it is not necessarily the most important factor.

Figure A2.1: Importance of factors when deciding to take up a 4G plan¹¹⁹



Source: YouGov, 4G tariffs 22-28 May 2015

Base: Online UK adults 16+ who do not currently have 4G (388)

Q40. Which of these would be most important when deciding which 4G plan to take up? Please put in rank order of 1-6 where 1 = most important and 6 = least important.

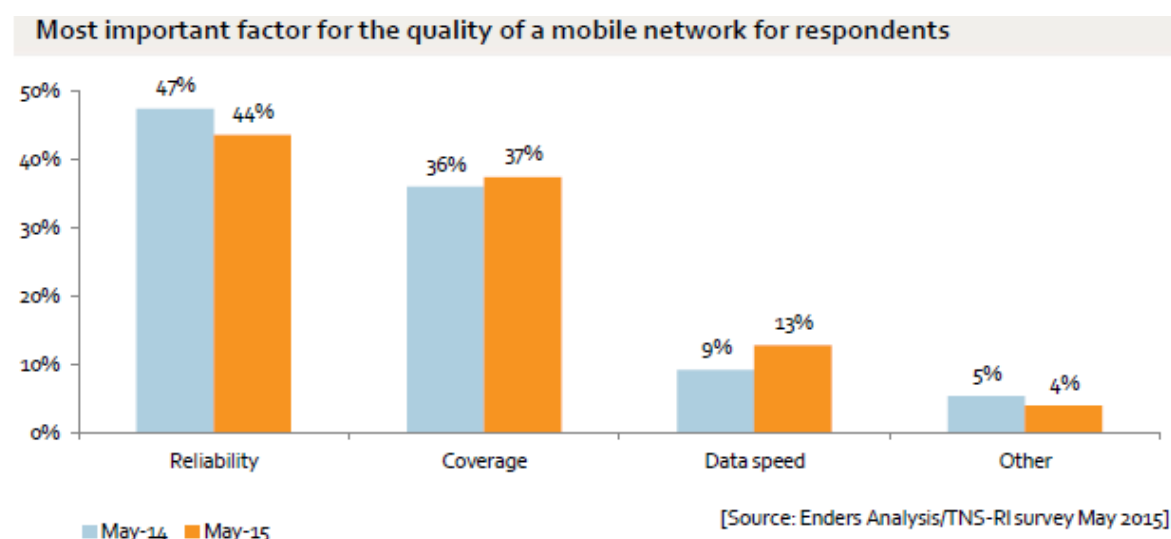
A2.4 In assessing the proposed merger of O2 and H3G, the EC investigated the relative importance of different parameters of competition in the retail mobile market, drawing on various sources, including a survey of retail customers. It found that, while price is a primary parameter of competition (in particular as regards data

¹¹⁹ Reproduced from Figure 4.7 of the Ofcom's 2015 Communications Market Report, http://stakeholders.ofcom.org.uk/binaries/research/cmr/cmr15/CMR_UK_2015.pdf

allowances), network performance related criteria were second in terms of importance.¹²⁰

- A2.5 Network performance or network quality is a broad concept, which includes several aspects valued by consumers such as network reliability, network coverage, download and upload speeds, latency, jitter, webpage browsing times, call quality and call success rate, etc. These metrics are not just related to the performance of the radio access network but also depend on the performance of the core and backhaul networks as well as other aspects. For example, web browsing times depend on download speeds as well as how quickly the network can identify the location of the website. Some of these parameters are also interrelated. Both coverage (network availability) and download speed for instance are important for consumers to qualify a network as "reliable".
- A2.6 In May 2015, Enders Analysis reported that "reliability" was still the most important factor for consumers when considering the quality of a mobile network, followed by coverage and data speed, though as explained above we accept that these factors are interrelated. Compared to results from the previous year though, reliability decreased in importance from 47% to 44% of respondents whereas data speed increased from 9% to 13%.

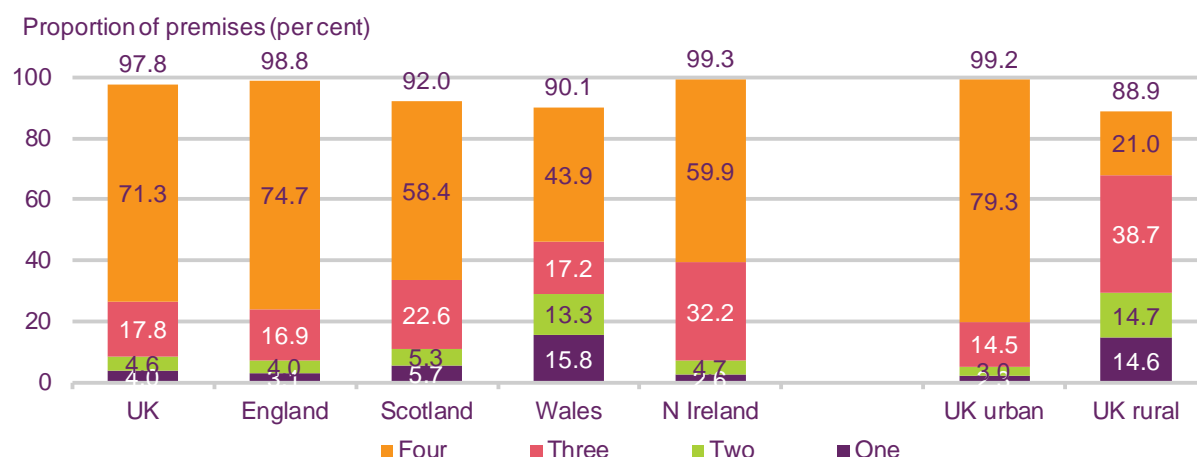
Figure A2.2: Enders Analysis - network quality according to consumers



- A2.7 In relation to network coverage, Ofcom data reports that by May 2016, 97.8% of UK premises were in areas with outdoor 4G coverage, with 71.3% benefitting from similar coverage from all four mobile network operators and fewer than 10% of premises being covered by one or two operators. Coverage varied significantly between urban and rural areas of the UK, with 99.2 % of premises in urban UK areas having outdoor 4G coverage, and 79.3% covered by all four operators compared to 88.9% of rural premises having outdoor 4G coverage from at least one operator, and just 21.0% having coverage from all four operators.¹²¹

¹²⁰ See from recital 214, EC Decision of 11 May 2016 declaring a concentration to be incompatible with the internal market (Case M.7612 - HUTCHISON 3G UK / TELEFÓNICA UK), http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=2_M_7612

¹²¹ Source: Ofcom CMR 2016

Figure A2.3: Outdoor 4G premises mobile coverage, by number of operators

Source: Ofcom / operators, May 2016 data

Note: Coverage is based on 100m² pixels covering the UK

Summary of responses

Importance of speeds for competition

- A2.8 H3G said that data speeds are increasingly important to consumers given the high quality they expect from the applications they want to use (particularly video streaming, web browsing and file downloads).¹²² It said that an MNO that cannot keep pace with its competitors on speeds will lose customers.¹²³ H3G considered that this can be evidenced by < [REDACTED] ¹²⁴ .
- A2.9 < [REDACTED]. H3G also stated that "EE reported in their recent financial statement that nearly 50% of its postpaid consumer connects were on the '4GEE double speed plans'.¹²⁵ Furthermore, H3G said that customer data usage increases as speeds increase on mobile networks because they allow more data heavy applications to run smoothly.¹²⁶
- A2.10 H3G commissioned a study by academics at Brunel University. The study aimed to identify *"the critical factors influencing customers' satisfaction and switching intention and to assess their interrelationships"*.¹²⁷ One of the major objectives of the study was to examine the importance of speed on customer switching intention. To do this the authors developed a conceptual model which hypothesised the interrelationships between factors believed to determine and influence customers' switching intention in the UK mobile industry. The conceptual model and hypotheses were developed from a review of relevant literature and tested via a

¹²² Page 2, H3G's response.

¹²³ Paragraph 15, Annex 3 of H3G's response.

¹²⁴ Paragraph 16, Annex 3 of H3G's response.

¹²⁵ Paragraphs 13-16, Annex 3 of H3G's response.

¹²⁶ Paragraphs 8-11, Annex 3 of H3G's response.

¹²⁷ Page 4, Annex 4 of H3G's response.

statistical model¹²⁸ which used data collected through a survey commissioned by H3G.

A2.11 The results of the statistical model suggest that of three elements of network performance (call quality, speed and reliability of network coverage) call quality and speed are 'key considerations' used by customers for assessing the service quality of mobile operators and that *"it can be predicted that in the near future, speed will emerge as the most significant component of service quality"*.

A2.12 Speed and call quality also have *"significant influence"* on brand image with speed having the highest impact on brand image. Speed and call quality are also considered to be *"significant drivers in the creation of perceived value"* because *"such value is underpinned by service quality and brand image"*. Perceived value is found to have a *"much higher"* impact on customer satisfaction than customer service. The results of the statistical study confirm that customer satisfaction is a proxy for switching intention. Drawing on these results, the authors consider that speed is *"an important factor influencing customer satisfaction and switching intention in the UK mobile industry"*. Furthermore they identify the following managerial and policy implications for mobile operators:

*"1) Mobile operators can pull various levers to manage customer satisfaction and switching intention but their efforts will be diminished if they can't effectively manage the speed factor."*¹²⁹

*"2) A mobile operator with an ability to offer higher speed will outperform competitors, keeping factors under operators' control equal (e.g. customer service, price level, distribution network, etc.)."*¹³⁰

A2.13 In annex 16 of H3G's response, Analysys Mason referred to its Connected Consumer Survey 2016. The results included that, among subscribers looking to move to a new mobile service (gross adds), 13% base their decision of where to go next primarily on 'higher data allowance.'¹³¹ It also found that for customers looking to churn, 'poor data speeds' is a key factor in the decision of 19% of customers.¹³²

A2.14 In its study for O2, NERA noted that < [REDACTED] . Whatever the reason, it seems that churn is likely to lag quality of service issues, and – against a background of rapid growth in data use per customer – unlikely to happen fast enough to resolve congestion."¹³³

A2.15 BT/EE noted research by Ofcom that suggested aspects of services related to voice (reception and quality) are more important than mobile internet speed. < [REDACTED] .¹³⁴

¹²⁸ "This study uses structural equation modelling (SEM), which is "a multivariate technique that combines the aspects of factor analysis and regression to examine the interrelationships among constructs".

¹²⁹ Page 20, Annex 4 of H3G's response.

¹³⁰ Page 20, Annex 4 of H3G's response.

¹³¹ Page 23, Annex 16 of H3G's response.

¹³² Page 23, Annex 16 of H3G's response.

¹³³ Page 75, NERA report for O2.

¹³⁴ Paragraphs 25 to 31, BT/EE's response.

A2.16 < [REDACTED] .¹³⁵

A2.17 BT/EE also noted that O2 had low churn rates and a YouGov survey rated H3G as the best network for internet. It considered that this supported the idea that speeds were not a key driver of purchasing decisions, or that a weakness in speeds could be offset by other aspects of commercial offerings.¹³⁶

A2.18 Vodafone also considered that consumer behaviour reflects that network capacity is not central to buying decisions. It referred to the YouGov survey for Ofcom on the ranking of factors for respondents choosing a 4G contract (shown in Figure A2.1 above). It noted that cheap price and extent of network coverage were ranked as 'most important' by 63% of respondents. It said that factors driven by the availability of spectrum, such as connection speed and unlimited data bundles were only ranked as 'most important' by 19% of respondents.¹³⁷ It said that the service characteristics that are delivered by access to spectrum – headline speeds and the ability to provide large data allowances – are most important to only a minority of customers. Even for those customers, it is unclear whether they desire the highest speed available in the marketplace, or actually a speed which is commensurate with the applications that they wish to use. Vodafone considered that only a small minority of customers would move away from an operator due to the implications of it having low spectrum holdings.¹³⁸

Level and consistency of speed required

A2.19 BT/EE considered it was important to distinguish between peak and average speeds. It considered peak speeds of less relevance to consumers.¹³⁹

A2.20 BT/EE also said that speed becomes less relevant to competition once a minimum speed is met. It said that services that may require the highest speeds such as UltraHD video only add marginal benefit to the user experience on larger devices (TV and tablets), being less relevant to very small screens because the human eye cannot see the difference between HD and UltraHD on small screens.¹⁴⁰

A2.21 In its study for O2, NERA said that EE put considerable emphasis on its position as the UK MNO that can provide the *"fastest speeds"* in its advertising, and that this implied that peak speeds do matter to some extent. However, it also noted that EE's peak speed is already well above what consumers need for everyday data use. It also said that survey work provided to it by O2 suggested that *"although consumers say they care about speed, what they really value is consistent performance with low latency, adequate speed and high availability, all factors that relate primarily to network congestion and roll-out, not peak speed."*¹⁴¹

A2.22 H3G said that although average speeds were extremely important, they did not tell the whole story. This was because reasonable average speeds do not guarantee a consistent user experience, and that this has implications for how high average

¹³⁵ Figure 1, page 14 of BT/EE response.

¹³⁶ Paragraph 34, BT/EE's response.

¹³⁷ Page 12, Vodafone's response, referring to Figure 4.7 of Ofcom's 2015 Communications Market Report.

¹³⁸ Page 15, Vodafone's response.

¹³⁹ Paragraph 25, BT/EE's response.

¹⁴⁰ Paragraph 61 and footnotes 55 and 79, BT's response.

¹⁴¹ Page 82, NERA report for O2.

speeds need to be in order for an MNO to provide an acceptable level of service.¹⁴² It said that *“the key driver of network requirements in the short term will be high quality video”*, which it said required high data speeds.¹⁴³ H3G considers that HD video is likely to be demanded by UK consumers in what we now call the first transitional period, and certainly by mid-2020, and that MNOs will need to provide ubiquitous HD video as a critical requirement to be credible.¹⁴⁴ H3G said that video streaming already accounts for around ¾ [REDACTED] of the traffic carried on its network.¹⁴⁵

- A2.23 H3G submitted a report by Real Wireless¹⁴⁶, which found that in order to provide HD video all MNOs will need to offer a minimum data-rate of 4 Mbps, with a recommended rate of 8 Mbps, in circa 2020. H3G also argued that web pages are getting larger and more content rich and customers are carrying out many more file downloads.¹⁴⁷
- A2.24 H3G fundamentally disagreed with Ofcom’s suggestion that customer experience in heavily loaded cells was more relevant than in lightly loaded cells. Rather, it said that customers expect consistently good network performance regardless of location or time of day, and hence the speed experienced by users across the network, in both congested and uncongested sites, was critical. H3G also said that there was no ‘cut-off speed’ above which performance plateaus.¹⁴⁸

Ofcom’s response

Importance of speed for competition

- A2.25 After considering the evidence in the consultation (summarised above) and in responses in the round, we remain of the view expressed in our consultation that speed is one factor affecting retail competition, but is far from being the only factor.
- A2.26 We consider that there are many other factors important for retail mobile competition, including price, customer service, handset choice, contract terms and other aspects of network performance (including coverage). Because speeds matter to some extent, if some MNOs were only able to deliver speeds experienced by their subscribers that are materially lower than rivals, competition could become weaker than it might be. We also recognise that consumers are not all the same, and speed is likely to be more important to some consumers than others. It is possible that in the future increased speeds will matter more, and to more consumers, than is currently the case, though the extent of any potential increase remains uncertain.
- A2.27 ¾ [REDACTED] . Moreover speed may have become more important over time. Consistent with BT/EE’s and Vodafone’s arguments, we also acknowledge that O2 and H3G are generally performing well in the market currently (as considered in

¹⁴² Paragraphs 32 and 34, Annex 3 of H3G’s response.

¹⁴³ Page 32, H3G’s response.

¹⁴⁴ Page 59 of H3G’s response.

¹⁴⁵ ¾ [REDACTED]

¹⁴⁶ Annex 11 of H3G’s response.

¹⁴⁷ Page 33 of H3G’s response.

¹⁴⁸ Pages 34-35, H3G’s response.

annex 1). This is consistent with speed not being the only factor important for retail competition.

A2.28 We do not consider that the evidence provided by O2 and H3G points to a stronger conclusion on the importance of speed than this. We note in particular the following on the evidence.

A2.29 **Analysys Mason's Connected Consumer Survey 2016:** While this shows that poor data speed was an important factor driving churn for 19% of consumers, cheaper deals was a key factor for 44% of consumers, poor coverage for 27% and poor customer services for 22%.¹⁴⁹

A2.30 **Brunel University study:** We have a number of comments on this study:

- i) The results of the statistical model suggest that call and text quality has slightly more influence on consumers' perceptions of service quality than speed. Whilst the authors say that *"it can be predicted that in the near future, speed will emerge as the most significant component of service quality"*¹⁵⁰, the statistical model does not substantiate this prediction i.e. it is simply a claim made by the authors.
- ii) The authors also find that, of all network quality elements, speed has the highest impact on brand image, whilst reliability of network coverage is insignificant.¹⁵¹ We consider that caution should be exercised before placing significant weight on this result as the statistical model is based on the results of a single consumer survey and therefore may be influenced by the construction of the survey questions regarding brand image. For example, the survey only gave respondents the option to choose from a set of positive statements and therefore would not have captured any negative perceptions of brand image.¹⁵² Furthermore, the results of the statistical model are not consistent with the results of other surveys such as the Enders Analysis survey discussed above. The Enders Analysis survey found that reliability is the most important factor for consumers when considering the quality of a mobile network, followed by coverage and data speed. In addition, we consider that, given the low coefficient of determination for brand image (R^2 is 23%), the model may be missing important parameters that influence consumers' perception of brand image.
- iii) The model performs poorly in explaining switching intention (R^2 is 17%)¹⁵³, which may be explained by the fact that the model does not explicitly consider the impact of price level on consumer switching intention, nor does it consider other factors that may be important for consumer switching intention as identified in the surveys discussed above, such as unlimited data, unlimited calls and texts, handset availability etc. Therefore, we do not consider that strong conclusions

¹⁴⁹ Other factors included aligning with friends, better combination of minutes, text and data, bundling with broadband and handset. This survey also found that the three key factors driving decisions on next mobile plan are better value (31%), lower price (23%) and handset choice (16%).

Page 23, Annex 16 of H3G's response.

¹⁵⁰ Page 17, Annex 4 of H3G's response.

¹⁵¹ Pages 16-17, Annex 4 of H3G's response.

¹⁵² Brand Image is made up of two questions BA1 and BA2. BA1 asked respondents "Which of the following statements do you associate with your current mobile network provider brand? (check as many as apply): fast network, reliable network, good network coverage, high quality products and services, good customer service, good value for money, low cost, widely recommended." BA2 asks respondents whether they agree with the following statement on a scale of 1-5: "My current mobile network provider brand is different to the other providers". Page 10, Annex 4 of H3G's response.

¹⁵³ Page 14, Annex 4 of H3G's response.

can reliably be drawn from this study regarding an MNO's ability to retain its customer base based on the speeds it can offer.

A2.31 Overall, we consider that for the reasons discussed above, caution should be exercised before placing significant weight on the results of this study for assessing the importance of speed for competition

A2.32 **NERA report:** This report says that \propto [REDACTED] . While this does not rule out the possibility that churn may lag quality of service issues there is currently no evidence of such a lagged effect.

A2.33 **H3G's reference to EE's data plans as purporting to show that customers are willing to pay a premium for higher speeds:**

- i) H3G said that when EE launched its 4G services in October 2012 these were priced at a premium of £5 above the existing 3G services of all other mobile operators. We agree that consumers who were early adopters of 4G, to whom speeds are perhaps especially important, were willing to pay a premium. However, it is not clear that a price premium for 4G has persisted. Some other operators have not charged a price premium for 4G (such as H3G). As regards EE's more recent pricing, we make the following observations.
- ii) In the fourth quarter of 2013, EE launched 'Double Speed 4GEE' providing higher speeds than EE's other 4G services. To get these higher speeds, consumers needed to buy a 4GEE Extra plan. Whilst these plans were marketed as costing £3 more per month than EE's standard 4G plans, in return for the extra cost consumers received benefits in addition to the higher speed such as double the data and inclusive roaming.¹⁵⁴
- iii) Furthermore, if we try to control for the difference in data allowance and compare options based on a consumer with a demand only for around 4GB of data per month, it becomes much less clear that there is a price premium for the higher speed 4GEE Extra plans.¹⁵⁵
- iv) Finally, looking at EE's current mobile data plans it continues to include additional benefits within the higher speed data plans. This can be seen in Figure A2.4 below, where the 4GEE Max plan is the only plan to include the BT Sport app.

¹⁵⁴ Pure Pricing, Q4 2013, UK mobile pricing developments, page 2.

¹⁵⁵ For example, when EE launched 4G Extra in Q4 2013, a consumer wanting the iPhone5C 16GB handset and 4GB data had the choice of a standard 4G plan giving 5GB data and costing £39.99 per month with an up-front charge of £9.99 or a 4G Extra data plan with 4GB and a lower monthly charge of £37.99 with an up-front charge of £29.99. Given these differences in monthly payment, upfront cost and data allowance, it is difficult to isolate a price difference related only to speeds when comparing the two plans. Nevertheless, for illustration, if we initially make the simplifying assumption that a consumer only has demand for 4GB of data and zero value for data above 4GB, then it is cheaper to take the faster speed 4G Extra plan when comparing monthly cost only. Furthermore, if we spread the upfront costs over 12 or 24 months and add this to the monthly payments then the 4G Extra plan is still cheaper for a consumer that only wants 4GB data (£41.74 standard 4G plan vs £40.49 4G Extra for 12 month plans or £40.86 standard 4G plan vs £29.34 4G Extra for 24 month plans). Although we recognise that this comparison might overstate the relative attractiveness of the 4G Extra plan because of the simplifying assumption (i.e. which implicitly assumes that the consumer place zero value on the additional 1GB of data in the standard 4G plan), it remains unclear that there is a price premium for the 4G Extra plan. The source for the pricing information is Pure Pricing, Q4 2013, UK mobile pricing developments, page 3.

Figure A2.4: Comparison of EE's 4G plans

	Compare plan details						
	Speed	WiFi Calling	Data usage alerts	Unltd calls & texts	EU calls & texts	EU data	BT Sport app
4GEE Max Plans	Our fastest 4G	✓	✓	✓	✓	✓	✓
4GEE Plans	Up to 60Mbps	✓	✓	✓	✓	✓	3 months
4GEE Essential Plans	Up to 20Mbps	✓	✓	×	×	×	3 months

Source: EE website <http://shop.ee.co.uk/price-plans/paymonthly> accessed 3 May 2017

Level and consistency of speed required

- A2.34 We remain of the view that speeds matter primarily to the extent they affect the consumer's experience. *Peak* speeds will rarely be experienced by consumers and may not provide any obvious benefit for most consumers most of the time. For this reason, we do not consider that peak speeds are particularly relevant to competition, though high peak speeds may provide some marketing advantage.
- A2.35 Whether the speed a consumer experiences at any particular time affects that consumer's experience will depend on the application being used. Some applications are not impacted significantly by the speed the consumer receives, and the consumer's experience will be the same for a wide range of speeds (such as receiving and sending emails). However, if the speed is too low for an application, then the consumer may notice (such as when there is extensive buffering when watching a video). The speed at which this happens will vary for different applications (and is also likely to vary for different consumers, with some being more tolerant of the impact than others). For example, watching videos requires higher speeds than browsing web pages, and some consumers may be more sensitive to a deterioration in the quality of a video than others. Consumers are most likely to notice the impact on their application when the network is heavily used and the amount of capacity is low compared to the number of users.
- A2.36 While it matters when consumers notice that they are not receiving sufficient speeds to deliver a good experience, we do not consider that there is strong evidence that suggests that consumers currently place a high value on having consistency of speed per se. Rather we believe that consumers will value speeds rarely falling below a level that is sufficient for the applications they use.
- A2.37 Our views are consistent with the CMA's decision on BT's acquisition of EE, where the CMA emphasised avoiding low speeds as being important rather than being able to offer very high average speeds. It said "*although higher spectrum bandwidth can facilitate higher peak and average speeds, it is not clear how much*

*consumers value such speed increases.*¹⁵⁶ On the other hand, it said that *“the incidence of slow speeds may be particularly important for competition”*.¹⁵⁷

- A2.38 In our competition assessment in section 6 we use the term ‘average speed’ and we express our competition concerns in terms of the risk that some operators are not able to provide sufficient average speeds to be strong competitors. We use this as short hand. As described above, we recognise that there is not a simplistic relationship between average speeds and speeds sufficient for the services consumers are demanding, which will vary depending on the applications they are using.¹⁵⁸
- A2.39 As the speeds consumers experience will tend to be lower in heavily loaded cells, if avoiding low speeds is more important than receiving high speeds, the speeds delivered in heavily loaded cells are likely to be more important for consumers’ general experience than performance in lightly loaded cells (when speeds will generally be higher). This would suggest that consumers’ experience in heavily loaded cells is more relevant than in lightly loaded cells.

Higher speeds required in the future

- A2.40 The importance of speed may increase in the future, as consumers may use more applications that need higher speeds. There is uncertainty, however, over how high the average speeds an MNO can provide would need to be for it to remain a strong competitor.
- A2.41 H3G considers that HD video is likely to be demanded by UK consumers in the first transitional period and certainly by mid-2020 and that MNOs will need to provide ubiquitous HD video as a critical requirement to be credible. In its report for H3G, Real Wireless says that in order to provide HD video MNOs will need to offer a minimum data-rate of 4 Mbps, with a recommended rate of 8 Mbps in around 2020.¹⁵⁹
- A2.42 We are cautious of predicting the specific speeds that might be required in the future for an MNO to be a strong competitor. While some individual users may require 4-8 Mbps when viewing a HD video in the future, it is not clear that this will be necessary for the *average* speed at a busy site during peak hours. This is because there are a range of different data services that may be accessed by different users. Not all users are likely to want to view HD video at any point in time.
- A2.43 Also, the benefits of HD video on a mobile phone screen are currently unclear. As BT/EE pointed out, the ability of the human eye to notice the difference between different resolutions will be a function of the screen size and the distance at which it

¹⁵⁶ Paragraph 116 page G33, Appendix G, CMA Final Report on the anticipated acquisition by BT Group plc of EE Limited https://assets.digital.cabinet-office.gov.uk/media/56991ae4ed915d468c00002b/FR-Appendices_and_Glossary.pdf

¹⁵⁷ Paragraph 117 page G33, Appendix G, CMA Final Report on the anticipated acquisition by BT Group plc of EE Limited https://assets.digital.cabinet-office.gov.uk/media/56991ae4ed915d468c00002b/FR-Appendices_and_Glossary.pdf

¹⁵⁸ We are not using the term ‘average speeds’ in the way it is sometimes used in capacity planning, where it relates to the average speed of a single user randomly located in a cell, which will be lower than the peak speed because the speed a single user can obtain will be lower the further from the base station that single user is located. Rather than this, we are interested in the speeds that users actually experience which are affected by a combination of their effective distance from the base station as well as the location and demand of other users within the cell.

¹⁵⁹ Pages i and 21, Annex 11 of H3G’s response

is viewed. There may not be any noticeable difference between 4k (i.e. 2160p) and 720p resolutions with most smartphone screen sizes. Nevertheless, there may be greater benefit for consumers using a tablet.

- A2.44 Therefore, while we acknowledge that video is one of the many services that people increasingly use on their smartphones, we do not necessarily believe there is strong evidence to suggest that MNOs will need to provide a minimum of 8 Mbps across their networks to be credible, at least in the first transitional period.

Annex 3

Mobile spectrum bands

A3.1 This annex presents the assessment of useability for mobile services of the different bands in the context of the 2.3 GHz and 3.4 GHz award process based on information available at present.¹⁶⁰ Where the bands are not currently used for delivering mobile services, we also consider when they are expected to become useable.

A3.2 As set out in section 5, we regard mobile spectrum as being useable once it satisfies all of the following conditions:

- **Allocation:** The spectrum has been allocated, for example by auction, and the licences allow it to be used for mobile services. There should also be sufficient time to allow for the network to be rolled out after the spectrum has been awarded.
- **No major constraints on use:** To the extent there are constraints on the use of the spectrum for mobile (e.g. due to a clearance programme of previous users or on-going requirements to address co-existence with other users) they must not be so significant that they undermine the substitutability of the band for adding capacity relative to the auctioned bands, 2.3 GHz and 3.4 GHz.
- **Ecosystem:** There is a sufficiently developed ecosystem for the spectrum for mobile services. In this regard, we see user devices (e.g. smartphones, tablets etc.) as the key constraint rather than network equipment. We also consider that spectrum can be useful for adding capacity even when it is supported in only a minority of user devices. This is because traffic can be offloaded to the proportion of devices that can use the new spectrum band, freeing up other bands on the remaining devices that cannot use the new band.

A3.3 Where relevant, we summarise relevant responses to the November 2016 consultation and any additional evidence that has been collected.

800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2.6 GHz

A3.4 In our assessment of the overall spectrum cap for the 2013 auction and in our November 2014 and November 2016 consultations, we identified the spectrum at 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2.6 GHz (paired and unpaired) as the main bands of current importance for mobile access.

A3.5 At the time, we did not include all 50 MHz of the unpaired 2.6 GHz spectrum as useable in our analysis. This is because the top 5 MHz of the 2.6 GHz band (held by BT/EE) and the lowest 5 MHz of any individual company's holding in the unpaired 2.6 GHz band are restricted to 25dBm. This is to manage the risk of interference between two users of the unpaired spectrum as well as between users

¹⁶⁰ For any future award, we would generally expect to make the assessment again in due course. If circumstances had changed between the two awards (e.g. if additional bands had become useable, or if it had become clear that some bands that were expected to become useable had not turned out to be useable), then the pool of relevant spectrum could change between the two awards.

of unpaired spectrum and users of paired 2.6 GHz spectrum. As a result, these portions of the 2.6 GHz unpaired spectrum do not meet our second criteria for useability, i.e. there are material constraints on the use of the band.

- A3.6 We therefore counted BT/EE's holdings at 2595-2620 MHz as representing only 15 MHz of unrestricted mobile spectrum and Vodafone's holdings at 2570-2595 MHz as representing only 20 MHz of unrestricted mobile spectrum¹⁶¹.
- A3.7 Aside from the low-power portions of the unpaired 2.6 GHz band discussed above, all other spectrum in the 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2.6 GHz (paired and unpaired) bands meets our three criteria for useability. Therefore, we have included these bands in the pool of immediately useable spectrum in this competition assessment.

2.3 GHz spectrum

Summary of our position in November 2016 consultation

- A3.8 In our November 2016 consultation, we stated that there was already a wide range of user devices available globally that can use the 2.3 GHz band. In the November 2016 consultation we used the Global mobile Suppliers Association (GSA) June 2016¹⁶² report, which stated that there were 1,604 devices available worldwide that can use 2.3 GHz spectrum for LTE.
- A3.9 At the time, we said that there were already a number of these devices in the UK market, including some popular mobile phones as the iPhone 6 and 6+ and Samsung Galaxy S7.
- A3.10 We therefore concluded that the 2.3 GHz spectrum is likely to be used for mobile broadband shortly after it is awarded. Our view that the 2.3 GHz spectrum can be used rapidly was consistent with the CMA's decision in the BT/EE merger.¹⁶³

Summary of responses

- A3.11 In their responses O2, BT/EE and Vodafone did not disagree with Ofcom's view on the availability of 2.3 GHz.
- A3.12 As part of its response H3G submitted a report by Analysys Mason¹⁶⁴ which stated that the compatible devices currently available in the market have tended to be priced at the higher end of the market.
- A3.13 Furthermore, the report stated that there may be some early limitations such as not being able to combine the 2.3 GHz band with existing FDD bands used by UK

¹⁶¹ For more explanation of the treatment of the unpaired 2.6 GHz in the overall spectrum cap in the 2013 award, see paragraphs 6.67 and 6.68 and Section 10 of our July 2012 statement.

¹⁶² *Status of the LTE Ecosystem*, GSA, June 24, 2016, <http://gsacom.com/paper/status-lte-ecosystem-report-5614-lte-devices-announced-455-suppliers/>

¹⁶³ The CMA found that: "The evidence therefore suggests that the 2.3 GHz spectrum may become useful in a substantial proportion of devices (and therefore allow significant offload) by 2017", paragraph 78, [https://assets.digital.cabinet-office.gov.uk/media/56991ae4ed915d468c00002b/FR-AppendiceAs part of its response, H3G submitted a report s and Glossary.pdf](https://assets.digital.cabinet-office.gov.uk/media/56991ae4ed915d468c00002b/FR-AppendiceAs%20part%20of%20its%20response%20H3G%20submitted%20a%20report%20s%20and%20Glossary.pdf)

¹⁶⁴ Annex 13 – Consequences of Ofcom's categorisation of frequency bands in its latest consultation on the award of 2.3 GHz and 3.4 GHz spectrum bands.

MNOs, for example for carrier aggregation. Nonetheless, the report concludes that these restrictions are likely to be short-term.

- A3.14 The report also found that in 2016 a total of 33 2.3 GHz TD-LTE networks were deployed around the world, with an additional nine networks planned for 2017. Of these, there are two such networks in Europe with two more planned for 2017.

Ofcom's conclusion

- A3.15 The set of mobile phones capable of using the 2.3 GHz band has continued to increase significantly. According to the GSA, there were 2,369 devices available worldwide that can use 2.3 GHz spectrum for LTE as at April 2017¹⁶⁵, a significant increase from the 1,604 devices that could use the band as of June 2016 as stated in our November 2016 consultation.
- A3.16 Furthermore, this includes new high-end phones such as the iPhone 7 and Google Pixel but also cheaper models such as the Samsung Galaxy A3, which is offered at no upfront cost with some post pay plans.¹⁶⁶ As a result, the band meets our ecosystem criterion for spectrum useability.
- A3.17 Given that there are no material restrictions in the use of the band and that it will be allocated as a result of this award process, we conclude that the 2.3 GHz spectrum should be considered as an immediately useable band.

1400 MHz spectrum

Summary of our position in November 2016 consultation

- A3.18 In the November 2016 consultation, we considered that the expected use of the 1400 MHz spectrum was Supplemental Downlink (SDL), in which the spectrum is used to provide only downlink capacity (in conjunction with another spectrum band, such as 800 MHz or 1800 MHz). We stated that we were not aware of any devices available that could use 1400 MHz spectrum, but we expected these to be developed in the near future. The case for device makers to include this band within their devices would be strengthened by there now being a number of operators licensed to use this spectrum for mobile service in several large European countries, namely Germany, Italy and the UK. We said that the price paid for this spectrum in the auctions in Germany and Italy, where it was won by MNOs for €330m and €460m respectively, is also consistent with an expectation of significant device development.
- A3.19 We also said that the 1400 MHz spectrum is likely to be used for mobile access in more European countries¹⁶⁷, and potentially outside Europe. The development of devices may also be helped by the role of Qualcomm, which is a major chipset

¹⁶⁵ *Status of the LTE Ecosystem*, GSA, April 2017, <https://gsacom.com/paper/lte-user-devices-ecosystem-7847-devices-announced/>

¹⁶⁶ As of 20/2/2017 H3G offered a 24-month contract for £30 a month with 8GB and 600 minutes monthly allowance (the Three Advanced Plan), where there was no upfront cost for the Samsung A3 2017.

¹⁶⁷ In March 2015, the European Commission made a mandatory decision to harmonise the 1452-1492 MHz band for terrestrial systems capable of providing electronic services in the European Union.

manufacturer and promotes the Supplemental Downlink standard, including these frequencies in its latest chipset.

- A3.20 In our consultation we expected the 1400 MHz spectrum to be included in devices on a similar timetable to, or shortly before, the 3.4 GHz spectrum.

Summary of responses

- A3.21 BT/EE said that the 1400 MHz band should be considered as immediately useable spectrum. It noted that the Google Pixel phone already included support for the 1400 MHz band. BT/EE also said that operators should be able to influence manufacturers in order to accelerate adoption of this band.¹⁶⁸
- A3.22 In its response Vodafone stated that while it and H3G had licences for 1400 MHz, < [REDACTED] .¹⁶⁹
- A3.23 NERA's report, which is part of O2's submission, stated that "(...) 1400 MHz will not become available in handsets until later this year and then take several years to penetrate the user base."¹⁷⁰ NERA argued that, based on conversations with vendors, it expects handsets incorporating 1400 MHz to become widely available from mid-2018, with the ecosystem reaching maturity in 2019.¹⁷¹ As a result, NERA expects the 1400 MHz band to become useable in "(...) the period from 2019 until mid-2020 or later (...)"¹⁷².
- A3.24 In its response H3G stated that it expects the 1400 MHz to be "fully ready" by 2020 and < [REDACTED] .¹⁷³ As part of its response, H3G also submitted evidence from Real Wireless, Analysys Mason, Samsung, and Frontier Economics.
- A3.25 The report by Real Wireless set out an investigation on the timing of the useability of different bands.¹⁷⁴ The report found that, at present, at least two network equipment vendors indicated that they support or intend to support the band by early 2017.¹⁷⁵ With regards to device availability the report stated that "1.4 GHz devices are becoming available during 2017 in their initial form and we anticipate rapid growth in their use in 2019. The band will attract sufficient device support to make useful to operators in supporting additional capacity but will not be a priority band for OEMs"¹⁷⁶.¹⁷⁷ It further argued that operators will need to find use cases in order to influence OEMs to launch 1400 MHz-compatible devices. The report concluded that this band will be useable from 2019 onwards.
- A3.26 The Analysys Mason report in annex 13 of H3G's response considered that "(...) the L-Band could begin to become useable in a similar timeframe to the 3.4GHz band, and potentially as early as 2018 or 2019, although there is some uncertainty due to the relatively limited device ecosystem for this band to date."¹⁷⁸ It concluded

¹⁶⁸ Paragraph 47, BT/EE response.

¹⁶⁹ < [REDACTED]

¹⁷⁰ Page 21

¹⁷¹ Page 85 NERA report

¹⁷² Page 78 NERA report

¹⁷³ Pages 82 and < [REDACTED] , H3G's response.

¹⁷⁴ Annex 12 "Spectrum timing investigation"

¹⁷⁵ Page 16

¹⁷⁶ Original Equipment Manufacturers (OEMs), which refers to device manufacturers.

¹⁷⁷ Page 31

¹⁷⁸ Page 5, Annex 13, H3G's response.

that “*although there might be initial deployment before 2020, full useability will depend on a broader range of devices becoming available*”.¹⁷⁹

- A3.27 In its report for H3G, Analysys Mason noted that various other European countries are planning to make 1400 MHz spectrum available within the next couple of years, including Austria, France, Switzerland, and Romania.¹⁸⁰
- A3.28 Analysys Mason also described some of the popular smartphones that can use 1400 MHz spectrum, based on the GaMBOD¹⁸¹ device database as at January 2017. It listed two models in the Sony Xperia XZ series, two models in the HTC 10 series and two models in the Google Pixel series.¹⁸²
- A3.29 In its presentation submitted as annex 7b of H3G’s response < [REDACTED] .
- A3.30 In the congestion model developed by Frontier Economics as part of the response by H3G the deployment of 1400 MHz < [REDACTED] .

Ofcom’s conclusion

- A3.31 The responses we received ranged from BT/EE’s view that the band is immediately useable to < [REDACTED] who claimed that the band will < [REDACTED] , with other suggestions in-between (such as Real Wireless¹⁸³).
- A3.32 Taking our three conditions set out above for useability of a spectrum band:
- a) The 1400 MHz band is already allocated in the UK to H3G and Vodafone.
 - b) There are no major constraints on use of the band.
 - c) The binding constraint on the timing of useability of the 1400 MHz band is therefore when we expect the device ecosystem to be sufficiently developed.
- A3.33 We have confirmed BT/EE’s suggestion that the Google Pixel device supports the 1400 MHz band, despite Vodafone’s argument that there are no mainstream terminals currently available that support the band. As of April 2017, it is reported that the 1400 MHz band can be used by four popular handsets, namely the Google Pixel¹⁸⁴, which BT/EE noted, the Sony Xperia XZ¹⁸⁵, the HTC 10¹⁸⁶ and some versions of the Samsung Galaxy S8¹⁸⁷. Furthermore, the 1400 MHz band is

¹⁷⁹ Pages 53 and 56, Annex 13, H3G’s response.

¹⁸⁰ Page 42-3, Annex 13, H3G’s response.

¹⁸¹ GSA Analyzer for Mobile Broadband Devices. For a full explanation see <https://gsacom.com/gambod/>

¹⁸² Page B-4 of Annex 13, H3G’s response.

¹⁸³ Real Wireless states that “1.4 GHz devices are becoming available during 2017 in their initial form, and we anticipate rapid growth in their use by 2019.” See page i in the executive summary of annex 12 of H3G’s response.

¹⁸⁴ <https://madeby.google.com/phone/specs/>

¹⁸⁵ http://www.gsmarena.com/sony_xperia_xz-8313.php

¹⁸⁶ http://www.gsmarena.com/htc_10_lifestyle-8031.php

¹⁸⁷ <http://www.samsung.com/uk/business/business-products/smartphones/smartphones/SM-G950FZKABTU/>

supported by the Qualcomm Snapdragon X16 modem¹⁸⁸, which is expected to be used in many of the upcoming phones.

- A3.34 Further, we have been told by < [REDACTED] .
- A3.35 BT/EE's claim that MNOs can exert some influence over device makers to include bands is consistent with what we have heard from some of these manufacturers < [REDACTED] . They have told us that the decision to include bands in handsets is at least partly driven by the requests of MNOs who tell them which bands need to be supported in the future. However, there is a limit to the influence a single national MNO could exert over manufacturers to include a band within a specified timeframe, and other considerations are also relevant (e.g. the technical challenges in adding a particular band).
- A3.36 We understand that Vodafone has plans to deploy some 1400 MHz sites during the 2017/2018 financial year, < [REDACTED] .
- A3.37 < [REDACTED] .
- A3.38 There is evidence that the 1400 MHz band has started to be deployed in other European countries. For example, in December 2016 Telecom Italia started to deploy the 1400 MHz band in several cities in Italy, advertising speeds of up to 500Mbps using the Sony Xperia XZ phone.¹⁸⁹ The service was commercially launched in Rome, Palermo and San Remo and achieves its maximum advertised speed by aggregating the 20 MHz of 1400 MHz spectrum with 20 MHz of 1800 MHz and 10 MHz of 800 MHz¹⁹⁰.
- A3.39 < [REDACTED] .
- A3.40 We also understand that Vodafone Germany has started trials of the 1400 MHz band but at present we are not aware of specific plans to roll out the band.¹⁹¹
- A3.41 Some press reports¹⁹² state that in Belgium operators have not shown much interest in the band. As a result the Belgian regulator has decided not to include the spectrum in the next multi-band auction. In contrast, the same press reports mention that Dutch operators have requested the Ministry of Economic Affairs and the regulator to relax the restrictions in the use of the band.
- A3.42 There is a regulatory judgement to be made in light of the evidence as to when we expect the ecosystem to be sufficiently developed for the 1400 MHz band to be considered useable for the purpose of our competition assessment. We have taken into account the updated evidence since the November 2016 consultation about the devices that already support the band, the future extension to other significant devices, and the network deployments in other European countries.
- A3.43 Therefore, we now expect the 1400 MHz band to be useable earlier than we previously thought. We now expect the 1400 MHz spectrum to be useable from

¹⁸⁸ <https://www.qualcomm.com/news/releases/2016/02/11/qualcomm-announces-mobile-industrys-first-gigabit-class-lte-modem>

¹⁸⁹ See <http://www.telecomitalia.com/tit/en/archivio/media/note-stampa/market/2016/TIM-500-Mbps-15-12-2016.html> and <http://telecoms.com/478300/tim-claims-500-mbps-4-5g-europe-first/>

¹⁹⁰ See GSA evolution to LTE Report – January 2017, page 61

¹⁹¹ <https://www.teltarif.de/vodafone-lte-netzausbau-1500-mhz/news/63225.html>

¹⁹² <https://www.policytracker.com/headlines/belgian-leaves-1400-mhz-out-of-spectrum-decision-on-auction-plans>

2018. As such, we now include the 1400 MHz band in the pool of immediately useable spectrum. Vodafone and H3G each holds 20 MHz of 1400 MHz spectrum.

3.4 GHz spectrum¹⁹³

Summary of our position in November 2016 consultation

- A3.44 In the November 2016 consultation we stated that, although we are auctioning the 3.4 GHz spectrum at the same time as the 2.3 GHz spectrum, it was likely to take longer to bring the 3.4 GHz frequencies into use than the 2.3 GHz frequencies, because of a lack of suitable user devices. Because of this, we did not expect the 3.4 GHz spectrum to be useable for at least two to three years after the auction.¹⁹⁴ This is because the 3.4 GHz ecosystem is lagging some years behind that of the 2.3 GHz band. When we published the consultation, we were not aware of any major handsets which incorporated the 3.4 GHz band. According to the GSA as of April 2016, there were a total of 118 devices that could use parts of the wider 3.4 GHz to 3.8 GHz band for TD-LTE.¹⁹⁵ However, we noted that the 3.4 GHz spectrum is now incorporated into some chipsets for mobile devices e.g. in Qualcomm's Snapdragon chipset.¹⁹⁶
- A3.45 We noted that following the WRC-15, the 3.4 GHz spectrum has a primary mobile allocation across Europe, the Middle East and Africa, the Americas and some countries in Asia/Pacific.
- A3.46 We also found that it was being deployed for mobile in various countries outside Europe. For example, in Japan three major networks (KDDI, NTT Docomo and SoftBank) were reported to be planning large scale deployments in the 3.4 GHz band by the end of 2016, driven by conditions put in place at the time the frequencies were awarded. We argued that this may generate momentum for the development of the ecosystem – although wide adoption may still take some time. We also noted that in its assessment for the BT/EE merger, the CMA concluded that a substantial proportion of devices were likely to be available for the 3.4 GHz band by 2020.¹⁹⁷
- A3.47 In our November 2016 consultation we also said that, while we expected the 3.4 GHz spectrum to be a sufficient substitute for other bands as regards capacity in the longer term, there was some risk that it would not be.¹⁹⁸

Summary of responses

- A3.48 BT/EE argued that it was wrong to state that 3.4 GHz was not substitutable for 2.3 GHz as both would allow operators to add capacity, regardless of whether they

¹⁹³ What we refer to as the 3.4 GHz spectrum is band 42, covering frequencies from 3400 MHz to 3600 MHz. This spectrum is also known internationally as the 3.5 GHz band or the 3.4-3.6 GHz band.

¹⁹⁴ See paragraph 4.38 of the November 2016 consultation.

¹⁹⁵ *Status of the LTE Ecosystem*, GSA, April 2017, <https://gsacom.com/paper/lte-user-devices-ecosystem-7847-devices-announced/>

¹⁹⁶ <https://www.qualcomm.com/news/releases/2016/02/11/qualcomm-announces-mobile-industrys-first-gigabit-class-lte-modem>

¹⁹⁷ Paragraph 12.47 https://assets.digital.cabinet-office.gov.uk/media/56992242ed915d4747000026/BT_EE_final_report.pdf And Table 8 and paragraphs 75 to 78 of appendix G, https://assets.digital.cabinet-office.gov.uk/media/56991ae4ed915d468c00002b/FR-Appendices_and_Glossary.pdf

¹⁹⁸ See footnote 77 on page 50 and paragraphs 4.86 to 4.89 of the November 2016 consultation.

were deployed at the macro layer, in small cells or a combination. BT/EE also argued that issues relating to differences in handset and network ecosystems were likely to be resolved before the end of the transition period.¹⁹⁹

- A3.49 Vodafone did not provide specific comments on when the band will be useable but did stress its importance in the deployment of 5G services and, therefore, encouraged us to ensure that the spectrum be awarded as soon as possible so that it could plan its network development accordingly. Vodafone also claimed that the band has interim uses before 5G services are launched. < [REDACTED] ²⁰⁰.
- A3.50 NERA expected handsets incorporating 3.4 GHz to become widely available from mid-2018, with full ecosystem maturity in 2019. NERA also argued that the 3.4 GHz band will initially be deployed as a 4G capacity band, eventually evolving into a 5G band²⁰¹. Therefore, NERA expected both the 3.4 GHz band to be useable for 4G services in the period between 2019 until mid-2020 (as for 1400 MHz).
- A3.51 In its response H3G argued that there is a narrow range of devices for 3.4 GHz at the moment but that the ecosystem is likely to develop, which would make the band fully ready for mobile by 2020.²⁰²
- A3.52 In its report for H3G, Real Wireless found that *“the TDD 3.4GHz band (band 42) is already in use in several areas of the world, in particular providing Fixed Wireless communication services. Several of these networks are utilising LTE technology, such as UKB and Imagine in Ireland”*²⁰³. Having received positive confirmation from network equipment vendors, Real Wireless concluded that there is already good LTE infrastructure support for the 3.4 GHz band.
- A3.53 With regards to 3.4 GHz devices Real Wireless found that *“The first devices are fixed wireless routers but a significant base of devices will build up from 2018 (40% of suppliers) to 2022, when 85% expect to support it.”*²⁰⁴
- A3.54 In its report for H3G, Analysys Mason found that there are currently 17 LTE TDD networks deployed worldwide which use the 3.4 GHz band with an additional seven planned. A further 20 existing 3.4 GHz networks use WiMAX technology.
- A3.55 This Analysys Mason report also considered that 3.4 GHz would be useable shortly after the 2.3 and 3.4 GHz auction, although widespread use will initially be limited due to a lack of device availability. However, it considered that the high level of industry attention that the 3.4 GHz band is receiving and early planning for 5G suggest that the ecosystem for this band could develop rapidly. Taking this into account, full useability of this band, including a critical mass of customers holding compatible handsets, could occur from the end of 2019, in Analysys Mason’s view.²⁰⁵
- A3.56 < [REDACTED] .

¹⁹⁹ Paragraph 74

²⁰⁰ See page 9 of Vodafone’s response

²⁰¹ Page 71 NERA report.

²⁰² Page 101. While not clearly specified, it is likely that the narrow range of devices H3G is referring to are devices for FWA access, such as the ones currently deployed by UK Broadband. We are not aware of any UK mobile devices that currently support 3.4 GHz.

²⁰³ Page 16 Real Wireless report

²⁰⁴ Page 21 Real Wireless report

²⁰⁵ Page 53, Annex 13, H3G’s response.

- A3.57 UK Broadband considered the 3.4 GHz band to be useful from as early as 2018 onwards for deployment in 4G LTE networks to provide additional capacity. Consequently, it did not agree with the distinction between spectrum that is immediately useable that which is not. UK Broadband said that industry forecasts predict significant 4G use of the 3.4 GHz band before the advent of 5G.

Ofcom's conclusion

- A3.58 3.4 GHz LTE fixed wireless networks have already been deployed around the world, including the UK. However, at present there are no mobile handsets in the UK market which are compatible with this band.
- A3.59 Although the latest Qualcomm Snapdragon modem also has support for the 3.4 GHz band²⁰⁶, it is likely that implementing it into handsets will take longer than for 1400 MHz. We are aware of only one handset that supports 3.4 GHz TDD LTE, the Sharp Aquos Crystal 2²⁰⁷, developed for the Japanese market. We are also aware that the Essential PH-1, which is due to be released in Q3 2017, will have support for the band²⁰⁸. While the Sharp phone is not available in the UK and the Essential PH-1 has not yet been launched, it shows that the technology required to incorporate the band into handset devices has already been developed.
- A3.60 The April 2017 GSA report on the Status of the LTE User Devices Ecosystem²⁰⁹ showed that there are 118 3.4 GHz devices available, an increase of 36 devices compared to June of 2016. Furthermore, the January 2017 GSA Evolution to LTE Report²¹⁰ states that there were a total of 28 networks around the world using bands 42 (i.e. 3.4 GHz) and/or 43 (i.e. 3.6-3.8 GHz).
- A3.61 We have been told by X [REDACTED] .
- A3.62 However, we were told by X [REDACTED] .
- A3.63 We now consider that there is greater certainty that there will be a sufficiently developed ecosystem in the period 2019 to 2020. This band already meets the other two criteria for useability - i.e. there will be no material constraints on its use and it will be allocated as part of this Auction.
- A3.64 Therefore, whereas in the November 2016 consultation we said that it may take 'at least' two to three years after the Auction for the band to be useable, we are now more confident that it will become useable in the period 2019 to 2020.
- A3.65 With regards to whether 2.3 GHz and 3.4 GHz are substitutes, we only received BT/EE's comments arguing that they were indeed substitutes. Given that none of the other respondents argued against treating these bands as substitutes, we are also now confident that 3.4 GHz will be a sufficient capacity substitute for other bands in the longer term.

²⁰⁶ See <https://www.qualcomm.com/news/releases/2016/02/11/qualcomm-announces-mobile-industrys-first-gigabit-class-lte-modem>

²⁰⁷ http://www.gsmarena.com/sharp_aquos_crystal_2-7251.php

²⁰⁸ See <https://www.essential.com/>

²⁰⁹ See <https://gsacom.com/paper/lte-user-devices-ecosystem-7847-devices-announced/>

²¹⁰ See <http://gsacom.com/communities/lte-tdd/>

700 MHz spectrum

Summary of our position in November 2016 consultation

- A3.66 In the November 2016 consultation, we noted that we had decided to aim to bring forward when the 700 MHz spectrum is available to Q2 2020.²¹¹ We said that we plan to auction the 700 MHz spectrum in advance of it being available.
- A3.67 We stated that user devices capable of using the paired 700 MHz spectrum were already in use in the UK and the proportion of such devices would grow over time. We expected MNOs to be able to make use of the 700 MHz spectrum as soon as it was available.
- A3.68 We also noted that, in addition to the 2x30 MHz of paired spectrum at 700 MHz, we had decided to award 20 MHz of the unpaired spectrum in the 'centre gap' of 700 MHz for mobile use.²¹²

Summary of responses

- A3.69 Vodafone highlighted that the *"2020 date for 700MHz availability for mobile usage is contingent upon Arqiva being able to erect temporary television transmission masts during 2017. Should there be bad weather, the whole programme could be subject to delay and Ofcom has built in a review point at the end of this summer."*²¹³
- A3.70 In the NERA report, which is part of the O2 response, NERA considered that the use of the 700 MHz band is part of the long term period (i.e. beyond 2020) when both this band and 3.6-3.8 GHz will be made available. NERA nonetheless requested that Ofcom provide an update on the plans for clearing the 700 MHz and 3.6-3.8 GHz band.
- A3.71 H3G argued that the 700 MHz band will be available later than Ofcom had assumed. H3G stated that *"700MHz is unlikely to be made available before Q2 2020, as it is used for broadcasting and PMSE. Were an auction to be held before then, and assuming a highly developed ecosystem, it would still take until 2021 at the earliest before paired 700MHz spectrum could be intensively used, with 700MHz unpaired lagging significantly behind. Two others risks could further delay availability: (i) the need to complete the award of 700MHz spectrum by Q2 2020 and (ii) the need to complete DTT and PMSE clearance by this time"*.
- A3.72 H3G also argued that Ofcom has a poor record in time taken to award spectrum, as Ofcom has taken a minimum of two to three years to conduct the auction from the time in which the first consultation was published. Furthermore, H3G warned that there was a risk that other operators could delay the award of other bands through the use of lobbying and litigation in order to cement any spectrum advantage that they may have.²¹⁴
- A3.73 In its report for H3G, Real Wireless concluded that the 700 MHz band should be available by Q2 2020 and that, for at least the paired portion of the band, delays

²¹¹ Section 3, *Maximising the benefits of 700MHz clearance*, statement, Ofcom, 17 October 2016, <https://www.ofcom.org.uk/consultations-and-statements/category-1/maximising-benefits-700mhz-clearance#>

²¹² Section 4, *Maximising the benefits of 700MHz clearance*, statement, Ofcom, 17 October 2016.

²¹³ Page 18, footnote 41

²¹⁴ Page 83

due to technical reasons were unlikely. It also found that 700 MHz networks in the LTE band 28 are already deployed in other parts of the world and there are plenty of handheld devices which are compatible with this band.

- A3.74 With regards to the centre gap of the 700 MHz band, Real Wireless highlighted that this band is unique to Europe and that at present there are no known operators that are planning to deploy in this band. Real Wireless considered that, once there is sufficient demand or a significant operator order, vendors should take 9-12 months to develop the equipment to introduce the band.²¹⁵
- A3.75 In its report for H3G, Analysys Mason noted that the accelerated timescale for the DTT migration is subject to a certain degree of uncertainty as a result of the complexity of re-deploying the DTT network and the smooth migration of PMSE users. However, Analysys Mason considered that once the spectrum is available it should be deployed quickly, given the growing equipment ecosystem. It therefore concluded that the spectrum will be useable within six months of making the band available for mobile, i.e. end of 2020.²¹⁶

Ofcom's conclusion

- A3.76 As we stated in our November 2016 consultation, Ofcom has already issued a statement aiming to bring forward the clearance of the 700 MHz band made up of 2x30 MHz and the 20 MHz in the centre gap to Q2 2020. In that statement, we noted that the accelerated plan relies on a substantial amount of DTT infrastructure work taking place in summer 2017, which is why prolonged periods of bad weather in 2017 could generate delays to the infrastructure works, potentially delaying the accelerated clearance date²¹⁷.
- A3.77 However, we also argued that we believed that the chance of clearance being pushed back is relatively small and we had agreed with Government to review the target date in August 2017.
- A3.78 With regards to Vodafone's comment & [REDACTED] . We plan to issue an update on the progress of the clearance programme in September of this year.
- A3.79 In our 700 MHz clearance acceleration statement we also issued a formal notice to PMSE owners that their access to the band would cease from 1 May 2020. In that statement we also said that Government had agreed to fund a grant scheme to support PMSE users affected by clearance²¹⁸. We have also recently published our consultation setting out how this grant scheme would operate.²¹⁹
- A3.80 We therefore disagree with H3G's position that DTT and PMSE clearance are likely to delay the date when the band will become available. Work is currently being carried out to migrate existing users of the band to alternative frequencies and the

²¹⁵ Real Wireless report. Page 16

²¹⁶ Analysys Mason report. Page 6

²¹⁷ See paragraph 3.20 of the 700 MHz clearance acceleration statement

²¹⁸ See paragraph 1.26.

²¹⁹ See https://www.ofcom.org.uk/_data/assets/pdf_file/0021/100965/700mhz-band-pmse-funding.pdf

programme is proceeding as planned.²²⁰ Therefore, we still expect the Q2 2020 date to be achievable and this is our assumption for the analysis in this document.

- A3.81 We also plan to award the spectrum in advance of the 2020 clearance date – most likely in 2019, thereby ensuring that it is awarded by the time the band is cleared.²²¹
- A3.82 With regards to the device ecosystem, there are already several 700 MHz compatible handheld devices²²², including some popular models²²³. There are also network deployments, including in Europe²²⁴, which use the duplex part of the 700 MHz band. The January 2017 GSA Evolution to LTE Report finds that there are a total of 34 commercially launched 700 MHz networks launched in 18 countries.
- A3.83 With regards to the centre gap, in our 700 MHz clearance acceleration statement²²⁵ in October 2016 we noted that while there are no devices currently available, the latest 3GPP release incorporates the band for use for SDL, which is the most likely use in the UK. We understood that other European countries such as Germany and France were considering the use of part of the centre gap for SDL services as well. Germany's federal network regulator (Bundesnetzagentur) has now published its 5G framework document in which it has identified 15 MHz of the 700 MHz centre gap as a suitable band for SDL²²⁶.
- A3.84 We argued in our 700 MHz clearance acceleration statement²²⁷ that the increase in traffic would translate into increased demand for spectrum. As a result, there would be strong demand for SDL to access the centre gap by 2020. We arrived at this view based on, among other things, the views expressed by H3G and Telefónica (O2). We therefore concluded that while there was uncertainty about the development of the ecosystem to use the centre gap, it was more likely than not that the devices would be available by 2020.²²⁸
- A3.85 We were told by 3< [REDACTED] .
- A3.86 We were told by 3< [REDACTED] .
- A3.87 We therefore expect that the centre gap will be useable by the time it is cleared.

²²⁰ With any major clearance programme of this nature, there is always a risk of delay – particularly weather-related delays to work at main DTT transmitter sites. Based on progress to date, and noting that 2017 is the year most at risk of weather delay, we still expect clearance by Q2 2020.

²²¹ Whereas we said in the November 2016 consultation that the award of the 700 MHz spectrum band might be in 2018/19, we now believe it is unlikely that the award will take place in 2018.

²²² 639 devices according to the April 2017 GSA report

²²³ Some of the handheld devices that can use the band include several models by Apple, Samsung and Sony, among others.

²²⁴ In France both Bouygues telecom and Free mobile have started to deploy their 700MHz network in some of their sites. See <http://www.anfr.fr/gestion-des-frequences-sites/observatoire-2g-3g-4g/les-resultats-de-lobservatoire/avril-2016/#menu2>

²²⁵ See https://www.ofcom.org.uk/_data/assets/pdf_file/0031/92659/Maximising-the-benefits-of-700-MHz-clearance-Statement.pdf

²²⁶ See https://www.telecompaper.com/news/germany-unveils-5g-spectrum-framework-plans-auction-in-2018--1201754?utm_source=headlines_-english&utm_medium=email&utm_campaign=29-06-2017&utm_content=textlink

²²⁷ See section 5 of https://www.ofcom.org.uk/_data/assets/pdf_file/0031/92659/Maximising-the-benefits-of-700-MHz-clearance-Statement.pdf

²²⁸ See paragraph 5.16

- A3.88 In summary, we still expect that the whole 700 MHz band will be cleared and allocated by Q2 2020, that there will not be any major constraints²²⁹ on its use and that there will be a device ecosystem as well as the necessary network equipment available by the time the band is cleared. Therefore, we continue to consider this as useable from Q2 2020²³⁰.

3.6–3.8 GHz spectrum

Summary of our position in November 2016 consultation

- A3.89 In our November 2016 consultation we noted that the characteristics of the 3.6–3.8 GHz spectrum make it suitable for a range of mobile applications, including increasing data capacity, and we identified this spectrum as a high priority band for mobile. We said that it was likely that when there are devices that can use 3.4 GHz spectrum, they will also be able to use the 3.6–3.8 GHz band.
- A3.90 We noted that UK Broadband held 84 MHz of spectrum at 3605–3689 MHz. In combination with its 3.4 GHz spectrum, UK Broadband used this to offer its ‘Relish’ LTE wireless broadband service. ‘Relish’ uses both indoor and outdoor Broadband Wireless Access (BWA) devices to offer services to consumers and businesses in central London, with plans for roll-out in other cities.²³¹ UK Broadband had stated that it intended to offer mobile broadband services in the future.²³²
- A3.91 The band is also used by several receiving Earth Stations (authorised under Permanent Earth Stations licences or Grant of Recognised Spectrum Access for Receive Only Earth stations) and fixed links, some of which are in locations which could potentially limit the deployment of mobile services of the band in densely populated areas such as Greater London if current coordination criteria are kept in place.
- A3.92 We mentioned that in October 2016 we published a consultation²³³ setting out our plans to make the 116 MHz not currently held by UK Broadband available for mobile and we presented options on how to deal with the receiving earth stations and fixed links.
- A3.93 We also argued in the November 2016 consultation that it was likely that the spectrum at 3.6–3.8 GHz will be used for mobile services in the future, including 5G,

²²⁹ Coexistence with DTT will need to be managed but should not limit the deployment of the band for mobile. We have recently put out a consultation on 700 MHz, which discusses technical alternatives for coexistence (see <https://www.ofcom.org.uk/consultations-and-statements/category-3/coexistence-of-new-services-in-the-700-mhz-band-with-digital-terrestrial-television>).

²³⁰ We consider the prospect of delays is limited, and any such delays would only be for a few months. Even if there were material delays in the clearance process, it is likely that there would be scope to make the band available on a regional basis across large parts of the UK from Q2 2020, ahead of full clearance. We would continue to work towards an award well in advance of the date at which the first areas became available for mobile.

²³¹ H3G has stated that “*There will be no immediate changes to the Relish wireless broadband operations or brand and Relish will continue to manage its 17,000 home and business customers*” as a result of the acquisition of UK Broadband. See <http://www.threemediacentre.co.uk/news/2017/ukb-completion.aspx>

²³² See paragraph 1.3, *Variation of UK Broadband’s 3.4 GHz licence*, Ofcom, June 2014 <http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/summary/condoc.pdf>

²³³ *Improving consumer access to mobile services at 3.6 to 3.8 GHz*, Ofcom, 6 October 2016, <https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz>

even if it may be subject to restrictions on its use to avoid interference with other uses in the band.

- A3.94 In our November 2016 consultation, we noted there was some uncertainty about the future useability of the 3.6-3.8 GHz band. However, we judged it sufficiently likely that the 3.6-3.8 GHz frequencies could be available and useable across the UK on similar timescales to the 3.4 GHz band to support our proposal for no overall cap on spectrum holdings .

Summary of responses

- A3.95 In its response BT/EE mentioned that the band may be auctioned off together with 700 MHz, that there are potential coexistence issues and that it has been identified as a key 5G band by RSPG.²³⁴
- A3.96 In its response Vodafone mentioned that there are considerable policy issues that need to be addressed by Ofcom in the 3.6-3.8 GHz band including whether satellite users will be allowed to use the band and, if so, for how long. Given this issue, Vodafone did not expect the 3.6-3.8 GHz band to be made available at the same time as the 3.4 GHz band.²³⁵
- A3.97 Figure 13 in O2's response indicated that O2 expects the 3.6-3.8 GHz band to be useable as early as mid-2020, similar to the 700 MHz band. In a report that forms part of the O2 response, NERA considered that the use of the 700 MHz band is part of its so-called "second transitional period" (i.e. beyond 2020) when both the 700 MHz and 3.6-3.8 GHz bands will be available.²³⁶ As a "soft measure" to promote an efficient auction process NERA requested that Ofcom provide an update on the plans for clearing the 700 MHz and 3.6-3.8 GHz bands.
- A3.98 H3G argued that the 3.6-3.8 GHz band is likely to develop much more slowly, so as to be fully available in 2023. H3G stated that there are no compatible devices available and there is only one TD-LTE network deployed worldwide.²³⁷ H3G also argued that the two options that Ofcom outlined in the October 2016 consultation to make 3.6-3.8 GHz bands useable for mobile ("retain" or "remove" existing users) imply a long lead time.
- A3.99 UK Broadband also argued that there is significant uncertainty around the timing, nature and structure of any future 3.6-3.8 GHz auction. It considered that even if the band was released, its effect on competition in the market would depend on the extent that existing permanent earth stations are cleared from the band. It considered that it was almost certain that the existing users will most certainly not have been cleared by the time 3.4 GHz (band 42) and 3.6-3.8 GHz (band 43) appear in consumer handsets (2018 onwards), thereby creating geographic restrictions.
- A3.100 In annex 14 of its response, H3G also noted that, in the past, it has taken at least two to three years to award bands, even when the award was uncontroversial. It therefore considered that the award of this band (as well as 700 MHz), is unlikely to

²³⁴ Paragraph 107

²³⁵ Page 9

²³⁶ NERA argues that there is uncertainty about when the 3.6-3.8 GHz band will be fully integrated into handsets and noted that Ofcom had indicated that clearance of fixed links may not take place before mid-2020. See page 85

²³⁷ Page 101

take place before late 2019 or, more likely 2020. H3G also raised the issue of potential litigation and the further delays of at least six months to a year that it would cause.

- A3.101 H3G also noted that Ofcom has not even started to prepare for the 3.6-3.8 GHz award as it is not even listed in the “prospective awards” section of the Ofcom website.²³⁸
- A3.102 In its report for H3G, Real Wireless stated that it has received confirmation that more than one infrastructure vendor currently supports LTE TDD in band 43.²³⁹ It also found that by 2022 three quarters of device makers are expected to have products supporting 3.6 GHz, often for 5G.²⁴⁰ However, Real Wireless stated that there are considerable uncertainties as to if, and when, this band will become useable throughout most of the UK given the potential geographic restrictions to its use for mobile given the presence of fixed links and permanent earth stations.²⁴¹
- A3.103 In its report for H3G Analysys Mason²⁴² argued that the prospect for use of the 3.6-3.8 GHz band are not clear. Specifically, it stated that *“3.6–3.8GHz spectrum is also receiving a high level of industry attention in Europe, and the eco-system for this band could, in theory, also evolve rapidly once there is greater certainty surrounding harmonised European plans for 5G. However, to date there have been virtually no mobile deployments in this band, and harmonisation is less clear than for other bands, meaning that availability of both network equipment and devices is uncertain. Furthermore, this band is not immediately available for mobile use in the UK and various other European countries due to the need to transition existing fixed and fixed satellite services from the band. (...) As such, timescales for this spectrum being available for mobile use in the UK are far from certain, and we do not expect this spectrum to be useable until after 2022.”*²⁴³

Ofcom’s conclusion

- A3.104 Vodafone, H3G, UK Broadband and O2 have raised questions about the time at which the band will be made available. In particular, they have highlighted the uncertainty with regards to the clearance of the band, the time this process would take to complete and the possibility of prevailing geographic restrictions.
- A3.105 As we stated in section 5, we will shortly publish a further document confirming our intention to make the band available for mobile and setting out our proposed approach.
- A3.106 The likely effect of our proposed approach would be to enable mobile services in the 3.6 GHz to 3.8 GHz band to be deployed in many areas from around 2020, but not necessarily nationwide. For example, the band may not be fully useable in some highly populated areas where we consider there to be a significant likelihood of capacity constraints (including greater London) until 2022. The consequence is that there could be material constraints on mobile deployment in the 3.6-3.8 GHz band beyond the stage at which we expect the 3.4 GHz spectrum to become useable (i.e. from 2020).

²³⁸ Page 84

²³⁹ Page 17

²⁴⁰ Page 21

²⁴¹ Page 14

²⁴² Page 6

²⁴³ Page 6

- A3.107 At present, there is limited evidence of 3.6-3.8 GHz networks being rolled out in other parts of the world. The January 2017 GSA Evolution to LTE Report finds that Bahrain, Argentina, Slovakia and Ivory Coast have already seen the deployment of 3.6-3.8 GHz networks with trials ongoing in Norway. We also understand that UK Broadband makes use of its 3.6-3.8 GHz spectrum for its Relish network in the UK.
- A3.108 With regards to the device ecosystem, we are aware that the Essential PH-1, which is due to be released in Q3 2017, will have support for the band²⁴⁴ but are not aware of any currently available handsets that can use the band. The GSA April 2017 report lists 93 devices for this band but we understand that none of these were handsets at the time the report was published²⁴⁵.
- A3.109 We were told by 3< [REDACTED] .
- A3.110 We also understand that at least some chipsets cover the wider 3.4–3.8 GHz band, thus potentially enabling products to operate in 3.6-3.8 GHz on the same timescale as the 3.4 GHz band. It is therefore possible that the device ecosystem will develop at a similar pace to the 3.4 GHz band.
- A3.111 Finally, we would aim to award the 3.6-3.8 GHz spectrum (not already held by H3G) in advance of it being made available for mobile, potentially at the same time as the 700 MHz band. We expect to have enough time between the proposed date of the award and the date when the spectrum is made available to deal with potential contingencies such as those raised by H3G.
- A3.112 Therefore, as we concluded in section 5 of this statement, although our aim remains to allocate the 3.6-3.8 GHz spectrum for mobile, we do not have certainty that this will be possible across the UK in similar timescales to those on which the 3.4 GHz will be useable. Although we believe it is possible that an ecosystem will develop in a similar timeframe to 3.4 GHz, it is uncertain that the band will be fully useable on this timescale – and we are less confident about this than we were at the time of our consultation document in November.

1900 MHz spectrum not relevant

Summary of our position in November 2016 consultation

- A3.113 In our November 2016 consultation, we stated that we did not consider the unpaired 1900 MHz spectrum was relevant to mobile competition in our analysis. It was not currently being used for mobile access and was unlikely to be able to be used for high power macro sites in practice due to the compatibility with the adjacent uplink band of the 2.1 GHz paired spectrum. Of this spectrum, BT/EE has 10 MHz, O2 has 5 MHz and H3G has 5 MHz.
- A3.114 We mentioned that BT/EE had recently requested a licence variation to allow it to use its 1900 MHz spectrum for LTE in support of delivery of the emergency services network, and we were consulting on this.²⁴⁶ Our preliminary view which we published in the consultation was to grant BT/EE's request so as to allow LTE in EE's 1900 MHz spectrum, subject to technical conditions consistent with CEPT

²⁴⁴ See <https://www.essential.com/>

²⁴⁵ These are likely to be FWA devices.

²⁴⁶ The consultation on EE's requested licence variation is here:

<https://www.ofcom.org.uk/consultations-and-statements/category-2/EE-licence-variation-1990-1920MHz>

Report 39. We noted that these technical conditions, if applied to all 1900 MHz spectrum, would allow different power levels in different 5 MHz blocks of the 20 MHz of 1900 MHz spectrum.

- A3.115 Specifically, BT/EE's lowest 5 MHz block (1900-1905 MHz) would be permitted to operate at up to 43 dBm, BT/EE's next 5 MHz block (1905-1910 MHz) would be permitted to operate up to 30 dBm, and O2's 5 MHz block (1910-1915 MHz) and H3G's 5 MHz block (1915-1920 MHz) would be permitted to operate up to 20 dBm. There might be an argument that the higher permissible power for BT/EE's lowest 5 MHz (or even all of its 10 MHz) meant that this spectrum could be used to support mainstream mobile services on microcells, even though the 1900 MHz spectrum of O2 and H3G could not. We noted that there are already many global mobile handsets available that cover this spectrum as part of a wider band and this band is included in many handsets available to UK consumers.
- A3.116 However, we concluded that it was not clear that even at 43 dBm it would be useful for mainstream mobile services. As far as we were aware, it was not used elsewhere in Europe for mainstream mobile services, despite the CEPT Report 39 dating from 2010.
- A3.117 We argued that, even if we were to include all or some of the 10 MHz of EE's 1900 MHz as immediately useable spectrum, we did not consider that it would undermine our preferred policy option. Rather, it would tend to strengthen the case for the option we proposed, of capping the spectrum immediately useable after the award. This was because, if BT/EE's 1900 MHz spectrum were included, the current distribution of immediately useable spectrum would be even more asymmetric, with BT/EE's current share of immediately useable spectrum increasing to 46%. After the auction, BT/EE's share would fall to 43%²⁴⁷.

Ofcom's conclusion

- A3.118 We did not receive any responses to our November 2016 consultation which discussed the 1900 MHz band.
- A3.119 In January 2017 we published our statement²⁴⁸ with the decision to grant the request to permit TD-LTE technologies in the 1899.9 to 1909.9 MHz spectrum. Our decision was predicated on the basis that additional technical conditions were included in BT/EE's licence in order to prevent interference to other users of adjacent spectrum.
- A3.120 In line with our framework we do not believe that the 1900 MHz should be considered as useable as we are not aware of devices which are capable of using the band and there are major constraints in the use of the band. Therefore, our view that this spectrum is not considered as relevant for our analysis remains unchanged.

²⁴⁷ These are the percentages that we presented in the consultation and did not include 1400 MHz in the relevant pool of spectrum. Taking into account 1400 MHz spectrum, BT/EE's share of currently useable spectrum is 43% falling to 40% after the auction.

²⁴⁸ See https://www.ofcom.org.uk/_data/assets/pdf_file/0032/96566/Statement-EE-application-for-licence-variations-in-support-of-enhanced-mobile-communications-for-the-emergency-services.pdf

Other potential future mobile spectrum

Summary of our position in November 2016 consultation

- A3.121 In our November 2016 consultation we mentioned that there are a number of other frequencies that may become useful for mobile access in the future. We published an update to our mobile data strategy in June 2016.²⁴⁹ This described some changes to our priorities for future mobile spectrum release, including making the release of spectrum at 1427-1452 and 1492-1518 MHz a high priority, as well as spectrum at 5725-5850 MHz and the mmWave bands.²⁵⁰
- A3.122 We noted that the award of the 2.3 and 3.4 GHz bands is part of the Government's Public Sector Spectrum Release (PSSR) programme. In April 2016, the Central Management Unit (part of UK Government Investments) proposed a new target (reported in the March 2016 Budget): "750MHz of valuable public sector spectrum in bands under 10GHz will be made available by 2022, of which 500MHz will be made available by 2020."²⁵¹
- A3.123 We also mentioned that in addition to the current release of cleared spectrum, the PSSR programme involves plans to make further public sector spectrum available for civil users. The lower 2.3 GHz band (2300–2350 MHz) was noted as a priority band for investigation as part of the CMU update. We are therefore currently working with MOD and other government departments to explore the potential to make available additional spectrum for civil users in the lower 2.3 GHz range. This may be on a time limited basis and/or in limited geographic areas. We argued that such opportunities remain uncertain at this stage and in any case will not be available for some years.

Ofcom's conclusion

- A3.124 We have now published an update on 5G spectrum in the UK²⁵² in which we explained that the diverse set of 5G services and applications will require a diverse set of spectrum bands, with different characteristics, addressing different requirements. We identified the 26 GHz band as the priority band for one of those requirements (millimetre wave cells using spectrum at very high frequencies with very large bandwidth, providing ultra-high capacity and very low latency). We have also started a programme of work to look at how the 26 GHz band can be made available for early 5G deployment in the UK, taking into account existing users and their requirements and we expect to publish a Call for Input shortly.
- A3.125 While we have identified 26 GHz as a priority band for release, we have not yet set out the timelines to make the band available and award it.

²⁴⁹ *Mobile Data Strategy, Update on our strategy for mobile spectrum*, Ofcom, 30 June 2016, <http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/update-strategy-mobile-spectrum.pdf>

²⁵⁰ In our February 2017 Update on 5G spectrum in the UK we noted that "Strictly speaking, mmWave is the band of spectrum between 30 GHz and 300 GHz – wavelengths at these frequencies are between 1mm and 1cm long. The term is commonly used refer to frequencies above 24 GHz and this is how we use it here".

²⁵¹

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518303/enabling_uk_growth_pssr_programme_annual_report.pdf

²⁵² See https://www.ofcom.org.uk/data/assets/pdf_file/0021/97023/5G-update-08022017.pdf

- A3.126 Furthermore, we are not aware of any current handheld devices or network equipment that can use the band. Therefore, for the purpose of the Auction, we do not consider 26 GHz to be useable.
- A3.127 Even if this band were to be useable, it has very different technical characteristics to other bands and we expect mobile deployments to be very different to those using other bands (e.g. not using macrocells).
- A3.128 In line with our framework, there is no clear outlook on device ecosystem, allocation timelines or potential usage constraints for the 26 GHz band, other mmWave bands and spectrum at 1427-1452 and 1492-1518 MHz, 2300–2350 MHz, and 5725-5850 MHz. Given the uncertainties, in our view, these bands should not be considered when assessing the impact on mobile competition of the frequencies in the Auction.

Annex 4

International benchmark of spectrum holdings

Introduction and summary

- A4.1 In this annex we replicate the international benchmark of spectrum holdings that we included in our November 2016 consultation and, where relevant, we refer to stakeholder responses to the consultation on individual countries and the discussion of spectrum concentration.
- A4.2 We have made a few adjustments to the data used in this benchmark, namely:
- We have updated market shares for 2016 using Analysys Mason data, except for Slovenia where updated market shares were not available.
 - We have corrected an error regarding the 2.1 GHz paired spectrum holdings of SFR in France.
 - We have included the 1400 MHz spectrum holdings of Telecom Italia and Vodafone in Italy as well as H3G and Vodafone in the UK.
 - We have corrected the figures for 900 MHz spectrum holdings of Si.mobil, Telekom Slovenije and Telemach Mobile as well as 1800 MHz and 2.1 GHz paired spectrum holdings of Telemach Mobile in Slovenia.
- A4.3 This annex presents the spectrum holdings of different operators in several Western European countries. We have focused on countries where there are at least four operators, namely Denmark, France, Italy, the Netherlands, Slovenia, Spain and Sweden, as these are better UK comparators.²⁵³ After setting out the evidence for these countries, we comment on the international comparison of spectrum concentration.²⁵⁴
- A4.4 In their responses both O2 and H3G have provided an expanded sample of countries. We summarise their findings later in this annex. O2 and H3G have also provided specific comments on some of the MNOs that were part of the international sample that we included in our November 2016 consultation. We include their comments in each of the relevant sections of this annex.

²⁵³ We have excluded Finland from our analysis as the fourth holder of spectrum - Ukko mobile - does not provide traditional mobile services, for example, it does not offer voice services.

²⁵⁴ We have not included Austria, Belgium and Germany, which were discussed in our 2012 Assessment of future mobile competition and award of 800MHz and 2.6 GHz Statement, but which now only have three MNOs (see assessment see paragraphs A2.182 to A2.259 in Annex 2 of our July 2012 statement for our earlier assessment). In Austria and Germany there are now only three MNOs because two of them merged. In Belgium, while a fourth operator obtained spectrum in 2011, it did not launch services and returned the spectrum rights in 2014 (See the discussion under 'mobile telephony' on page 10 of Telenet's 2014 Annual Report, <http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9Mjc5MDYyYfENoaWxkSUQ9LTF8VHlwZT0z&t=1>).

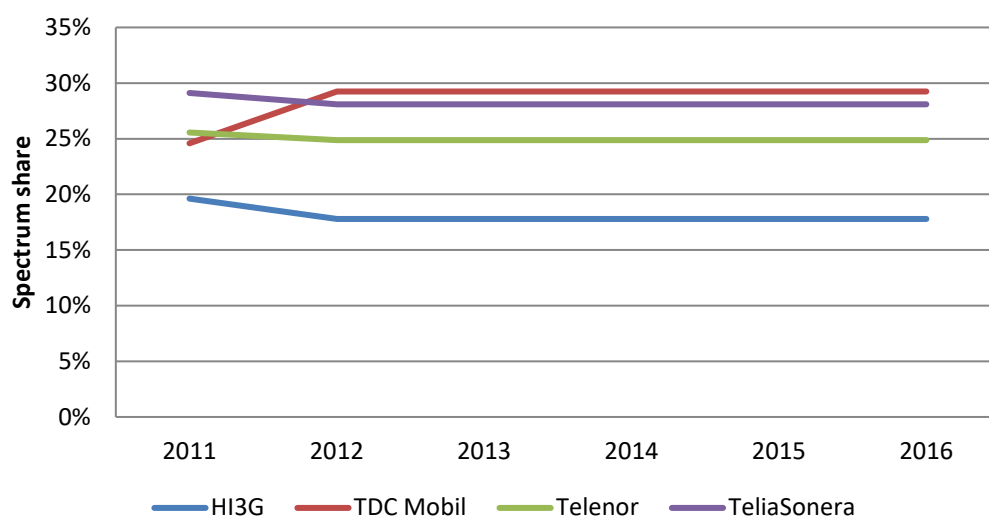
- A4.5 The analysis in this annex is based on spectrum holdings in bands which are currently useable by mobile operators, namely 800 MHz, 900 MHz, 1800 MHz, paired 2.1 GHz and paired and unpaired 2.6 GHz, plus 1400 MHz which we now include in the pool of immediately useable spectrum. We present a time-series of total spectrum holdings over the past five years.
- A4.6 We compare this evolution of spectrum shares with the evolution of market shares²⁵⁵ as an indication of how MNOs have performed. We are mindful that spectrum is not the only resource on which the market performance of an MNO hinges and that market shares are only one indication of this. Nonetheless, market share does provide some insights.
- A4.7 Our key conclusions in this annex are as follows:
- Based on the evidence from other European countries described in this annex, in our view there is not enough evidence to reach a reliable conclusion either that a spectrum share of 10-15% is enough to enable an MNO to be credible or that it is insufficient.
 - The current spectrum asymmetry in the UK is generally materially larger than in other comparable countries.

Denmark

- A4.8 Spectrum allocations in Denmark have remained stable since 2012, with the four MNOs having spectrum shares between ca. 18-29% each.²⁵⁶

²⁵⁵ Source: Analysys Mason Telecom Market Matrix – April 2016, except for Slovenia

²⁵⁶ We have assumed that each of the spectrum holdings of TeliaSonera and Telenor include 50% of the spectrum holdings of TT Netværket, which is a joint venture of Telenor and TeliaSonera, holding 2x10 MHz of 800 MHz spectrum. TT Netværket does not operate as an MNO on its own but rather as the infrastructure company of Telenor and TeliaSonera in Denmark. See <http://www.tt-network.dk/>

Figure A4.1: Spectrum shares in Denmark

Source: Cullen international

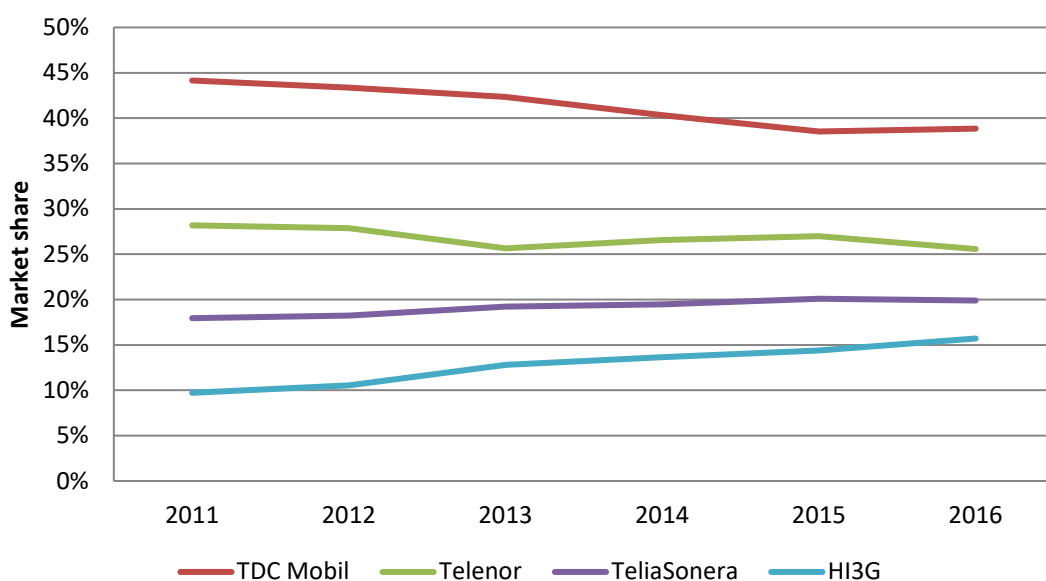
Figure A4.2: Spectrum holdings in Denmark – 2016 (MHz)

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
TDC Mobil	40	18	43.6	31	40	0	172.6
Telenor	10	18	38.8	30	40	10	146.8
TeliaSonera	10	23.6	47.2	30	40	15	165.8
HI3G	0	10	20	30	20	25	105

Source: Cullen international

- A4.9 Up to 2015 the three smaller operators in Denmark have increased their subscriber market share at the expense of the largest operator (TDC), except for a dip by Telenor between 2011 and 2013. However, between 2015 and 2016 TDC Mobil and HI3G experienced an increase in subscriber share (0.3 and 1.3 percentage points respectively), while Telenor and TeliaSonera experienced a fall (1.4 and 0.2 percentage points respectively).

Figure A4.3: Subscriber market share in Denmark²⁵⁷



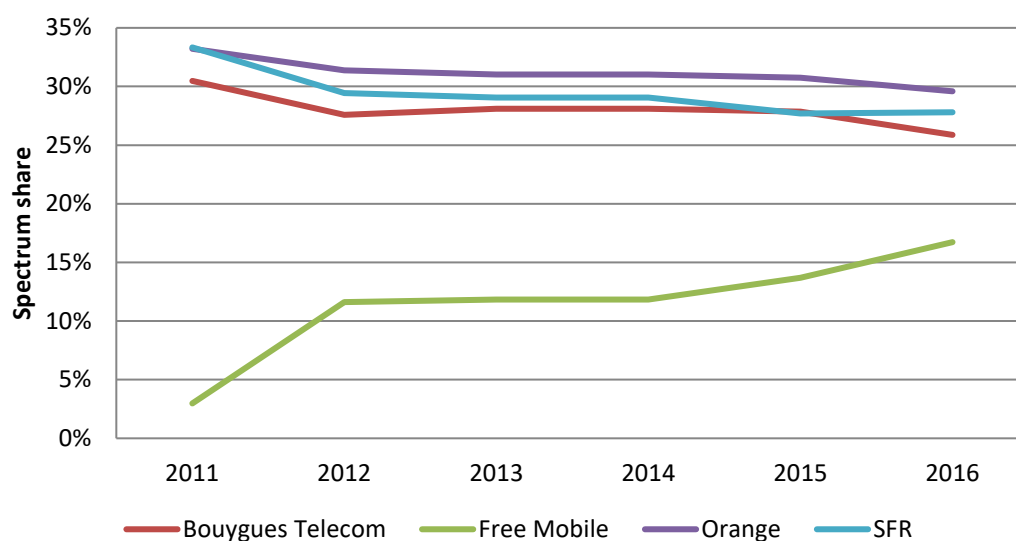
Source: Analysys Mason

A4.10 There is a larger dispersion of subscriber market shares in Denmark than spectrum shares. TDC's subscriber market share is larger than its spectrum share, but it has lost market share to competitors over the 2011-2016 period. TeliaSonera has a slightly lower share of spectrum than TDC but a significantly lower subscriber share (albeit rising over time). HI3G's subscriber share has increased over time reaching 15.7% in 2016, but remains lower than its share of spectrum.

France

A4.11 In France there are currently four operators with the largest three having relatively similar spectrum holdings between ca. 25-30%, while the fourth operator -Free - now holds just over 15%:

Figure A4.4 Spectrum shares in France



²⁵⁷ Updated with 2016 market shares.

Source: Cullen international / ARCEP

Figure A4.5: Spectrum holdings in France – 2016 (MHz)²⁵⁸

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
Orange	20	20	40	39.2	40	0	159.2
SFR	20	20	40	39.6	30	0	149.6
Bouygues Telecom	20	19.6	40	29.6	30	0	139.2
Free Mobile	0	10	30	10	40	0	90

Source: Cullen international / ARCEP

- A4.12 Free, which launched its service in 2012, currently holds a total of 90 MHz of paired spectrum in the 900 MHz, 1800 MHz, 2.1 GHz and 2.6 GHz.
- A4.13 Current spectrum holdings include 2x15 MHz that it was assigned as a result of the refarming of the 1800 MHz band by Arcep.²⁵⁹ In this refarming process each of the other three operators relinquished 2x5 MHz of 1800 MHz spectrum, which was then awarded to Free, in exchange for authorisation to use this band for 4G services.²⁶⁰
- A4.14 Despite its significantly smaller spectrum share, Free has been very effective at increasing its subscriber base and has recently become the third operator by number of subscribers.

²⁵⁸ We have corrected an error in in the November 2016 consultation about SFR's spectrum holdings of 2.1 GHz paired spectrum.

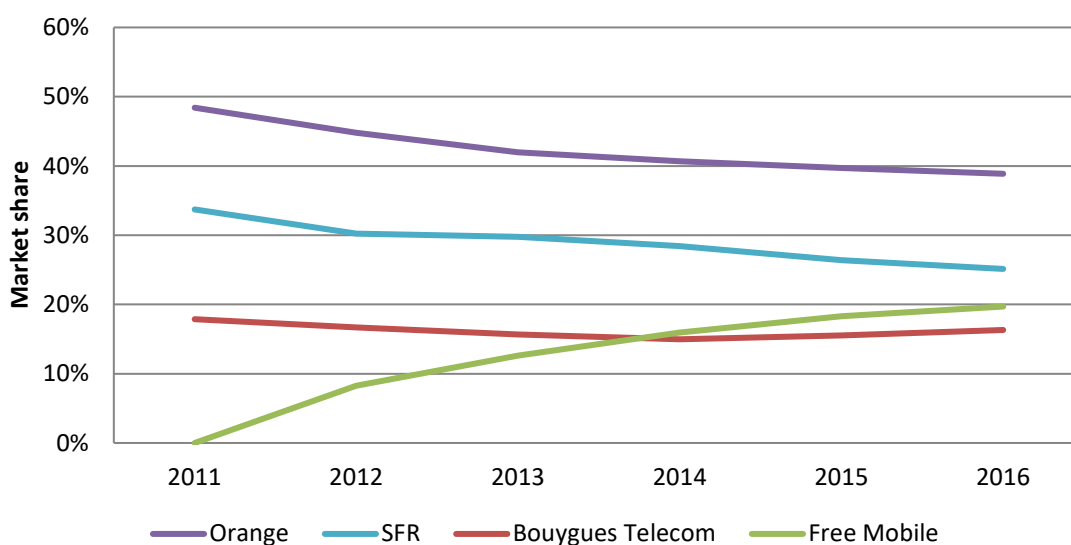
²⁵⁹ See

[http://www.arcep.fr/index.php?id=8571&tx_gsactualite_pi1\[uid\]=1771&tx_gsactualite_pi1\[annee\]=&tx_gsactualite_pi1\[theme\]=&tx_gsactualite_pi1\[motscle\]=&tx_gsactualite_pi1\[backID\]=26&cHash=c871b5f7f09a340df41c676b07559218&L=1](http://www.arcep.fr/index.php?id=8571&tx_gsactualite_pi1[uid]=1771&tx_gsactualite_pi1[annee]=&tx_gsactualite_pi1[theme]=&tx_gsactualite_pi1[motscle]=&tx_gsactualite_pi1[backID]=26&cHash=c871b5f7f09a340df41c676b07559218&L=1)

²⁶⁰

http://www.arcep.fr/index.php?id=8571&tx_gsactualite_pi1%Buid%5D=1766&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=9b7d91056645812f50705838413cb4f4&L=1

Figure A4.6: Subscriber market share in France²⁶¹



Source: Analysys Mason

- A4.15 Since its entry into the market Free has been consistently increasing its market share, even when it held just under 12% of the total spectrum share. For example, in 2014 it had almost 16% of the subscriber market share with 11.8% of the spectrum share.
- A4.16 It should be noted that Free currently has a national roaming agreement with France Telecom (FT) which was signed in 2012 and was expected to last until 2018. In 2013 the competition authority prevented this agreement from being extended beyond the original date.²⁶² In 2016 it was agreed that the roaming agreement will start to be phased out from January 2017, coming to a complete end by 2020. We do not have information on how much of Free's current traffic is carried over Orange's network but our understanding is that this agreement covered 2G and 3G services only.²⁶³
- A4.17 In our 2016 ICMR we compared the share of 4G data use as a proportion of total data use for 2015²⁶⁴. In the case of France, we found that 65% of the data traffic in 2015 was carried over 4G networks. By 2016 Free stated that it was covering 84.5% of the population with 3G services and 68.3% with 4G services. In the absence of specific evidence, Free's 4G coverage and the share of data traffic on 4G networks in France tend to suggest that most of Free's data traffic is carried over its own network (i.e. 4G traffic plus at least at least a share of 3G traffic).

²⁶¹ Updated with 2016 market shares.

²⁶² See http://www.autoritedelaconcurrence.fr/user/standard.php?id_rub=482&id_article=2061

²⁶³ See <http://inpublic.globenewswire.com/2016/06/15/+Iliad+Press+Release+Free+Mobile+and+Orange+have+signed+an+addendum+to+their+2G+3G+roaming+agreement+HUG2020936.html>

²⁶⁴ See figure 3.6, page 82 of 2016 ICMR

- A4.18 In 2015 France carried out the auction for 2x30 MHz of 700 MHz spectrum, which is expected to be cleared by mid-2019.²⁶⁵ In the auction 2x5 MHz were awarded to each of SFR and Bouygues while Orange and Free each won 2x10 MHz.²⁶⁶
- A4.19 For this auction ARCEP put in place a cap of 2x15 MHz for any operator in this band as well as a cap of 2x30MHz on sub 1 GHz spectrum holdings.²⁶⁷
- A4.20 If the awarded 700 MHz spectrum is considered, Free's spectrum share stands at 18.4%. However, deployment of the band only started in Q2 2016²⁶⁸. It should be noted that the band has only been cleared in some areas in France and full clearance is not expected to take place until mid-2019²⁶⁹

Italy

- A4.21 Before the 2016 merger between HI3G and Wind, which we discuss below, all four operators in Italy had relatively similar spectrum holdings after 2012, although HI3G's spectrum share was consistently the lowest.

²⁶⁵

http://www.arcep.fr/index.php?id=8571&no_cache=1&L=0&tx_gsactualite_pi1%5Buid%5D=1754&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=81da221e448ecb894f8a4f7b6fc5a742

²⁶⁶

[http://www.arcep.fr/index.php?id=8571&L=0&tx_gsactualite_pi1\[uid\]=1806&tx_gsactualite_pi1\[annee\]=&tx_gsactualite_pi1\[theme\]=&tx_gsactualite_pi1\[motscle\]=&tx_gsactualite_pi1\[backID\]=26&cHash=7e1d824a1659bb2e7723a117bffbff80](http://www.arcep.fr/index.php?id=8571&L=0&tx_gsactualite_pi1[uid]=1806&tx_gsactualite_pi1[annee]=&tx_gsactualite_pi1[theme]=&tx_gsactualite_pi1[motscle]=&tx_gsactualite_pi1[backID]=26&cHash=7e1d824a1659bb2e7723a117bffbff80)

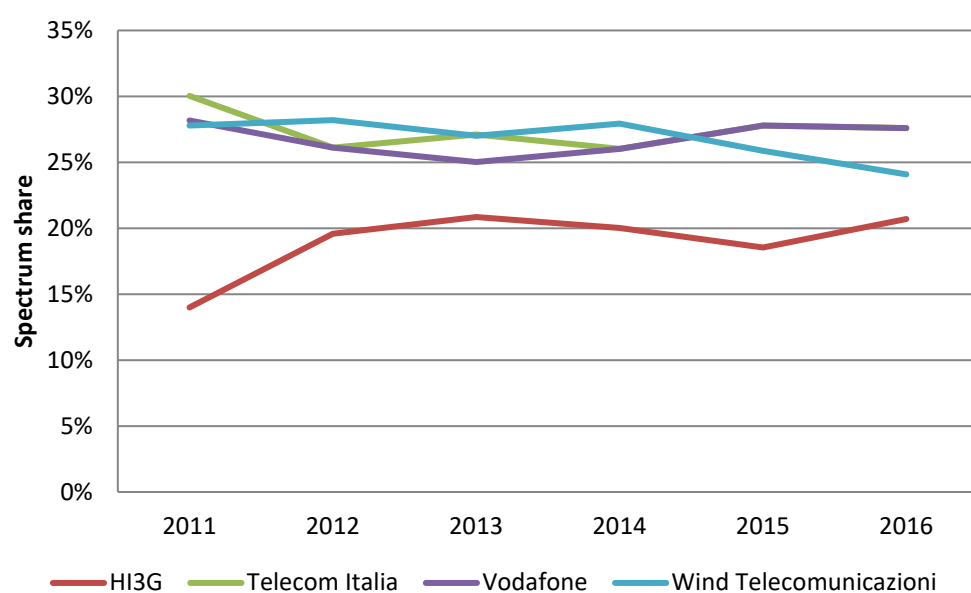
²⁶⁷

http://www.arcep.fr/index.php?id=8571&no_cache=1&L=0&tx_gsactualite_pi1%5Buid%5D=1754&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=81da221e448ecb894f8a4f7b6fc5a742

²⁶⁸ See <http://www.fiercewireless.com/europe/bouygues-free-first-to-win-permits-for-4g-sites-france-s-700-mhz-band>

²⁶⁹ See <http://www.anfr.fr/gestion-des-frequences-sites/bande-700-mhz/> for details on dates for clearance in each area

Figure A4.7: Spectrum shares in Italy²⁷⁰



Source: Cullen international

Figure A4.8: Spectrum holdings in Italy – 2016 (MHz)²⁷¹

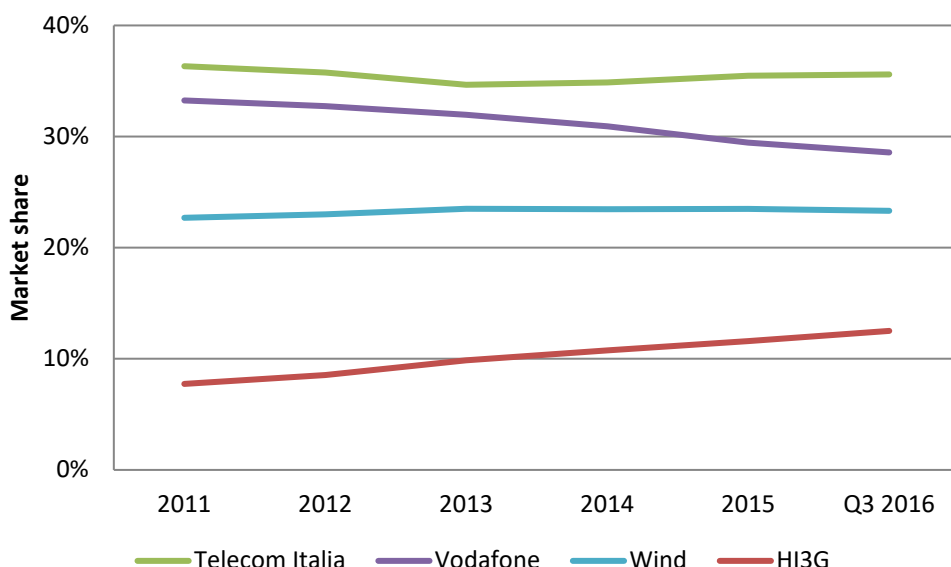
	800 MHz	900 MHz	1400 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
Telecom Italia	20	20	20	40	30	30	0	160
Vodafone	20	20	20	40	30	30	0	160
Wind	20	19.6	0	30	30	40	0	139.6
HI3G	0	10	0	30	30	20	30	120

Source: Cullen international

A4.22 Despite relatively stable and symmetric spectrum shares, there have been significant differences in subscriber market shares between the different operators.

²⁷⁰ Includes 1400 MHz

²⁷¹ Pre-merger

Figure A4.9: Subscriber market share in Italy²⁷²

Source: Analysys Mason

A4.23 For example, HI3G's spectrum share was relatively close to its competitors whilst its market share was growing but remained significantly below its spectrum share.²⁷³

A4.24 HI3G and Wind (Vimplecom) agreed to merge, pending approval from the European Commission (EC). The merger was notified on the 5th of February 2016²⁷⁴, with the Commission approving the merger on the 1st of September 2016.

A4.25 In order to address the EC's competition concerns the merging parties offered remedies aimed at allowing the creation of a new fourth MNO.²⁷⁵ These remedies included:

- Divestment by the merged entity of spectrum in different bands.
- An infrastructure sharing agreement with the new MNO giving it access to the base stations of the merged entity.
- A transitional national roaming agreement allowing the new MNO to use the merged entity's network to provide nation-wide 2G, 3G and 4G services while the new operator builds its own network.

A4.26 Before the agreement was cleared by the EC, the merging parties reached an agreement with Iliad of France (owners of the French MNO Free) to acquire the assets which constituted this proposed remedy.²⁷⁶ The agreement included the

²⁷² We only have market shares before the merger up to Q3 2016.

²⁷³ H3G has spectrum in the 900 MHz, 1800 MHz, 2.1 GHz, and 2.6 GHz (paired and unpaired) bands.

²⁷⁴ See http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=2_M_7758

²⁷⁵ http://europa.eu/rapid/press-release_IP-16-2932_en.htm

²⁷⁶ See http://www.iliad.fr/presse/2016/CP_050716_Eng_.pdf

See also slide 18 of http://www.iliad.fr/finances/2016/slideshow_S1_2016_310816.pdf

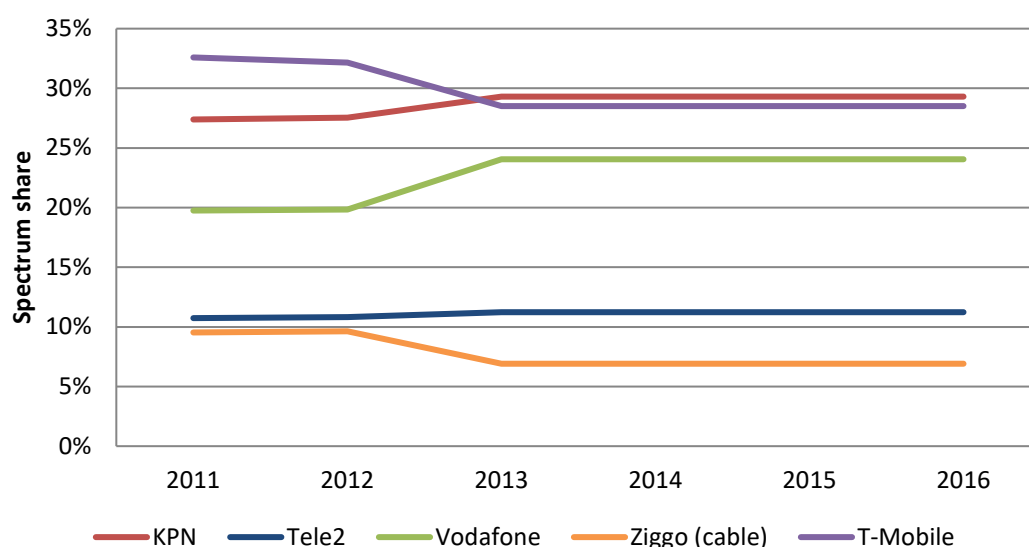
transfer of a total of 2x35 MHz of spectrum, comprising the 900 MHz (2x5 MHz), 1800 MHz (2x10 MHz), 2.1 GHz (2x10 MHz) and 2.6 GHz (2x10 MHz) bands.

A4.27 This agreement means that the merged entity will control ca. 35% of the useable spectrum once it divests the agreed spectrum into the new MNO. This new MNO will therefore begin operation with the equivalent of 12%²⁷⁷ of the total spectrum.

The Netherlands

A4.28 At present there are five companies in the Netherlands with mobile spectrum, including two which have only recently launched services (Tele2 and Ziggo).

Figure A4.10. Spectrum shares in the Netherlands



Source: Cullen international

Figure A4.11. Spectrum holdings in the Netherlands – 2016 (MHz)

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
KPN	20	20	40	39.6	20	30	169.6
Vodafone	20	20	40	39.2	20	0	139.2
T-Mobile	0	30	60	40	10	25	165
Tele2	20	0	0	0	40	5	65
Ziggo	0	0	0	0	40	0	40

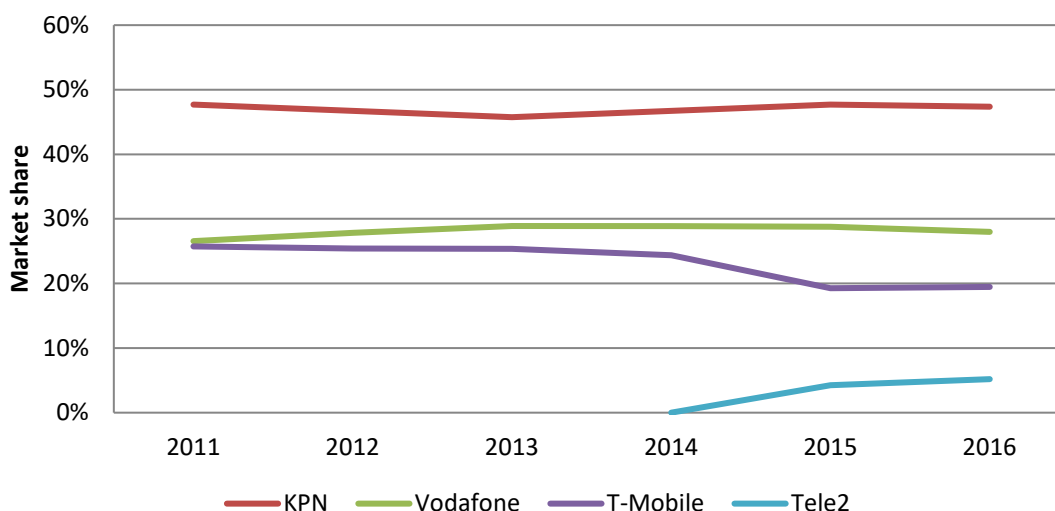
Source: Cullen international

A4.29 While Tele2 had been allocated spectrum in the 2.6 GHz band since 2011, with a further award in the 800 MHz band in 2013, it only launched its own 4G-based mobile service in November of 2015. Until then, it had been providing service as an MVNO using T-Mobile's network.

²⁷⁷ This takes into account the 40MHz of 1400 MHz spectrum held by Telecom Italia and Vodafone. Excluding the 1400 MHz spectrum, the spectrum share of the new MNO would be 13%.

- A4.30 In spite of now running its own network, Tele2 is reported to be continuing its MVNO agreement with T-Mobile for 2G and 3G services for at least five years, in addition to signing an infrastructure sharing agreement with them.²⁷⁸
- A4.31 On the other hand, Ziggo (Liberty Global), which had originally started to provide mobile services as an MVNO using Vodafone's network²⁷⁹, has now received approval to merge with Vodafone.²⁸⁰ Thus, the Dutch market will likely shrink to four mobile operators, with Vodafone effectively controlling just under 32% of the total spectrum in the country, including the 2x20 MHz of 2.6 GHz spectrum currently held by Ziggo.
- A4.32 At present Tele2 has 5.2% of the subscriber share.²⁸¹ However, as it has only recently made the transition from MVNO to MNO, it is too early to draw any conclusions on how its spectrum holdings affect its ability to compete in the market. We do not have information available on Ziggo's number of subscribers.

Figure 4.12. Subscriber market share in the Netherlands



Source: Analysys Mason

- A4.33 KPN has been able to maintain a market share close to 50% despite having relatively similar spectrum holdings to T-Mobile, which has only managed around 25%, with a significant decrease in subscriber share to below 20% between 2014 and 2016.

Slovenia

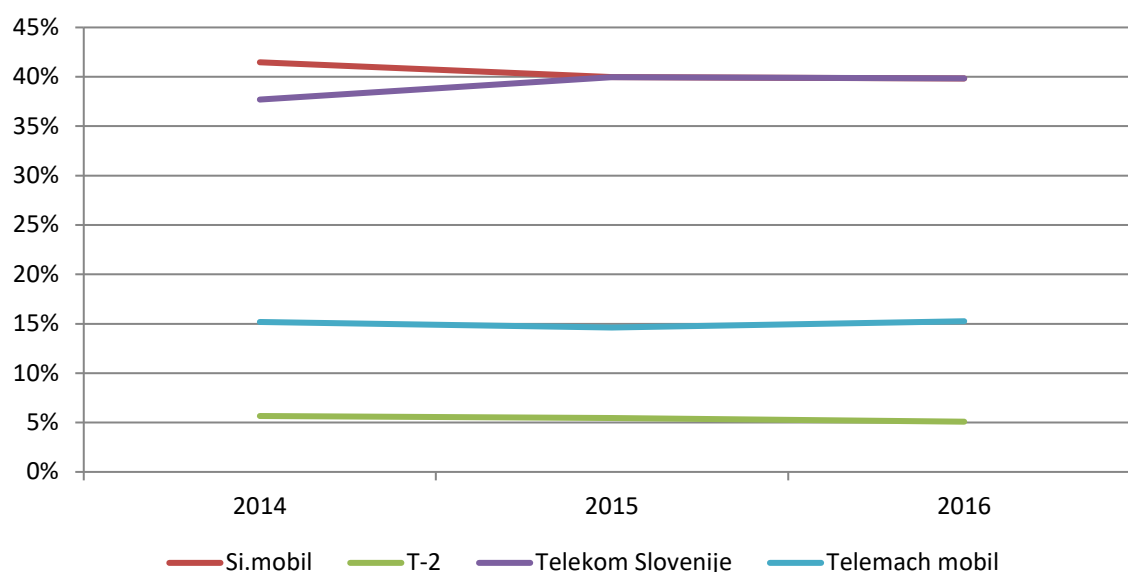
- A4.34 There are significant differences in the spectrum holdings in Slovenia with the two main operators holding around 40% of the total spectrum each, with the other two smaller operators sharing the remaining 20% as the chart below shows.

²⁷⁸ See <http://www.totaltele.com/view.aspx?ID=482816>

²⁷⁹ See <https://www.telegeography.com/products/commsupdate/articles/2013/09/18/ziggo-launches-voicedata-mvno-service/>

²⁸⁰ See http://europa.eu/rapid/press-release_IP-16-2711_en.htm

²⁸¹ We do not have subscriber market share data for Tele2 for years earlier than 2015, so have only shown the 2015 figure. In reality its subscriber growth may have been more gradual than is shown here as it probably includes the subscribers it already had as an MVNO.

Figure A4.13. Slovenian spectrum shares

Source: Cullen International

Figure A4.14: Spectrum holdings in Slovenia – 2016 (MHz)²⁸²

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
Si.mobil	20	30	60	30	70	25	235
T-2	0	0	0	30	0	0	30
Telekom Slovenije	20	30	50	40	70	25	235
Telemach mobil	20	10	40	20	0	0	90

Source: Cullen International

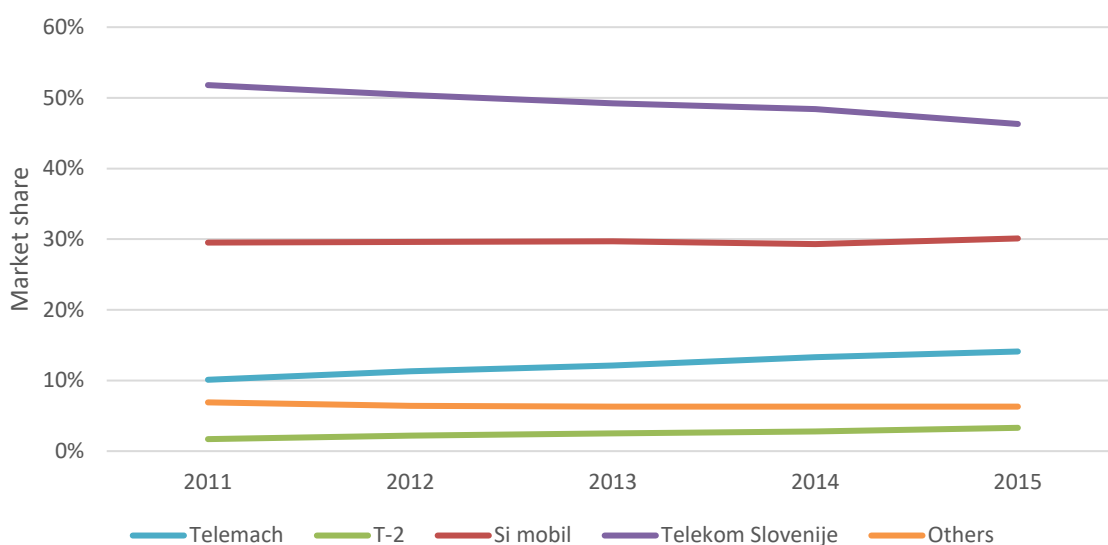
A4.35 Telekom Slovenije and Si.mobil have similar spectrum shares and materially different subscriber shares, while being the largest two operators by spectrum and subscribers. Telemach mobil's growing share of subscribers is now similar to its share of spectrum. T2, which is reported to have filed for bankruptcy²⁸³, only had ca. 3% share of the market and 5% share of spectrum.²⁸⁴

²⁸² We have adjusted spectrum holdings based on the latest report by Cullen. In late 2016 the Slovenian regulator auctioned some additional spectrum on the 1800 MHz and 2.1 GHz paired bands, which was won by Telemach. See

<https://www.telegeography.com/products/commsupdate/articles/2016/09/06/telemach-wins-new-wireless-spectrum/>

²⁸³ See <https://www.telegeography.com/products/commsupdate/articles/2016/03/08/slovenias-t-2-forced-back-into-bankruptcy/>

²⁸⁴ Source: <http://www.telekom.si/o-podjetju/Annual-Report-of-the-TSG-and-TS-for-2015.PDF>

Figure A4:15. Subscriber market share in Slovenia²⁸⁵

Source: Telekom Slovenije Group Annual Report 2015

- A4.36 In 2014 the Slovenian regulator carried out an auction for spectrum in the 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz (paired and unpaired) and 2.6 GHz (paired and unpaired) bands. For this auction it placed a number of caps on specific bands, namely a cap of 2x15 MHz for the 900 MHz band and 2x30 MHz for the 1800 MHz band. It also put in place more general caps of 2x30 MHz on sub 1 GHz spectrum and a cap on total spectrum of 2x105 MHz.²⁸⁶
- A4.37 In addition to these caps, it reserved 2x10 MHz out of the total 2x30 MHz of 800 MHz spectrum for operators with less than 15% of market share, effectively ruling out Si.mobil and Telekom Slovenije, both of whom won 2x10 MHz each of the unreserved spectrum. The reserved spectrum was won by Telemach (then Tusmobil), which was the only operator other than the two incumbents who participated in the auction. It also won 2x5 MHz of 900 MHz spectrum that was left over as both Si.mobil and Telekom Slovenije reached their cap in this band in addition to 2x10 MHz of 1800 MHz spectrum.²⁸⁷
- A4.38 The national regulatory authority, AKOS, explained why it had put in place competition measures as follows *“Because of the extreme asymmetry of operators in the Slovenian market agency had reserved up to two 2 x 5 MHz blocks of 800 MHz spectrum that only new entrants or existing operators with a market share of active end users of at most 15% could acquire. The goal was to maintain and develop effective competition in the markets for mobile electronic communication services.”*²⁸⁸

²⁸⁵ “Others” include Izi mobil and Debitel

²⁸⁶ See annex 8 of the “Annual licence fees for 900 MHz and 1800 MHz spectrum” statement by Ofcom at <https://www.ofcom.org.uk/consultations-and-statements/category-2/annual-licence-fees-further-consultation>

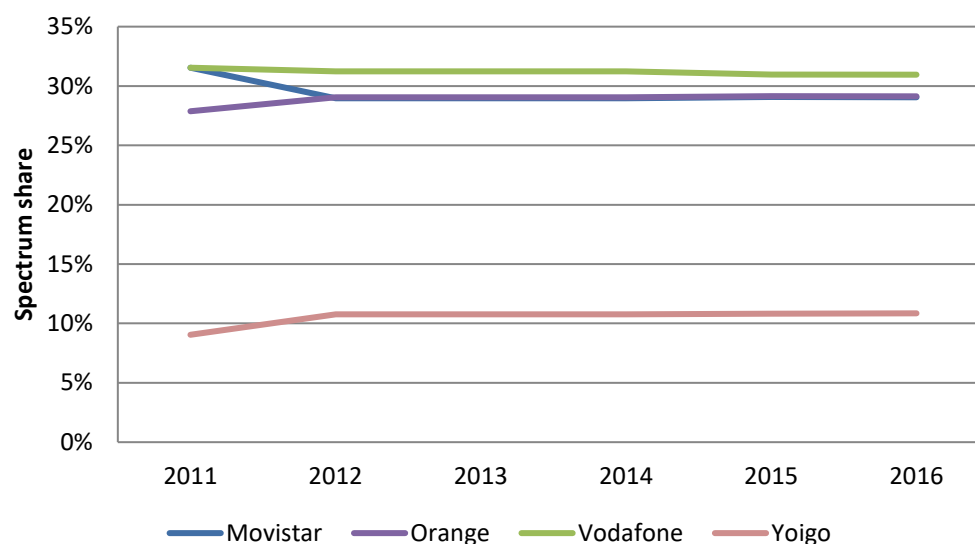
²⁸⁷ Si.mobil reached the 1800MHz cap

²⁸⁸ <http://www.akos-rs.si/public-tender-with-a-public-auction-for-assigning-radio-frequencies-for-the-provision-of-public-communication-services-successfully-concluded>

Spain

A4.39 In Spain there is a significant difference in spectrum distributions between the largest three operators, which each holds around 30% of the total spectrum, and the fourth operator (Yoigo), which holds just over 11%.

Figure A4.16. Spanish spectrum shares



Source: Cullen International

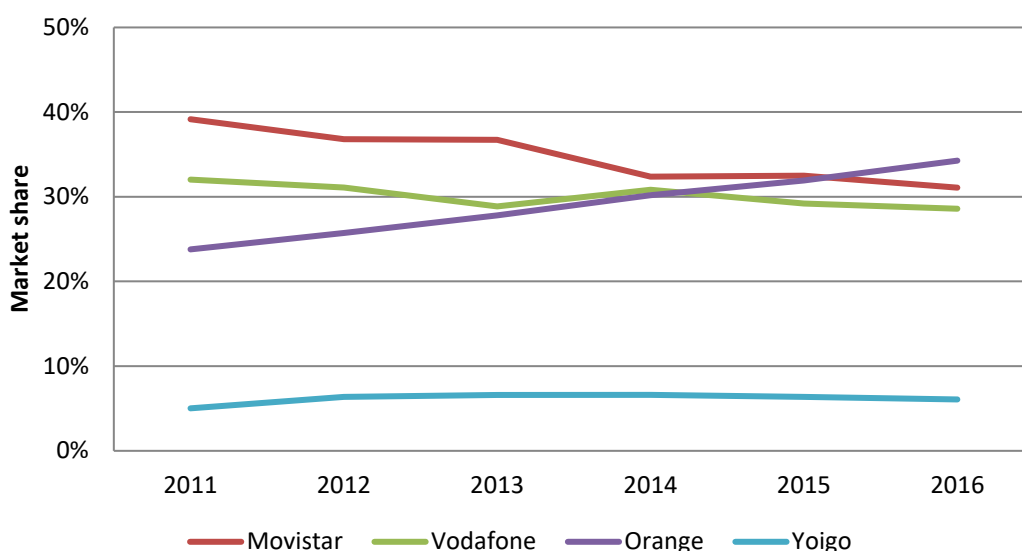
Figure A4.17. Spectrum holdings in Spain – 2016 (MHz)

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
Movistar	20	19.6	40	30	40	0	159.6
Vodafone	20	20	40	30	40	20	170
Orange	20	10	40	30	40	10	160
Yoigo	0	0	29.6	30	0	0	59.6

Source: Cullen international

A4.40 Although Yoigo is reported to have a 2G/3G roaming agreement with Movistar (part of Telefonica)²⁸⁹ in addition to its own spectrum holdings, it has failed to grow beyond ca. 6% market share since its launch. It is Orange which has been most effective at increasing its market share, achieving the largest subscriber share in 2016, above that of Movistar.

²⁸⁹ http://tecnologia.elpais.com/tecnologia/2008/03/11/actualidad/1205227683_850215.html

Figure A4.18. Subscriber market share in Spain²⁹⁰

Source: Analysys Mason

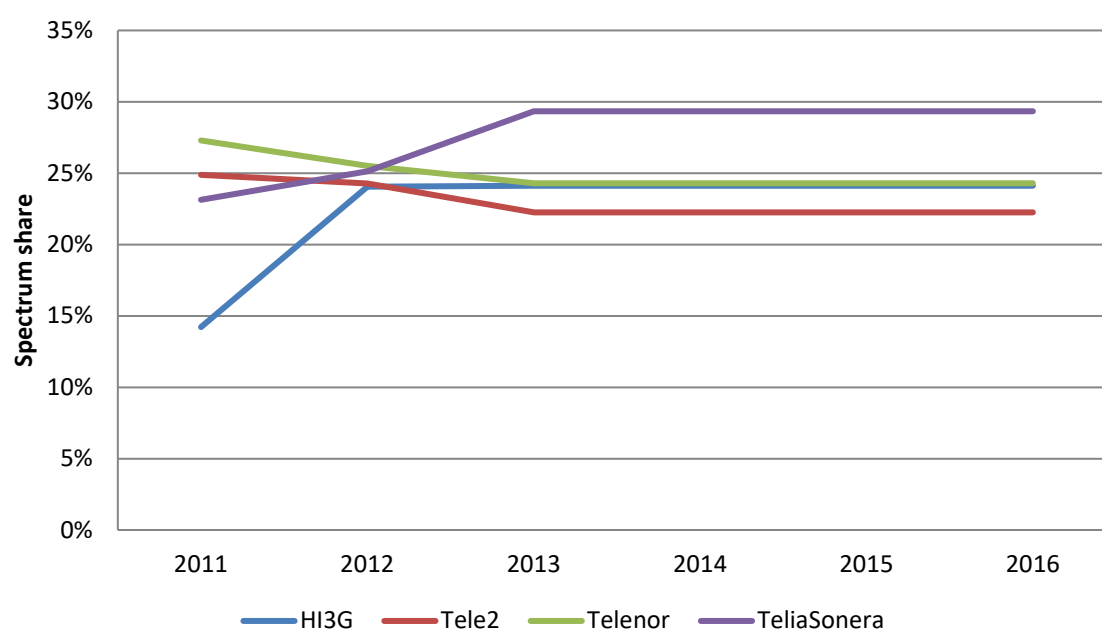
- A4.41 Yoigo has had the opportunity to acquire access to more spectrum. In 2011 Spain carried out a total of three spectrum awards. In the first award – a beauty contest - Yoigo was awarded 2x15 MHz of 1800 MHz spectrum. The second award of the year was an auction for spectrum in the 800 MHz, 900 MHz and 2.6 GHz (paired and unpaired) bands. Two caps were in place for this auction: 2x20 MHz cap on sub 1 GHz spectrum and a limit of 115 MHz on joint 1800 MHz, 2.1 GHz and 2.6 GHz spectrum.
- A4.42 Despite the caps in place, Yoigo was not awarded any spectrum in this auction. Furthermore, the caps meant that 2x5 MHz of 900 MHz spectrum remained unsold thereby requiring a third award process where the caps were raised and Telefónica acquired access to the 900 MHz that was left.
- A4.43 In 2016 Yoigo was sold by TeliaSonera and is now part of the Spanish telecommunications group MASMOVIL.

Sweden

- A4.44 In Sweden spectrum shares by the different operators are relatively even (22% to 29%) when taking into account the spectrum holdings of joint ventures.²⁹¹

²⁹⁰ Updated with 2016 data

²⁹¹ Telenor and Tele2 are part of the Net4Mobility joint venture, which holds around 30% of the total spectrum in the country. Furthermore, Svenska UMT-licens AB is a 50:50 joint venture between TeliaSonera and Tele2. While we do not have the detailed agreements of these joint ventures, we have assumed that each member has access to half of the spectrum of the JV. See <https://www.telenor.com/investors/company-facts/business-description/telenor-sweden/> and <http://www.tele2.com/media/press-releases/2002/tele2-abs-umts-joint-venture-in-sweden-is-fully-funded-on-signing-sek-11-billion-credit-facility/>

Figure A4.19. Spectrum shares in Sweden

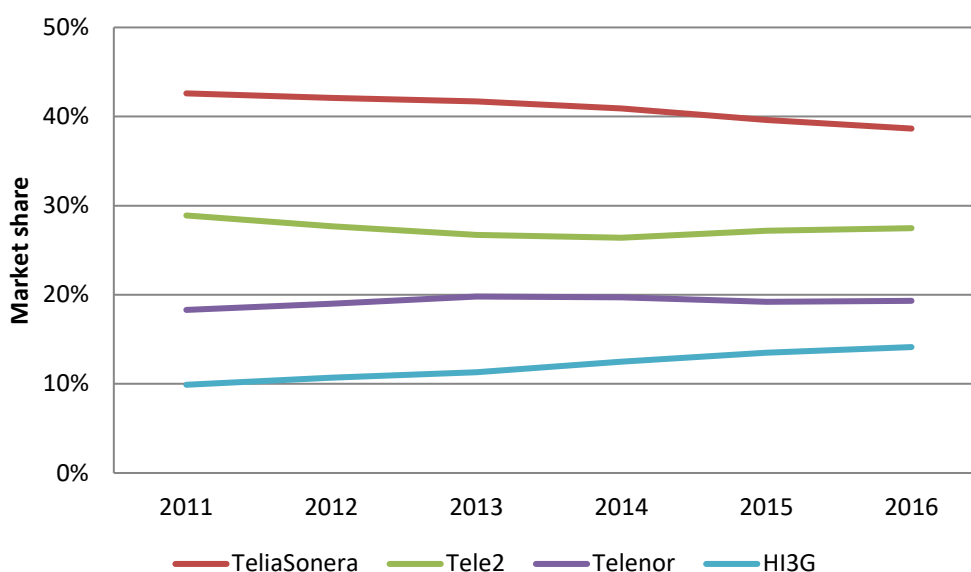
Source: Cullen International

Figure A4.20. Spectrum holdings in Sweden – 2016 (MHz)

	800 MHz	900 MHz	1800 MHz	2.1 GHz (Paired)	2.6 GHz (Paired)	2.6 GHz (Un-paired)	Total
TeliaSonera	20	20	70	19.8	40	0	169.8
Tele2	10	24	35	19.8	40	0	128.8
Telenor	10	16	35	39.6	40	0	140.6
HI3G	20	10	0	39.6	20	50	139.6

Source: Cullen international

A4.45 There is much more variation in subscriber shares than spectrum shares. For example, despite holding ca. 25% of the spectrum available, HI3G has the lowest subscriber market share in the country, albeit with a gradual upward trend.

Figure A4.21. Swedish subscriber market share²⁹²

Source: Analysys Mason

Summary of responses on the international comparison of spectrum holdings and Ofcom's response

A4.46 In its response H3G states that in eight of the ten countries that were used as reference by Ofcom in 2012²⁹³ MNOs have either ceased operations, merged, had a merger blocked or have not gained scale. In this section we focus on the comments relating to the countries discussed above, namely Italy, the Netherlands, Spain and Denmark. We discuss H3G's comments on Austria, Belgium and the USA in paragraph A8.88 of annex 8. In the subsequent section we set out our conclusion on the international comparison of spectrum holdings.

Denmark

A4.47 In its response H3G claims that in its Phase I submission to the EC Ofcom considered H3G Denmark to be a failed operator.

A4.48 This claim is incorrect. In our Phase I submission we argued that H3G Denmark was in a weaker position than H3G UK, but we did not conclude anything with regards to whether it was a viable operator or not.

France

A4.49 The NERA report, which is part of the O2 response, argues that while Free has established itself as a credible player, it has done so as a result of government policies relating to spectrum reservations and mandated roaming access to Orange's network. Thus, NERA argues that Free has never been spectrum constrained as it has always been able to shift traffic to competitors' networks. As evidence of this NERA mentions reports that 97% of calls by Free customers are carried by Orange's network and that Free has already warned 3G customers of a decrease in speeds as the roaming agreement ends. Furthermore, NERA notes that

²⁹² Updated with 2016 data

²⁹³ Belgium, Austria, Italy, the Netherlands, UK, USA, Spain and Denmark

Free has now raised its share of useable spectrum to 18.4% thanks to the spectrum caps and reservations that have been put in place.

- A4.50 H3G argues that, as a fixed line operator, Free does not rely principally on its mobile business. H3G also quotes an Enders Analysis report stating that consolidation talks have restarted in France.
- A4.51 For the relevance of the evidence in this annex to our assessment in this statement, the means of obtaining spectrum (e.g. through reservation) is less pertinent than whether the operator is credible with those holdings.
- A4.52 In our November 2016 consultation we had already highlighted the fact that Free has been able to roam on Orange's network. We also noted that this was a transitory agreement which is now expected to end by 2020.
- A4.53 We do not have information on the details of Free's roaming agreement with Orange and do not know the extent to which Free relies on this for capacity, rather than coverage. However, we understand that this agreement only covers 2G and 3G services. Therefore, as discussed in paragraph A4.17, the evidence available to us tends to suggest that most of Free's traffic is being carried over its own network.
- A4.54 According to Iliad's reports, its mobile business generated €2.04bn in revenues in FY 2016, compared to €2.7bn of its broadband business, with mobile revenues increasing by 12% year on year compared to 3.6% for broadband²⁹⁴. Furthermore, Iliad had nearly twice as many mobile subscribers than broadband subscribers as of December 2016²⁹⁵. Therefore, we disagree with H3G's view that Free does not rely principally on its mobile business as it currently represents almost 45% of its revenue base and two thirds of its subscriber base.
- A4.55 It is also worth bearing in mind that Free has increased its mobile market shares at the expense of other integrated fixed/mobile operators in France, including the national incumbent, France Telecom (Orange).

Italy

- A4.56 In its response H3G notes Italy as one of the countries where a merger has taken place.
- A4.57 H3G is correct to point out that Italy is one of the markets where there has been a merger between existing MNOs. However, it is important to note that as a result of the merger remedies a new fourth MNO will be created, which will have ca. 12% of the useable spectrum as well as access to infrastructure and a transitional roaming agreement with the merged parties (H3G and Wind). The EC considered that this remedy was sufficient to create a new MNO that would preserve effective competition in the Italian market.²⁹⁶

²⁹⁴ See page 25 of http://www.iliad.fr/finances/2017/Slideshow_2016_070317.pdf

²⁹⁵ 12.7 million mobile subscribers vs. 6.4 million broadband subscribers as per http://www.iliad.fr/finances/2017/Slideshow_2016_070317.pdf

²⁹⁶ "The Commission found that the proposed remedies address its concerns, because they ensure that a new mobile network operator, Iliad, will enter the Italian mobile market. This will preserve effective competition, maintain incentives to invest in innovative technologies, and ensure that consumers will continue to benefit from effective competition." See http://europa.eu/rapid/press-release_IP-16-2932_en.htm

The Netherlands

- A4.58 NERA argues that Tele2's entry into the Dutch market had been facilitated by government intervention and that its current modest market share means that it has no immediate need for more spectrum. Specifically, NERA argues that Tele2 benefited from the reservation of 4G spectrum and the site sharing and 2G/3G roaming agreement with T-Mobile.
- A4.59 H3G argues that Tele 2 started as an MVNO and only launched its own 4G service in 2015.
- A4.60 With regards to Ziggo NERA argues that it was never a credible MNO and it never attempted to roll out a nationwide network. NERA notes that Ziggo has now been bought by Vodafone.
- A4.61 Similarly to Free in France, we consider that the way in which Tele2 obtained its spectrum is less relevant than whether or not it is sufficient to be credible. Furthermore, site sharing is not a clear distinguishing feature from the UK where all four MNOs are involved in two network sharing arrangements.
- A4.62 We are aware that Tele2 has a 2G/3G transitional roaming agreement. We do not have evidence on how much it relies on it for capacity rather than coverage. We also recognise in paragraph A4.32 above that Tele2 has only recently made the transition from MVNO to MNO, and we comment that it is too early to draw any conclusions on how its spectrum holdings affect its ability to compete in the market.
- A4.63 Finally, in our November 2016 consultation we had already acknowledged that Ziggo would be merging with Vodafone, which would make the Netherlands a four-MNO market. Furthermore, in our consultation we had already argued that both Ziggo and T-2 in Slovenia might not be what we would regard as credible MNOs²⁹⁷.

Slovenia

- A4.64 The NERA report argues that T-2 is no longer considered a credible competitor, with only 3.2% of the market share despite having had a 3G licence for ten years. NERA notes the financial difficulties that T-2 has encountered, including falling into bankruptcy in March 2016. NERA argues that the small reservation put in place for the 4G auction was possibly because the regulator did not expect T-2 to participate, as turned out to be the case.
- A4.65 NERA also argues that the weak position of T-2 means that Slovenia should be considered a three-MNO country. NERA agrees that the third operator by scale, Telemach, is a credible player but notes that it has a clear path to acquire access to additional spectrum as it grows. NERA considers that Telemach's growth has been helped by spectrum reservations and that it has options to acquire access to spectrum in the 1800 MHz and 2.1 GHz bands. Thus, NERA argues that if Telemach were to exercise its options its spectrum would increase above 20%.
- A4.66 H3G argues that Slovenia was not included in the 2012 sample of countries by Ofcom. It also argues that T-2 had reportedly filed for bankruptcy and should not be considered as a credible MNO.

²⁹⁷ See footnote 30 of November 2016 consultation.

- A4.67 In our November 2016 consultation we had already acknowledged that T-2 had filed for bankruptcy and noted that its market share was 3% and spectrum share was 5% (i.e. significantly below the range of 10-15% of spectrum).
- A4.68 Despite the application for bankruptcy, it is our understanding that T-2 is still operational and is still offering mobile services. For our sample, we selected countries that had at least four operators. However, the fact that a country was included in our sample did not mean that all operators were necessarily considered to be credible.
- A4.69 NERA highlights that Telemach has options to acquire access to spectrum in the future, but this does not change the fact that, until now, it has been able to compete with spectrum shares of around 15%.

Spain

- A4.70 NERA highlights the history of financial troubles and delayed network launches by Yoigo. NERA notes that previous spectrum acquisitions by Yoigo were a result of beauty contests and that it failed to participate in the auction for 4G spectrum, despite a de facto spectrum reservation for it. NERA argues that despite having been purchased by the MASMOVIL group, it remains to be seen if it can improve its disappointing performance and that it is likely to require additional spectrum to do so.
- A4.71 H3G notes Spain as one of the countries where one of the MNOs (Yoigo) has not gained scale and is not considered credible.
- A4.72 In our November 2016 consultation we had already noted that Yoigo had struggled to obtain market share. We had mentioned that they could be an example of an operator with a spectrum share between 10-15% which was not credible but we argued that it was not clear whether their spectrum share had been an obstacle to them becoming credible.
- A4.73 The information provided in the responses further suggest that Yoigo has struggled to compete in the Spanish market. However, we still have not seen evidence which would indicate a clear causal link between Yoigo's inability to become credible and its spectrum share.

Sweden

- A4.74 We received no specific comments on Sweden.

Ofcom's conclusion on international comparison of spectrum holdings

- A4.75 In our November 2016 consultation, we had already considered some of the specific circumstances of the MNOs in the sample.
- A4.76 In the case of Yoigo in Spain and T-2 in Slovenia the evidence does not clearly suggest that their situation has come about because of their spectrum shares. Both MNOs effectively declined the opportunity to acquire access to spectrum that had been either reserved for them or not made available to larger MNOs.
- A4.77 Tele2 in the Netherlands is also not a good indicator as it has only recently made the transition into a full MNO, so it is too early to draw any conclusions on how its spectrum holdings affect its ability to compete in the market.

- A4.78 In Denmark and Sweden, no operator has a spectrum share in the 10-15% range.
- A4.79 Free in France is an example of an MNO that was successful with a spectrum share in the 10-15% range. However, its spectrum share is now above 15% and it is unclear how much it relied on the 2G/3G roaming agreement with France Telecom.
- A4.80 Telemach in Slovenia, with ca. 15% of the spectrum, seems to have made reasonable progress in a market with two large incumbents, both of which had ca. 40% of the spectrum and one that at one point had more than half of the subscribers.
- A4.81 In Italy, the merger remedies provided for the entry of a new fourth MNO, which will have ca. 12% of the useable spectrum (and access to infrastructure and a transitional roaming agreement with the merged parties).
- A4.82 Based on the evidence from other European countries described in this annex, in our view there is not enough evidence to reach a reliable conclusion either that a spectrum share of 10-15% is enough to enable an MNO to be credible or that it is insufficient.

International comparison of concentration and spectrum distribution

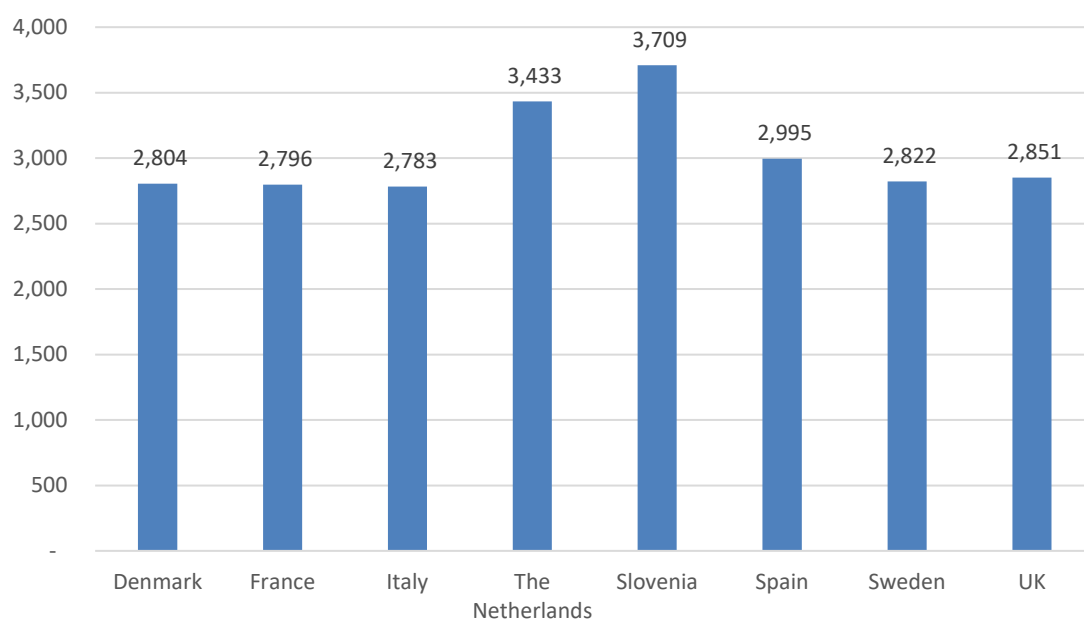
- A4.83 We have carried out an analysis to compare the concentration levels in terms of the market (i.e. subscribers) as well as spectrum for the different countries in our sample, including the UK.²⁹⁸ We have included spectrum holdings in the 800 MHz, 900 MHz, 1400 MHz²⁹⁹, 1800 MHz, 2.1 GHz, and 2.6 GHz paired and unpaired bands. We have not included 700 MHz spectrum as we understand that the only country in our sample where it is being deployed is France and can only be deployed in certain areas which have already been cleared, therefore there are restrictions to its deployment.
- A4.84 We first estimated the level of market concentration of the different countries using the Herfindahl-Hirschman Index (HHI).³⁰⁰ In our sample the highest levels of market concentration are in the Netherlands and Slovenia, both with HHIs above 3,400. The UK has concentration levels relatively similar to those of the rest of the sample, which has HHIs ranging from 2,783 for Italy to 2,995 for Spain.

²⁹⁸ For the UK wholesale market shares have been used, i.e. MNO's own subscribers and those of hosted MVNOs. 2016 subscriber numbers used for all countries except for Slovenia where only Q4 2015 figures are available and Italy where only Q3 2016 figures are available pre-merger.

²⁹⁹ Only Italy and the UK have operators with 1400 MHz spectrum in this sample.

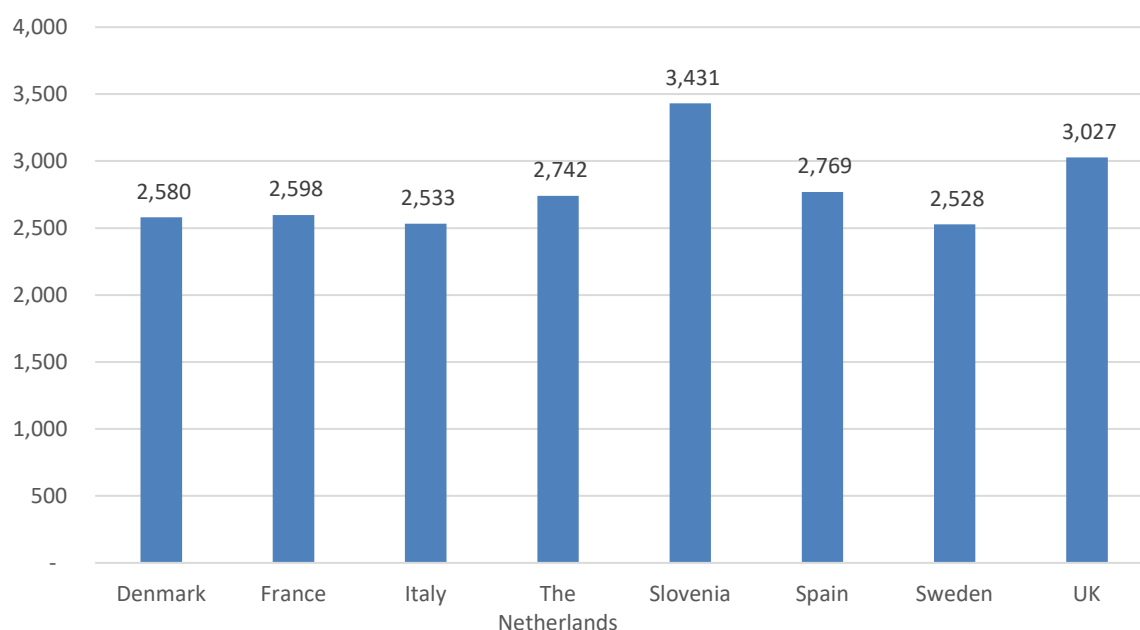
³⁰⁰ For an explanation of the HHI, see annex 1, paragraph A1.47.

Figure A4.22: Market HHI indices for different countries³⁰¹



A4.85 The same approach can be used to compare the levels of spectrum concentration between the different countries, i.e. using spectrum shares rather than subscriber shares. Using this measure, the highest levels of spectrum concentration are in Slovenia and the UK, with spectrum HHI indices of 3,431 and 3,027 respectively. Concentration levels of other countries are relatively similar between 2,528 and 2,769.

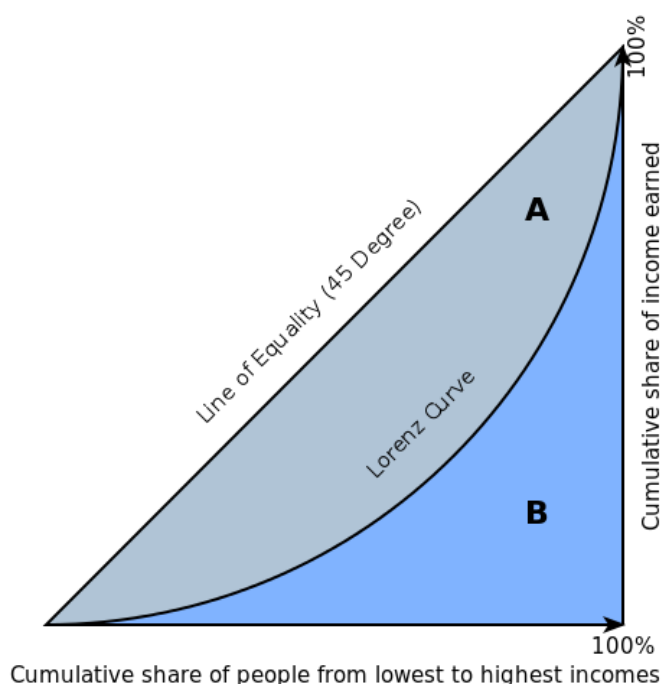
³⁰¹ HHIs estimated using own and hosted subscribers, i.e. excluding MVNO market share for which we do not have data for other countries. As a result, the HHI for the UK is larger than the one estimated in figure A1.9. as the shares of MVNOs have been excluded.

Figure A4.23: Spectrum HHI indices for different countries

A4.86 An alternative method to estimate potential asymmetry in the holdings of spectrum is to use the Gini coefficient. The Gini coefficient is generally used to estimate how unequally wealth or income are distributed throughout a country³⁰² by comparing actual distribution to a scenario where there is full equality. In the figure below the Gini coefficient corresponds to the ratio between the area A and the sum of A+B. The relative sizes of these areas depend on the Lorenz curve, which shows the cumulative percentage of total national income (or spectrum) plotted against the cumulative percentage of the corresponding population. The Gini coefficient therefore ranges between 0 when A=0 (i.e. full equality, where everyone has the same level of income) and 1 when B=0 (i.e. full inequality where one individual has all the income).

³⁰²See: <http://www.intmath.com/blog/mathematics/the-gini-coefficient-of-wealth-distribution-4187>

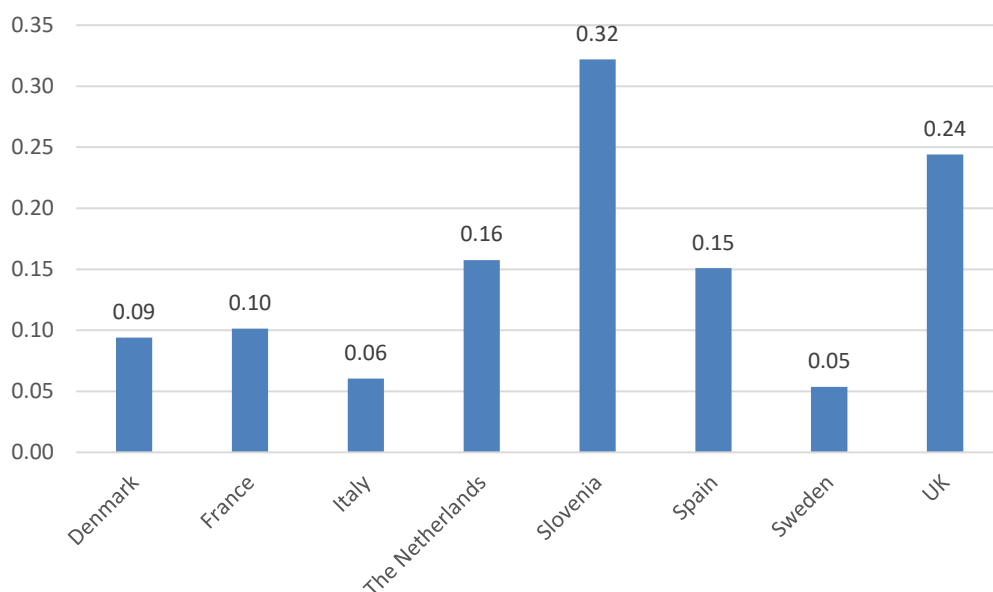
Figure A4.24: Gini coefficient calculation elements



Source: <https://commons.wikimedia.org/w/index.php?curid=7114030>

- A4.87 In the case of spectrum, we can estimate the Gini coefficient by assuming that in the Line of Equality (LOE) each operator has $1/n$ of the spectrum, where n is the number of MNOs in the country.³⁰³
- A4.88 Under this approach Slovenia and the UK have the highest levels of asymmetry in the spectrum distribution with Italy and Sweden having the lowest levels. Given that the Gini coefficient measures deviations from a scenario where there is equal distribution of wealth - or spectrum in this case - it is unsurprising that Italy and Sweden have the lowest coefficients as operators in these countries have ca. 25% of the total spectrum each.

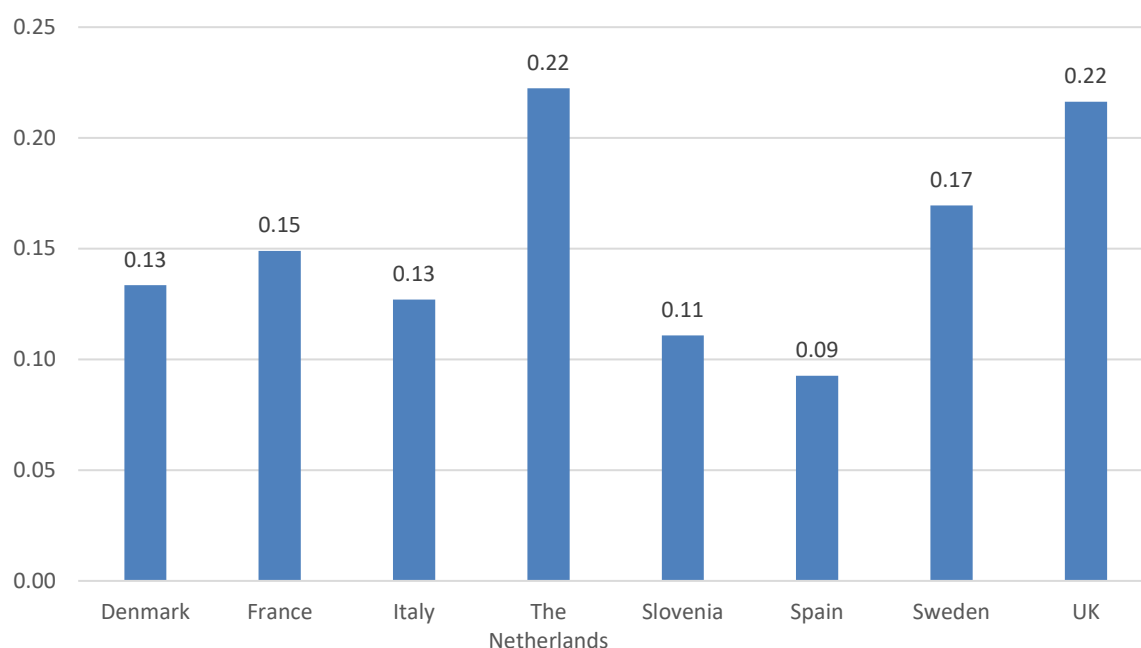
³⁰³ To build the Lorenz curve each MNO would be evenly spaced in the X-axis and the cumulative spectrum shares would give the coordinates in the Y-axis. The operators have to be arranged from the lowest to the highest spectrum share to derive the Y-axis coordinates so that the slope of the Lorenz curve is always increasing.

Figure A4.25. Gini coefficient with LOE where each MNO has 1/n of total spectrum

A4.89 However, the line of equality could be specified in different ways. For example, an alternate approach is to take into account subscriber shares for the estimation of the Gini coefficient, i.e. assuming that the line of equality is one where each subscriber has access to the same amount of spectrum, regardless of its MNO.³⁰⁴ In this case the Gini coefficient of both the UK and the Netherlands are the highest, but at a slightly lower level than that in figure A4.25 for the UK and closer to that of Sweden. Furthermore Slovenia, which had the highest Gini coefficient in figure A4.25, now has the second lowest coefficient.

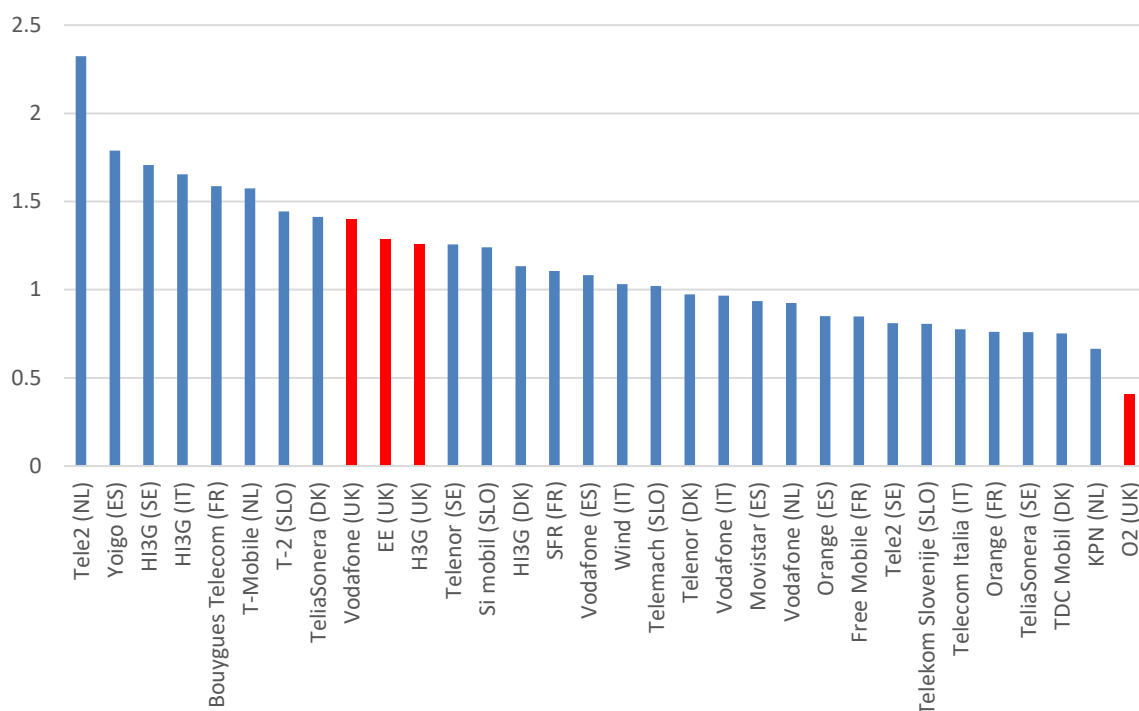
³⁰⁴ In this case the coordinates in the X axis would be given by the subscriber shares of each operator. The slope of each segment of the Lorenz curve would therefore be a function of the market share and spectrum share of each operator. As in the previous case, the operators have to be arranged in such a way as to have a strictly increasing slope in the Lorenz curve.

Figure A4.26. Gini coefficient with LOE where each subscriber has the same spectrum



- A4.90 The measure of spectrum inequality is therefore dependent on the way in which the LOE is specified.³⁰⁵ While the analysis presented here gives useful insight, it is important to bear in mind that the Gini coefficient measures deviations from a very specific scenario, which may not necessarily reflect an optimal outcome. Given our view in section 6 that operators do not need to have the same, or close to the same, shares of spectrum in order for there to be strong competition, a high Gini measured with respect to a benchmark of perfect spectrum symmetry is not necessarily an indication of a bad outcome.
- A4.91 There are other ways to analyse and compare the distribution of spectrum to subscribers. For example, for each of the operators in our sample, we have estimated the ratio of spectrum shares to subscriber shares. Much like our second Gini estimation, this ratio allows us to compare the spectrum distribution from a subscriber point of view.
- A4.92 In our sample of 32 operators across eight countries, O2 has the lowest spectrum to subscriber share ratio while Vodafone, H3G and EE are placed 9th, 10th and 11th respectively with relatively similar ratios.

³⁰⁵ For example, a third way to specify it is by using data traffic instead of subscribers, i.e. assume that full equality means that each MB carried has access to the same amount of spectrum, regardless of the MNO that carries it.

Figure A4.27. Spectrum share to subscriber share ratios for different European MNOs

A4.93 Much in the same way as different LOEs can be specified for the Gini analysis, it is possible to specify other ratios that assess spectrum distribution against different variables. For example, spectrum share to data traffic share potentially provides an estimate of actual spectrum usage. However, we do not have the data traffic by operator for other countries to carry out this calculation.

A4.94 But we have conducted this calculation for the UK – we show the relative ratios of data traffic to spectrum for the four UK MNOs in figures A1.58a and A1.58b (alongside their relative ratios of subscribers to spectrum). We note that the relative ratios of operators using this measure of traffic to spectrum share are materially different from the relative ratios for the UK MNOs using the measure of subscribers to spectrum, e.g. because H3G carries significantly more data traffic per MHz of spectrum than the three other MNOs. It is therefore possible that in an international comparison we could also see material differences in the relative ratios, depending on the measure being used.

Summary of responses on spectrum concentration

- A4.95 Both H3G and O2 presented an expanded sample of spectrum shares in different countries.
- A4.96 H3G carried out a comparison of spectrum distribution across 95 different markets including national licences between 700 MHz and 2.6 GHz but excluding unpaired 2.1 GHz. NERA's report, part of O2's response, first compares the spectrum holdings of 90 MNOs across 27 European countries and then 320 operators across 100 countries.
- A4.97 H3G uses the expanded sample of countries to carry out a Gini coefficient analysis to compare the levels of spectrum imbalances across different countries. H3G finds that among the 50 top economies in the world the UK has the 48th highest Gini coefficient (only lower than Thailand and Malaysia), while also having the highest

Gini coefficient among G20 countries and the 19th among the 20 countries in Western Europe, only lower than Iceland.

- A4.98 In its response H3G also presents its own analysis in which it calculates the ratio of spectrum share to data traffic share for the sample of MNOs used by Ofcom in 2012. In its analysis Vodafone, BT/EE, O2 and H3G occupy the 3rd, 12th, 30th and last places respectively out of a sample of 44 MNOs.³⁰⁶
- A4.99 In its report NERA first shows that BT/EE have the second highest absolute spectrum holdings in Europe after Telia in Estonia, while H3G and O2 have the 4th and 6th lowest and Vodafone is roughly in the middle of the sample.
- A4.100 NERA then ranks the MNOs in this sample by the number of 20 MHz and 10 MHz FDD downlink or TDD carriers that can be deployed with current spectrum holdings. NERA finds that O2 is one of only six MNOs unable to deploy 20 MHz carriers while H3G could deploy one, Vodafone three and BT/EE could deploy five. O2 is one of only two MNOs that could only deploy two 10 MHz carriers, H3G could deploy four, Vodafone eight and BT/EE could deploy 11.
- A4.101 NERA also assesses the spectrum concentration levels (HHI) in 26 four player markets. It finds that the UK's concentration levels are the third highest in the sample, below Slovenia and Slovakia. However, NERA categorises Slovenia and Slovakia as a market where the fourth player is not established.
- A4.102 NERA states that current spectrum holdings already represent “extreme asymmetry” and that only 18 of the 320 mobile operators across the world have less than O2's current holdings of immediately useable spectrum (15%). The report states such asymmetry “should raise concerns regarding...sustainable four-player competition in the UK market”³⁰⁷ and if allowed to continue, “could have damaging repercussions for consumers and the economy”.³⁰⁸
- A4.103 Finally, NERA estimates the ratio of spectrum share to subscriber share for 320 worldwide MNOs. It finds that BT/EE is ranked 55, despite operating in a four MNO market, Vodafone ranks 83rd, H3G is near the average while O2 ranks last.

Ofcom's response

- A4.104 The expanded analysis that both H3G and O2 provided is consistent with the analysis we had already presented in the November 2016 consultation and updated above. The results are also similar, i.e. that the current spectrum asymmetry in the UK is generally materially larger than in other comparable countries, albeit both H3G and NERA have provided an increased sample of countries beyond those that we assessed in our consultation.

³⁰⁶ Figure 5, page 21

³⁰⁷ Pages 6-7, NERA report

³⁰⁸ Page 28, NERA report

Annex 5

Current network performance

- A5.1 This annex summarises information comparing the current network performance of the four MNOs. Most of the network performance indicators show that all the mobile operators provide a similar quality of service and all have improved since the November 2016 consultation.
- A5.2 We discuss in detail the position of O2 and we have now seen additional evidence suggesting that 3< [REDACTED] , its network continues to perform well across the UK and provides a quality of service similar to the other network operators.
- A5.3 H3G has also provided evidence about SD and HD video download success rates by users on its network to support its claim that 3< [REDACTED] , in the context of a wider set of metrics we observe that H3G's network continues to provide a good service across the UK.

Summary of our position in November 2016 consultation

Performance and quality of UK mobile networks

- A5.4 In our 2016 consultation, we said that network performance is one of the factors that a consumer is likely to consider when choosing a mobile phone service. Other factors include price, customer service, handset choice and contract terms.
- A5.5 When considering what network performance metrics matter the most to consumers, we quoted analysis by Enders which showed that consumers value network reliability and coverage the most. Data speeds were the third most important aspect currently, but were growing in importance. We noted that price is the most important factor for most consumers, closely followed by network performance. Network performance metrics however include coverage, data speeds and many other factors which give a quantifiable impression of the overall quality of a network.

Performance metrics

- A5.6 A number of regular studies assess the performance of UK mobile networks with specific focus on mobile broadband and smartphone performance. These include: Ofcom's Smartphone Cities study;³⁰⁹ Rootmetrics biannual report;³¹⁰ and Ookla speed tests.³¹¹ UK MNOs also rely on consumer surveys to understand how the services offered on their networks are perceived by consumers. The YouGov survey SMIX (Smartphone, Mobile Internet eXperience) is one such example.³¹²
- A5.7 We observed that all performance tests consistently show EE achieving the highest average data download speeds. In general, however, there is not a predetermined

³⁰⁹ "Smartphone Cities", Ofcom, <https://www.ofcom.org.uk/research-and-data/telecoms-research/mobile-smartphones/smartphone-cities>

³¹⁰ Rootmetrics, "Mobile Network Performance in the UK: A Special Report" <http://www.rootmetrics.com/en-GB/home>

³¹¹ <http://www.speedtest.net/awards/gb/carrier/2015>

³¹² <https://reports.yougov.com/services/smixon/>

download speed below which customers experience a poor service. Typically, it depends on the type of service they are requesting from the network and the bitrate the network can supply to support that service. There may be certain download speeds below which customers perceive that the service is not acceptable, and certain download speeds above which the service is perceived as good. We discuss this in greater detail in annex 2.

- A5.8 We were careful to highlight that measuring network performance is not a straightforward exercise and, as recognised by those performing such tests, each methodology is likely to have limitations. However, results can provide an indication of the likely customers' experience on mobile networks.

Performance Metric Update

- A5.9 In this section, we start by summarising the performance metrics we referenced in our November 2016 consultation and any more recent updates available from these sources. We go on to discuss the changes in greater detail.

<i>Previously reported</i>	<i>What's changed?</i>
<i>Ofcom Smartphone Cities 2015</i> ³¹³	<i>Ofcom Smartphone Cities 2016</i> ³¹⁴
Scorecard	All mobile networks have improved, particularly when serving low data rate applications like web browsing.
4G download speeds	All networks have improved, and have reduced the number of connections where the data speed is 2 Mbps or less.
Average 4G download speed, by city and MNO	All networks have increased their average data speeds across the UK, apart from in London where O2 has been able to increase its uplink speeds, but not its downlink speeds.
<i>Ofcom Connected Nations Report 2015</i> ³¹⁵	<i>Ofcom Connected Nations Report 2016</i> ³¹⁶
UK coverage for mobile voice services	All operators have improved marginally, further improvement anticipated as the end of 2017 deadline for 90% geographic coverage approaches.
UK coverage for mobile data services	Significant improvements as operators progress their 4G rollouts.

³¹³ "Smartphone cities", Ofcom, March 2016,

http://stakeholders.ofcom.org.uk/binaries/research/broadband-research/smartphone-cities/smartphone_cities.pdf

³¹⁴ https://www.ofcom.org.uk/_data/assets/pdf_file/0009/101430/Smartphone-Cities-phase-4-reissued-270416.pdf

³¹⁵ https://www.ofcom.org.uk/_data/assets/pdf_file/0028/69634/connected_nations2015.pdf?lang=rsn_dbigovjfdsv

³¹⁶ https://www.ofcom.org.uk/_data/assets/pdf_file/0035/95876/CN-Report-2016.pdf

<i>Rootmetrics September 2016</i> ³¹⁷	<i>Rootmetrics February 2017</i> ³¹⁸
Network rankings	All operators have improved and Rootmetrics suggested that O2 and H3G could improve their scores further through better 4G coverage.
<i>OpenSignal April 2016</i> ³¹⁹	<i>OpenSignal April 2017</i> ³²⁰
4G download speeds	Greater 4G coverage is increasing network speeds for all operators.
<i>Ookla Speedtest Awards 2015</i> ³²¹	<i>Ookla Speedtest Market Report Nov 2016</i> ³²²
UK speedtests	New results reflected a general improvement in mobile data speeds across all operators.
<i>We did not report previously on P3</i>	<i>P3 Mobile Network Test in the UK Report 2016</i> ³²³
UK drive and walk testing	P3 puts both EE and Vodafone in joint lead overall with EE performing slightly better for data and Vodafone performing slightly better for voice.
<i>Ofcom Communications Market Report 2016</i>	No new report at the time of writing
<i>Twinprime</i>	No new report at the time of writing

In our Smartphone Cities report, we observed that all mobile networks had improved, particularly when serving low data rate applications like web browsing

- A5.10 In the November 2016 consultation, we quoted our 2015 Smartphone Cities data. At that time we observed that EE had the fastest 4G network and slightly better web browsing performance than the other operators.
- A5.11 Since then, we have published our 2016 Smartphone Cities data which we have reproduced below alongside the 2015 data in Figure A5.1 to Figure A5.4. EE has consistently increased speeds in all three cities and leads by quite some margin, although Vodafone has closed the gap in London and H3G has closed the gap in Cardiff. O2 has raised data speeds from a low baseline in Cardiff, but they remain relatively low in London. We see that all networks have improved their average 4G data speeds with EE remaining in the lead, Vodafone and H3G joint second and O2 in fourth place. Within these results there are some regional variations, for example,

³¹⁷ <http://www.rootmetrics.com/en-GB/content/mobile-network-performance-in-the-uk>

³¹⁸ <http://www.rootmetrics.com/en-GB/content/mobile-performance-in-the-uk-part-1-performance-across-the-entire-uk>

³¹⁹ <https://opensignal.com/reports/2016/03/uk/state-of-the-mobile-network>

³²⁰ <https://opensignal.com/reports/2017/04/uk/state-of-the-mobile-network>

³²¹ <http://www.speedtest.net/awards/gb/2015>

³²² <http://www.speedtest.net/reports/united-kingdom/>

³²³ <https://www.p3-group.com/en/wp-content/uploads/2016/11/Report-UK-2016.pdf>

H3G is faster than Vodafone in Cardiff and Edinburgh but the position switched in London where Vodafone is faster than H3G.

- A5.12 We particularly notice that network performance has improved for low data rate applications such as web browsing with reduced loading times and a very low failure rate across all operators. The percentage of connections that would support 2 Mbps or more increased for all operators, with 90% for O2 and over 99% for EE.

Figure A5.1: Smartphone Cities 2015 and 2016 – Scorecard

		O2		Vodafone		BT/EE		H3G	
		2015	2016	2015	2016	2015	2016	2015	2016
<i>Loading the BBC Homepage</i>									
Average Load Time	seconds	6	5	6	4	5	4	6	4
Successful Loading	%	89	97	91	98	98	99	95	98
<i>Loading Amazon Homepage</i>									
Average Load Time	seconds	-	2	-	2	-	2	-	2
Successful Loading	%	-	98	-	98	-	99	-	98
<i>Loading Youtube Homepage</i>									
Average Load Time	seconds	-	1	-	1	-	1	-	1
Successful Loading	%	-	99	-	99	-	100	-	99
<i>Voice Calling</i>									
Success Rate	%	98	97	98	99	99	98	98	99

Figure A5.2: Smartphone Cities 2015 and 2016 – 4G download speeds [% of test samples]

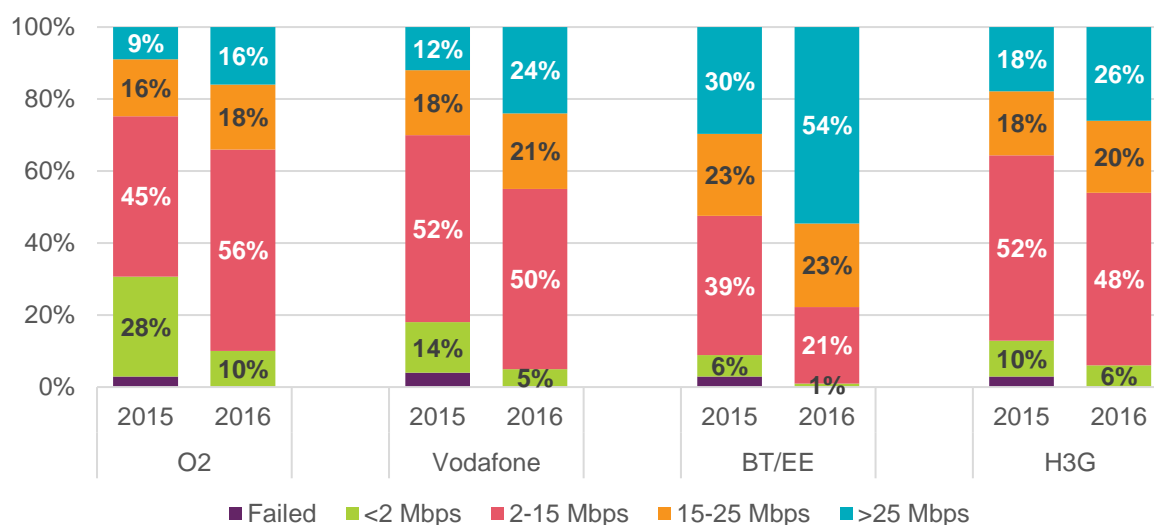


Figure A5.3: UK-wide 4G upload and download speeds for each MNO: 2015 vs. 2016

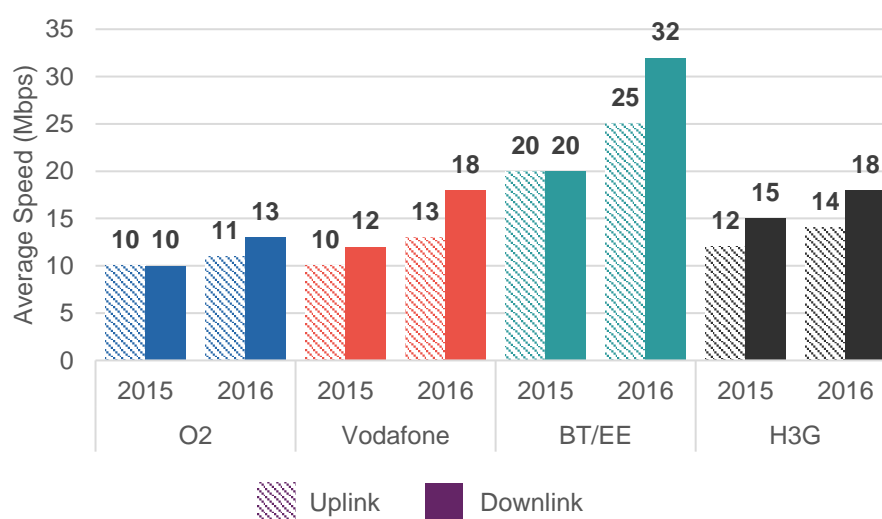
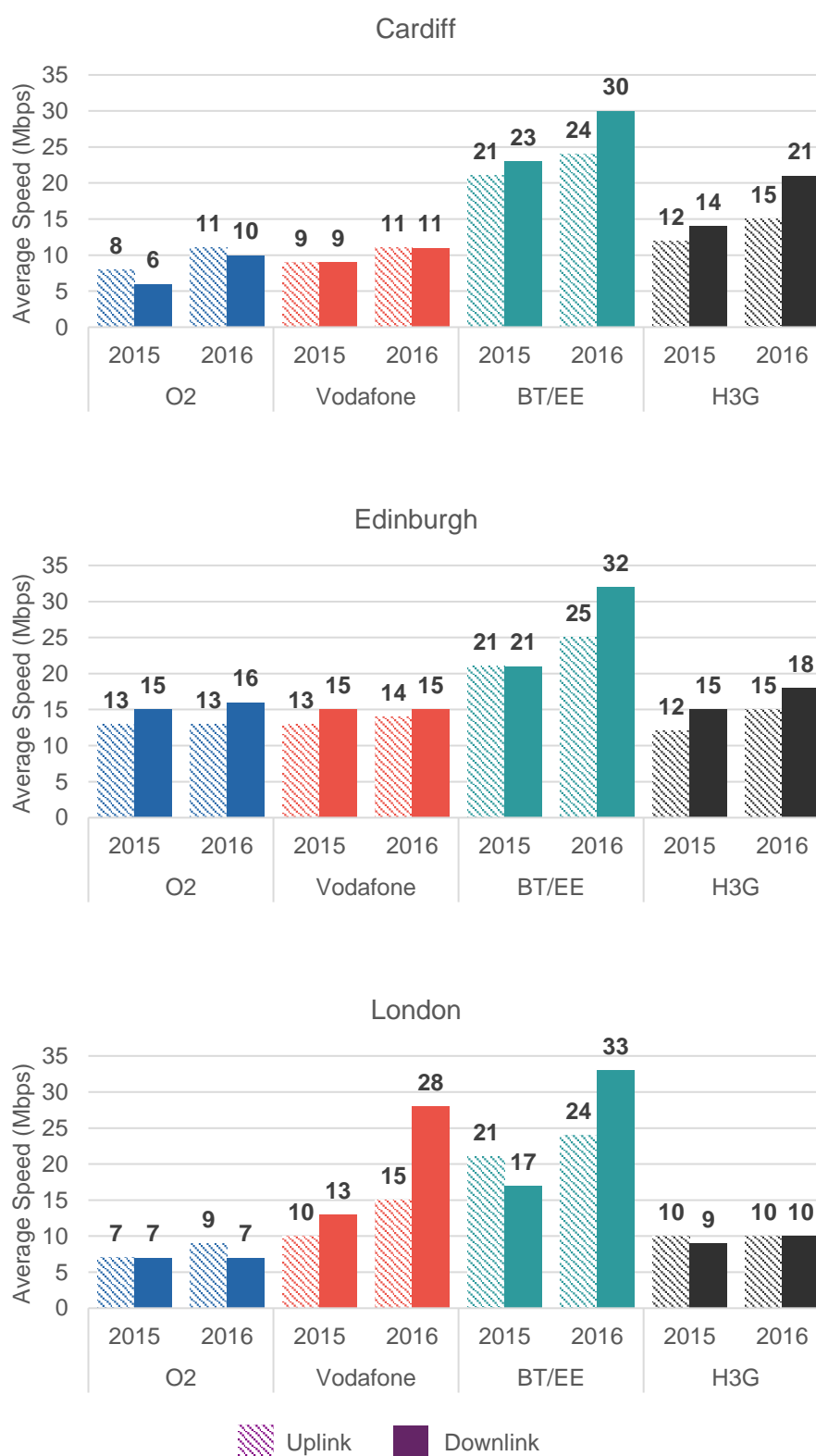


Figure A5.4: 4G upload and download speed, by city and MNO: 2015 vs. 2016



Source: Ofcom Smartphone Cities 2015 and 2016 reports.

Fieldwork November and December 2015 and July to October 2016.

Our Connected Nations data shows that voice and data coverage has improved for all mobile operators

- A5.13 In the November 2016 consultation, we quoted our Connected Nations 2015 data, observing that EE had the highest overall coverage of both data and voice. We published our Connected Nations Report 2016 in December of 2016 and compare the data and voice coverage results in Figure A5.5 and Figure A5.6.
- A5.14 Both voice and data coverage have increased between 2015 and 2016 for all MNOs. Further improvements in voice and data coverage are likely as operators complete their 4G rollouts and approach the deadline in their license obligation to provide 90% geographic voice coverage by end of 2017.
- A5.15 O2 and Vodafone provide voice services primarily using their 2G and 3G networks. EE and H3G recently upgraded their 4G networks to support voice services which accounts for some of their improvement in coverage between 2015 and 2016. H3G has no 2G network.

Figure A5.5: UK coverage for mobile voice services, based on combined 2G and 3G coverage³²⁴

[Percentage coverage]

%	O2		Vodafone		BT/EE		H3G	
	2015	2016	2015	2016	2015	2016	2015	2016
Indoor, premises	93	96	92	95	94	96	93	95
Outdoor, geographic landmass	72	78	77	82	78	80	68	76
Outdoor, premises	98	99	98	99	99	99	98	99

Figure A5.6: UK coverage for mobile data services, based on combined 3G and 4G coverage³²⁵

[Percentage coverage]

%	O2		Vodafone		BT/EE		H3G	
	2015	2016	2015	2016	2015	2016	2015	2016
Indoor, Premises [a]	86	92	83	92	94	95	93	87
Outdoor, geographic landmass	47	63	49	66	75	76	68	70
Outdoor, premises	92	96	92	97	98	99	98	97

[a] Note that the assumptions around coverage thresholds changed between 2015 and 2016 which is why H3G's indoor coverage has reduced

³²⁴ Reproduced from Figure 20 of Ofcom's Connected Nations 2015 report and Figure 18 of Ofcom's Connected Nations 2016 report.

³²⁵ Reproduced from Figure 21 of Ofcom's Connected Nations 2015 report and Figure 19 of Ofcom's Connected Nations 2016 report.

Rootmetrics observed that all MNOs had improved since their previous drive test measurements and suggested that O2 and H3G could improve their scores further through better 4G coverage

A5.16 The latest Rootmetrics research published on 15 February 2017 covers the second half of 2016 and rates MNOs across 6 performance categories: overall performance, reliability, speed, data, call and text performance. The test looks at performance across the breadth of the UK, in each of the four nations, and within the 16 most populous metro areas. We reproduce Rootmetrics' scores for the second half of 2016 in Figure A5.7 below alongside the scores it gave each MNO for the first half of 2016.

A5.17 Rootmetrics observed that:

- **BT/EE** came top in all the test categories. Rootmetrics also noted that EE had come top in the overall rankings since the Rootmetrics UK-wide testing began in the second half of 2013.
- **O2** had similar results to those measured in the second half of 2015 and the first half of 2016. O2's network speed ranking slipped from third to fourth between the first and second halves of 2016, but this was because H3G's network had improved rather than any decline in O2's network performance and O2 and H3G continue to offer similar data speeds. Rootmetrics believed that O2 might most effectively improve its ranking by expanding its 4G services beyond metropolitan areas.
- **H3G** took second place overall and was close behind EE in many categories, although it remained in third behind Vodafone for network speeds. Similar to O2, Rootmetrics believed that H3G could improve its scores by improving coverage UK-wide.
- **Vodafone** came second or third in most categories and held onto second place for data speeds. Rootmetrics noted that Vodafone had invested heavily in its 4G rollout and that it expected Vodafone's future results to improve significantly.

Figure A5.7: Rootmetrics rankings in the first and second half of 2016

%	O2		Vodafone		BT/EE		H3G	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
	half	half	half	half	half	half	half	half
	2016	2016	2016	2016	2016	2016	2016	2016
Overall	77.7	81.5	81.3	86.2	92.1	93.1	85.3	89.2
Reliability	78.1	82.7	82.0	87.1	93.5	94.5	90.0	92.8
Speed	76.9	78.2	79.4	83.1	89.9	90.7	74.8	81.1
Data	77.8	81.3	80.9	85.2	93.5	94.5	87.2	90.5
Call	76.0	80.1	80.4	86.7	89.7	90.9	81.7	86.9
Text	90.6	95.1	93.1	94.6	96.3	97.1	92.3	93.9

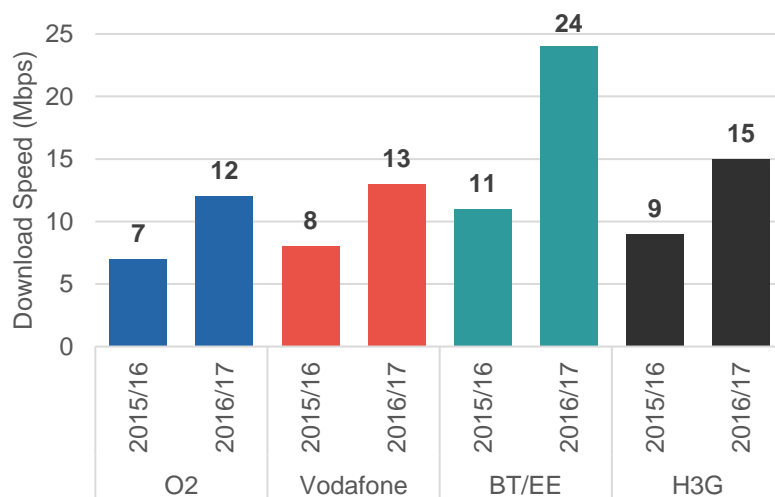
Source: Rootmetrics

OpenSignal shows EE in the lead, but greater 4G coverage is increasing network speeds for all operators

A5.18 OpenSignal collects data from its app installed on consumer smartphones under conditions of normal usage. It is not possible to tell whether the phone is being used indoors or outdoors, but results reflect overall use in the places smartphones tend to be used. The OpenSignal dataset is also the most recent out of those we have reviewed, covering December 2016 to February 2017. Measurements will not be as well controlled as formal drive testing but a much greater set of measurements is produced – around half a billion datapoints from around thirty thousand users in OpenSignal's most recent dataset. We summarise OpenSignal's results for download speeds in Figure A5.8 below.

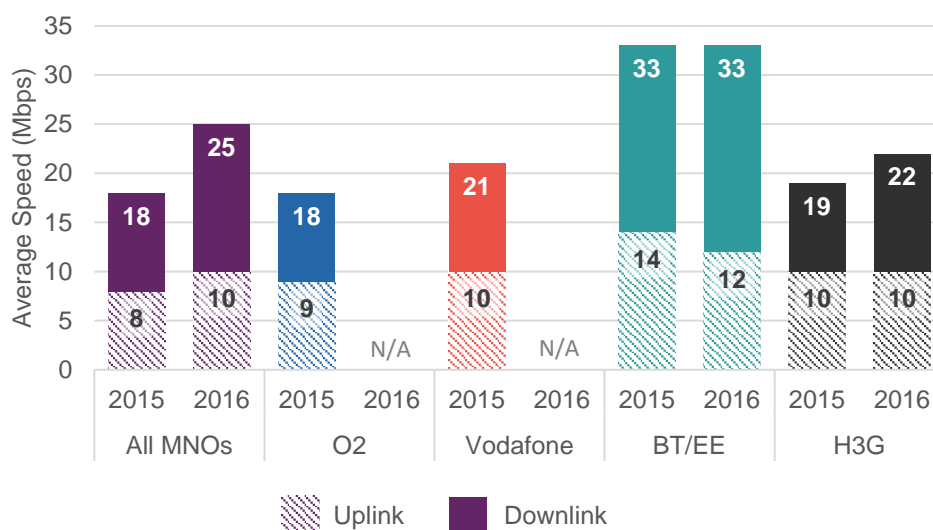
A5.19 OpenSignal's analysis shows that EE leads in download speeds, but that download speeds for the other networks also continue to improve. OpenSignal said that the improvement in download speeds was largely a result of much better 4G availability meaning that users are using slower 2G and 3G networks less frequently. This supports RootMetric's prediction in its February 2017 report that greater coverage would lead to better download speed scores.

Figure A5.8: Download speeds Nov 2015 to Dec 2016 and Dec 2016 to Feb 2017



Ookla results reflected a general improvement in mobile data speeds

A5.20 Ookla collects data from users running speedtests which means that measurements will not be as well controlled as formal drive testing. Nevertheless, Ookla's results followed the general trend in increased data speeds as shown below in Figure A5.9.

Figure A5.9: Ookla UK speedtests for Q2-Q3 2015 and Q2-Q3 2016³²⁶

P3 puts both EE and Vodafone in joint lead overall with EE performing slightly better for data and Vodafone performing slightly better for voice

- A5.21 We did not consider the P3 reports in our November 2016 consultation so we only consider P3's most recent report which was also published in November 2016. P3 has conducted mobile network quality surveys for the UK MNOs since 2014 and uses a combination of drive tests and walk tests in cities, towns and major roads for its benchmarking. It anticipates adding a crowdsourcing element to its network performance measurements in future using its "U Get" app, similar to OpenSignal.
- A5.22 We summarise P3's scores for the UK and London as well as more detailed statistics for its city drive testing in Figure A5.10 below. We focus on these measurements because we believe that any evidence of capacity constraint is likely to manifest first in dense urban areas. Additionally, we compare the download speeds for cities with those for the towns.
- A5.23 Overall, P3 ranked EE and Vodafone joint-first, with EE performing slightly better for data and Vodafone performing slightly better for voice. H3G was third, with O2 coming in fourth, though P3 observed that O2 had the best voice performance in London and the second-best voice performance overall.
- A5.24 P3's benchmarking weights its results towards cities, so the MNO ranking for data download speeds in cities broadly follows the overall scores. On major roads, EE is the leader with H3G in second and Vodafone and O2 performing similarly in last place. However, in towns all the MNOs get similar scores for data downloads.
- A5.25 In London, O2 is best for voice and EE is best for data but Vodafone gets best overall for good performance in both categories.

³²⁶ Note that the 2016 update only gave partial information about operators which is why there are no results for O2 and Vodafone in 2016.

- A5.26 Looking in more detail at the results, we can see that all MNOs have a high success rate when serving web pages and can deliver them in a few seconds. This is similar to the results of the Ofcom Smartphone Cities data.
- A5.27 All MNOs have good scores for serving video and have similar success rates and low interruption rates. The average resolution for video for each operator broadly follows the same pattern as the average data download speeds for each operator because video streaming services such as YouTube use adaptive bitrates, adjusting the quality of the video stream dependent on the bit rate available to the end user.

Figure A5.10: P3 network tests for mobile networks in the UK 2016

		O ₂	VF	BT/ EE	H3G
<i>UK Scores</i>					
Total Score	/ 1000	747	803	803	778
Voice Score	/ 400	326	329	303	318
Data Score	/ 600	421	474	500	460
<i>London Scores</i>					
Total Score	/ 675	494	548	543	511
Voice Score	/ 270	220	213	203	203
Data Score	/ 405	274	335	340	308
<i>Web-page download (Live pages, City drive test)</i>					
Success Ratio	%	94.9	97.5	97.5	96.3
Average Session Time	s	3.2	2.9	2.5	2.9
<i>File Download (10 seconds, City drive test)</i>					
Success Ratio	%	98.8	99.6	99.1	99.3
Average Throughput	Mbps	14.7	27.0	43.1	22.9
10% faster than	Mbps	33.2	59.7	85.6	52.2
90% faster than	Mbps	2.1	4.1	10.2	2.7
<i>File Download (10 seconds, Town drive test)</i>					
Success Ratio	%	99.1	98.9	98.7	98.5
Average Throughput	Mbps	18.2	20.8	41.0	24.8
10% faster than	Mbps	37.0	38.6	76.7	58.9
90% faster than	Mbps	4.4	5.6	10.2	3.4
<i>File Upload (10 seconds, City drive test)</i>					
Success Ratio	%	98.5	98.8	99.1	99.3
Average Throughput	Mbps	10.2	11.3	20.7	12.2
10% faster than	Mbps	19.4	20.7	40.7	27.3
90% faster than	Mbps	1.5	2.0	3.8	1.5
<i>YouTube video (City drive test)</i>					
Success Rate	%	98.0	98.3	97.8	99.4
Start Time	s	1.8	1.7	1.5	1.6
Video playouts without interruptions	%	99.4	99.2	99.8	99.5
Average Video Resolution	p	569	624	663	603

Source: P3 2016 Mobile Network Test in the United Kingdom, fieldwork September 2016

O2 and H3G provided information on the performance of their networks

A5.28 In this section, we summarise the information provided by O2 and H3G on the performance of their networks before discussing this evidence in more detail.

<i>MNO Evidence</i>	<i>Summary</i>
O2	
Network metrics	O2 argued that ¶< [REDACTED] .
Internal drive tests	O2 argued that its internal drive testing ¶< [REDACTED] .
H3G	
P3 drive tests and data rate distribution simulation	H3G argued that high average speeds are necessary to reduce the proportion of users experiencing a very low data rate.
Video download success rate	Maps show that ¶< [REDACTED] .

O2 argued that ¶< [REDACTED]

A5.29 O2 presented information from its network showing that ¶< [REDACTED] ³²⁷ .

A5.30 ¶< [REDACTED] .

A5.31 We agree with O2 that ¶< [REDACTED] . We discuss O2's capacity and demand modelling in more detail in annex 6.

O2 argued that its internal drive testing ¶< [REDACTED]

A5.32 O2 presented data from its own internal drive testing showing that ¶< [REDACTED] .

Figure A5.11: ¶< [REDACTED] ³²⁸

A5.33 ¶< [REDACTED] our Smartphone Cities 2016 data shows that O2 has a higher uplink speed than downlink speed in London. In Figure A5.4 we can see that O2's upload speeds have increased in London between 2015 and 2016, but its download speeds have remained the same.

A5.34 As the amount of download data typically exceed upload data by a significant margin, it is likely that congestion will appear on the downlink before the uplink when using paired spectrum bands. Therefore, a narrowing of the average throughput rates between download and upload would indicate that the download is becoming more constrained than the uplink.

A5.35 Whilst O2's download speeds in London are lower than those of the other operators it continues to provide a good data service overall as shown in P3's data scores for

³²⁷ ¶< [REDACTED] .

³²⁸ ¶< [REDACTED] .

London in Figure A5.10. As we mentioned previously, download speeds are only one element of the quality of service of a data network with coverage and reliability also being important.

- A5.36 We therefore agree with O2 that \times [REDACTED] and we see that O2 continues to provide a good data service in London and across the UK. We discuss O2's demand and capacity model in more detail in annex 6.

H3G argued that considering average speeds masked the number of users experiencing very low speeds

- A5.37 H3G believed that data speeds could not be judged on average speed alone, because different applications require different data rates and future applications are likely to demand even higher data rates to deliver an acceptable service. Similarly, H3G suggested that data speeds cannot be judged only when the network is congested because network performance when the network is more lightly loaded is also important to customers' experience.
- A5.38 H3G argued that high average speeds are necessary in order to minimise the number of users experiencing very low speeds and that average speed rankings can be misleading when considering users who receive low data speeds. It cited P3's Q1 2015 drive survey data which shows that H3G and O2 have a greater proportion of lower data speed samples than BT/EE as well as the Ofcom Smartphone Cities 2015 data which gave similar results. It compared the proportion of sampled data rates over 2 Mbps with estimates of 4G spectrum deployment at the time, arguing that network performance correlated with spectrum deployed.
- A5.39 H3G provided a simulation to assess the distribution of data speeds that would result from use of its network with different amounts of spectrum. It considered a range of minimum threshold speeds and showed that an MNO with half the spectrum of a competitor could only provide a comparable service for those receiving low data rates by increasing the density of their network by around \times [REDACTED] times.
- A5.40 However, when we look at more recent drive test data taken as part of the Smartphone Cities 2016 report we can see that all mobile networks have improved between 2015 and 2016 with higher average speeds and higher throughput when serving users at the lower end of the data speed distribution as shown in Figure A5.2 above. When considering the proportion of samples at 2 Mbps or less, EE still leads with 1%, H3G and Vodafone are similar with 6% and 5% respectively and O2 at 10%. Whilst there remains a correlation between average speeds and the proportion of samples at 2 Mbps or less, this correlation has weakened as average speeds have risen for all mobile networks.
- A5.41 Similarly, we can also look at the latest P3 drive testing which we summarise in Figure A5.10. This shows that more than 90% of measurement samples in both towns and cities had a data rate of over 2 Mbps for all operators.
- A5.42 H3G's simulation for its network using different amounts of spectrum and the proportion of users receiving a low data rate gives results which are consistent with the drive test data. However, we note that the proportion of users in this bracket is very sensitive to the "low data rate" threshold considered. We can see this in the Ofcom Smartphone Cities data which shows that a modest increase in O2's average speeds (10 Mbps in 2015 to 13 Mbps in 2016) was accompanied by a

large fall in the number of users receiving less than 2 Mbps (30% in 2015 to 10% in 2016).

- A5.43 H3G does not consider in its modelling the impact that user device upgrades, traffic shaping and new technologies can have on increasing speeds for those users receiving low data rates. These users tend to be those using older equipment or receiving the weakest mobile signal (either far from a mobile mast or deep indoors).
- A5.44 Over time, we would expect the proportion of users receiving low data rates to fall as users replaced older 2G and 3G mobile devices with 4G devices. The GSMA data provided by H3G showed that UK subscribers had rapidly shifted from 2G and 3G to 4G technology, but that just under 50% of subscriptions were still 2G or 3G only as of Q3 2016.
- A5.45 Traffic shaping and network management can improve quality of service for those receiving low data rates by altering how LTE resource blocks are shared between users. This approach can be very effective when there are a small proportion of users consuming a lot of data.
- A5.46 However, we acknowledge that traffic management can only have a limited impact when the users receiving a low data rate are at edge-of-cell, either far from the mobile mast or deep indoors, because these users consume a disproportionately high number of resource blocks to achieve the same data rate as users nearer the mobile mast. For these edge-of-cell users, we expect carefully deployed small cells may help to increase data speeds in some areas. Also, new technologies such as coordinated multipoint which improves throughput for edge-of-cell users may help to increase data speeds, but only in the second transitional period and the longer term. We discuss the extent to which small cells and new technologies could increase data rates in more detail in annex 6.

H3G argued that video download success rates indicated that ✕ [REDACTED]

- A5.47 H3G provided maps showing success rates for SD and HD video downloading across the UK. ✕ [REDACTED] .
- A5.48 It was not clear from H3G's response what the definition of a failure is in this context. Most video streaming services use adaptive data rates, adjusting the video quality depending on the available bitrate. P3 took this into account in its 2016 mobile network test and achieved success rates of nearly 100% for all operators as shown in Figure A5.10. We therefore do not agree with H3G that this data shows that ✕ [REDACTED] ; most of the network performance tests we have discussed in this annex show that H3G has a similar data speed to Vodafone, subject to regional variations. ✕ [REDACTED] . We discuss H3G's demand and capacity model in more detail in annex 6.

Annex 6

Network investment and capacity growth

A6.1 This annex considers future growth in data traffic, and the extent to which it is possible for an operator to expand capacity through network investments as well as through the deployment of additional spectrum. We discuss in detail the position of O2 and H3G and conclude the following:

- In respect of O2, we have now seen additional evidence suggesting that the scope to add network capacity without additional spectrum is more limited than we considered in the November 2016 consultation. We have therefore reviewed our earlier analysis in the light of this additional evidence.
- H3G's ability to increase network capacity has been enhanced materially both by its acquisition of UK Broadband and its potential to use 1400 MHz spectrum earlier than we anticipated. As a result, we are less concerned than in the November 2016 consultation about H3G's ability to continue to add capacity to their network in the first and second transitional periods.

Summary of our position in November 2016 consultation

We said that additional spectrum increases capacity, but there are alternative options for adding capacity

- A6.2 In our November 2016 consultation, we said that we believed that operators with lower shares of licensed spectrum than rivals may be able to deliver comparable levels of capacity by relying on approaches other than by adding additional spectrum. These approaches might include densifying their networks, moving to more efficient technologies and using licence exempt spectrum.
- A6.3 We also considered spectrum availability in the 2-3 year transitional period during which the 3.4-3.6 GHz band might not be immediately available for mobile, and also in the longer term. In the longer term, we believed that all operators could increase their capacity to match their competitors, so we focussed our attention more closely on the transitional period and on O2 and H3G in particular. We focussed our attention on these two operators because they have lower spectrum holdings than Vodafone and BT/EE.
- A6.4 We acknowledged that the trade-off between network investment and spectrum was not perfect, but we still believed that there were several options for MNOs to increase capacity in the longer term. Network investments could include site densification, small cell deployments and 6-sector upgrades, quicker refarming plans, LTE-Advanced technical improvements, use of carrier aggregation, enhanced MIMO, interference cancellation mechanisms, and self-optimising networks (SON).

We considered that any capacity constraints H3G faced in the next few years would not be severe enough to affect competition

- A6.5 We noted that H3G had a subscriber base with a particularly high data use per subscriber when compared to the other three MNOs. We had not undertaken a detailed assessment of whether H3G might struggle to add sufficient capacity to meet demand during in the next few years. However, we noted that the EC

concluded in its decision on the O2/H3G merger that, *“based on the available evidence in its file, it could not be reasonably predicted that H3G’s ability to compete would materially deteriorate due to capacity constraints in the next two to three years.”*³²⁹

We considered that < [REDACTED]

A6.6 < [REDACTED] .

A6.7 < [REDACTED] ³³⁰ .

A6.8 < [REDACTED] .

A6.9 < [REDACTED] .

A6.10 < [REDACTED] .

Consumers judge the quality of networks on several factors and peak speeds are less important for most consumers

A6.11 We said that site densification was likely to be able to deliver capacity resulting in similar average speeds in heavily loaded networks to those achievable from using additional spectrum. We believed that considering the heavily loaded cells was more important because consumers tend to notice negative experiences more than positive experiences and heavily loaded conditions were when consumers were most likely to have a negative experience.

A6.12 We said that there were many factors which impact the customer experience such as network reliability and latency. Amongst these, peak speeds are unlikely to be the most significant deciding factor for most consumers, so the high peak data rates available with more spectrum and carrier aggregation are unlikely to be of high importance to most consumers. We discuss this in more detail in annex 2.

Summary of responses

Responses from O2 and H3G primarily focussed on the challenges associated with increasing network capacity through densification

A6.13 O2 submitted a further report by NERA and H3G submitted several annexes challenging our assessment that network investment can increase network capacity with no increase in spectrum. We had argued that MNOs had three main alternatives in the longer term – densifying their networks; moving to more efficient technologies; and using licence exempt spectrum – and that they might be able to bring some of these techniques forward in the transitional period before the 3.4 GHz spectrum becomes useable.

A6.14 The O2/NERA report sought to rebut our argument and show that only a smaller subset of these options might be practical in the transitional period. O2 identified spectrum refarming as the most credible way in which an MNO might increase its capacity and that limited capacity gains might be possible through deployment of

³²⁹ Recital 775, EC merger decision on the O2/H3G merger, available online at http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6415_10.pdf

³³⁰ < [REDACTED] .

small cells. It argued that the other methods we had suggested were either not practical, not relevant or only possible in the longer term and < [REDACTED] .

A6.15 H3G argued that < [REDACTED] .

A6.16 We first discuss O2's response on increasing network capacity and our updated position on this before moving onto our analysis of H3G's response.

O2's response and our updated position

O2 identified spectrum refarming as the most credible technique to increase capacity but noted it had limits

A6.17 We summarise O2's responses on possible network capacity enhancements in the below and summarise our updated position in light of this response. The most credible capacity enhancement technique in what we now identify as the first transitional period is spectrum refarming, but small cells can also play a role and we discuss this in greater detail after the summary table. In the second transitional period, we consider that MIMO, advanced interference cancellation techniques and CoMP can increase capacity, but that it may take some time for the gains from these techniques to be fully realised. We also discuss to what extent carrier Wi-Fi networks might be used to relieve demand on the mobile network in the first and second transitional periods.

	O2/NERA position	Our updated position
Network densification		
<i>Increasing network capacity by installing new sectors and building new sites</i>		
Small cells <i>New, localised sites within a macrocell</i>	There are limited capacity gains (60% to 100%) which can be made using small cells and site acquisition is expensive and time consuming.	We still consider that these small cell capacity gains could be significant and note O2 recently announced a small cell rollout in London. < [REDACTED] .
6 Sector Sites <i>Splitting existing sites into more sectors</i>	Inter-sector interference limits capacity gains and not all sites have the spare space to install the extra antennas. < [REDACTED] .	We still consider that capacity gains from sector splitting could be significant, however, these gains can be reduced when a network has high self-interference and < [REDACTED] .
New macrocells <i>Splitting existing cells by building new macrocells</i>	Expensive and time consuming to build new macro sites. Inter-site interference limits capacity gains. Macrocell geometry in urban areas means they have an irreducible, minimum coverage area.	Changes to the Electronic Communications Code in the recent Digital Economy Act primarily benefit sites in rural areas, but may also make site acquisition easier in urban areas.

Using more spectrally efficient technologies

Increasing network capacity by using new technologies which increase bits / s / Hz / sector

Faster refarming <i>Upgrading existing 2G and 3G spectrum to 4G</i>	Refarming can give substantial capacity gains, \propto [REDACTED] .	We agree, \propto [REDACTED] .
MIMO <i>Multiple antennas harnessing spatial diversity</i>	High order MIMO is impractical at low frequencies because more space is needed. \propto [REDACTED] . Higher order MIMO gives no greater capacity because devices typically have no more than two antennas.	Gains from higher order MIMO might be low in the first transitional period, however, sites in very congested areas might benefit from 4x2 MIMO. In the second transitional period devices may have more than two antennas and so it might be possible to provide further capacity gains using higher order MIMO.
Beamforming Massive MIMO <i>Splitting existing sectors into multiple beams</i>	Requires TDD spectrum to be effective and spectrum at 2.3 GHz or higher to reduce the size and separation of antenna elements.	We note that this will only become practical in the second transitional period and later and with access to new TDD spectrum.
Self-optimising networks <i>SON, Automated network optimisation</i>	SON has the greatest impact when planning frequency reuse, but cannot provide significant capacity enhancements in 4G SFNs.	SON is already used in mobile networks and is a necessary enabler for RAN virtualisation in SFN ³³¹ HetNets with small cells.
Interference cancellation <i>Improving throughput by enhancing SINR</i>	Inter-site interference cancellation not possible without dedicated fibre network. Inter-sector IC can only be of limited effectiveness.	IC techniques will continue to improve and may yield capacity gains in the second transitional period and later. We expect future mobile networks to connect more sites using fibre and microwave links in preparation for 5G.
Co-ordinated Multipoint <i>Enhanced edge-of-cell service</i>	CoMP requires a fibre network which would be very costly. This technology is still in the research stage.	CoMP may become practical in the second transitional period and later. Similar to IC, we expect greater use of fibre and microwave links in future mobile networks.
Algorithmic changes <i>Improving network scheduling</i>	No significant capacity enhancements seen in the past and none expected soon.	Smart scheduling algorithms can help improve the customer experience even in heavily loaded cells.
Radio layer improvements <i>Upgrading the radio layer</i>	No significant further capacity increases at the radio layer planned in 3GPP rel. 13, 14 and 15.	It is widely accepted that most future capacity gains will be through techniques other than improvements in the basic radio layer.
Carrier Aggregation <i>Increased peak speeds to individual devices</i>	Increases peak speeds, not a capacity increasing technology. \propto [REDACTED] .	There may be some marginal capacity benefits in some circumstances, low loaded sites in particular.

³³¹ Single frequency network

Using licence exempt devices in shared spectrum

Decreasing demand for mobile networks by “offloading” users onto Wi-Fi and LTE-LAA

Wi-Fi <i>Short-range, high-capacity mobile broadband</i>	Wi-Fi can only substitute for licensed mobile in some scenarios, including in-building.	Wi-Fi can give outdoor coverage; we note O2 has an extensive Wi-Fi network and is rolling out a new network in the City of London with Vodafone through CTIL. Ofcom is making more spectrum available for Wi-Fi. We consider that %< [REDACTED] .
LTE-LAA <i>New technology, similar to Wi-Fi, but based on LTE</i>	LAA equipment availability is low, the spectrum is shared with Wi-Fi, congestion can move users back to LTE, coverage similar to Wi-Fi.	LAA equipment is unlikely to become cheap and ubiquitous in the next few years. However, costs may fall in the second transitional period and later. LTE-U is currently being rolled out in the USA ³³² .

O2 said that spectrum refarming can yield significant capacity gains, %< [REDACTED]

A6.18 NERA/O2 supplied us with its refarming plan for 2015 to 2025 for its current spectrum holdings. %< [REDACTED] .

A6.19 %< [REDACTED] .

A6.20 %< [REDACTED] .

A6.21 %< [REDACTED] ³³³ .

Figure A6.1: %< [REDACTED]

In the first transitional period, small cells can provide an increase in capacity and O2 is currently rolling out small cells in London, %< [REDACTED]

A6.22 NERA presented simulation evidence showing that small cells can only increase capacity by 60% when using 4 small cells in a macrocell and, even with a much larger number of small cells, it argued that 100% is the maximum possible capacity gain. It observed that the macrocell would be the limiting factor because there would always be some users that small cells could not cover and who could only be covered by the macrocell including users on higher floors in buildings or high mobility users.

A6.23 BT/EE commented that the NERA model might be pessimistic because it considered 70% Almost Blank Subframes (ABS) when underlaying a macrocell with 20 small cells and BT/EE did not believe that it was reasonable to consider that the macrocell would only be operating for 30% of the time.

³³² <https://newsroom.t-mobile.com/news-and-blogs/lte-u.htm>

³³³ %< [REDACTED]

- A6.24 NERA also cited the National Infrastructure Commission (NIC) December 2016 “Connected Future” report which highlighted the difficulties that operators face when attempting to install small cells including site acquisition, urban restrictions such as local authority permits and traffic management, providing backhaul and the complexity associated with managing a very large number of sites. NERA believed that a small cell ‘hot-spot’ strategy will nearly double the cost of carrying traffic in the sector on a \$/bit basis compared to using a macrocell alone, however, NERA did not produce detailed evidence for whether this increase in cost would necessarily make small cells uneconomic in all potential deployment scenarios.
- A6.25 We consider that NERA is too pessimistic about the capacity gains possible by sector splitting and adding new macrosites. We agree that the full theoretical benefits of cell splitting by sector splitting or adding new macrosites cannot be realised because of inter-sector interference, but consider that some capacity gain is still possible and < [REDACTED] .
- A6.26 We consider that the NERA evidence for the maximum capacity enhancement of small cells is pessimistic, but in the right order of magnitude. In particular, we consider it is very conservative to assume that small cells can provide no coverage for users in buildings above the first floor.
- A6.27 BT/EE supplied material from Qualcomm suggesting that small cells might provide a capacity increase of 60% when using four small cells in a macrocell, but that this capacity increase could be up to 200% when used in conjunction with small cell range extension.³³⁴ Last autumn, Telekom Austria deployed five small cells in a macrocell at Weiner Weisn-Fest and reported a doubling in average and peak download throughputs compared with just using the macrocell.³³⁵ Huawei has conducted simulations showing capacity gains of 80% to 130% when using three small cells in a macrocell.³³⁶
- A6.28 Whilst we recognise the difficulties associated with small cells, we still consider that alternative creative solutions are feasible for finding suitable sites. As we previously said, Vodafone signed a deal with JCDecaux at the end of 2014 gaining it access to the latter’s street furniture and billboard assets for deployment of small cells.³³⁷ < [REDACTED] .
- A6.29 More recently, O2 and Vodafone announced that they would be building small cell sites throughout the City of London through their joint venture, CTIL.³³⁸ These sites will be housed in street furniture, such as lamp posts, street signs, buildings and CCTV columns, across the Square Mile and is expected to be operational by Autumn 2017. Additionally, O2 announced that it is investing £80 million to install 1,400 small cells in London by the end of 2017.³³⁹
- A6.30 < [REDACTED] .

³³⁴ “The 1000x Mobile Data Challenge: More cells, more spectrum, higher efficiency”, Qualcomm, <https://www.slideshare.net/qualcommwirelessevolution/the-1000x-mobile-data-challenge-14120915>

³³⁵ “Telekom Austria toasts first small cells test”, Mobile Europe, Issue no. 251, April / May 2017

³³⁶ http://www.huawei.com/ilink/en/solutions/broader-smarter/morematerial-b/HW_204152

³³⁷ <http://www.vodafone.com/content/index/media/vodafone-group-releases/2014/jcdecaux.html>

³³⁸ <http://www.mobileeurope.co.uk/press-wire/o2-is-cornerstone-of-new-public-wi-fi-network-for-the-city-of-london>

³³⁹ <http://www.mobileeurope.co.uk/press-wire/o2-uk-launches-small-cell-blitz-to-improve-its-london-coverage>

- A6.31 We acknowledge that small cells may not be economic for all locations in O2's network, however, we still consider that small cells can deliver increases in capacity where it is needed, perhaps doubling capacity in high traffic areas. We also understand that there may be less small cell equipment available for sub-1 GHz spectrum, however, there is more equipment above 1 GHz & [REDACTED] . We therefore remain of the view that small cells are a useful technique for MNOs to increase the capacity of their networks and & [REDACTED] .
- A6.32 The material BT/EE supplied from Qualcomm also suggested that much greater gains might be possible in the longer term when using indoor picocells, up to 37 times capacity gains when using 32 picocells in a macrocell. However, this still required additional spectrum (the macro network using spectrum around 2 GHz and the small cell underlay using 3.4 GHz) and new Further Enhanced Inter-Cell Interference Coordination (FeICIC) technology.
- A6.33 NERA distinguishes between outdoor small cells, which are practical in the first transitional period, and ultra-dense deployments requiring indoor picocells which might be practical only in the second transitional period or beyond. O2 told us that it was necessary to negotiate individually with each building and that multi-tenanted buildings in particular were challenging because it was hard to agree acceptable terms with the landlord unless the landlord saw value in providing good mobile coverage in its buildings.
- A6.34 Clearly, there are still several hurdles to be addressed to make ultra-dense picocell deployments practical, including site acquisition, backhaul and new technologies including advanced interference management, SONs and advanced RAN virtualisation. We still consider that significant capacity gains could be possible through ultra-dense picocell deployments in the second transitional period or later, but we acknowledge that there are uncertainties around the scale of the gains which might be practical & [REDACTED] .

'Wi-Fi offload' can relieve demand for data on mobile networks and Vodafone and O2 are currently rolling out a new Wi-Fi network in London
& [REDACTED]

- A6.35 NERA's response on licence exempt technologies focussed on LTE-LAA which is a technology similar to Wi-Fi, but based on LTE and uses a licensed carrier for carrying control information whilst sending user data over spectrum shared with other users including Wi-Fi. NERA notes several concerns about O2's ability to increase network capacity using LTE-LAA.
- A6.36 We agree with NERA that low cost, ubiquitous LTE-LAA equipment might not be available in the first transitional period, but could become available in the second transitional period or later as equipment costs fall. T-Mobile has already deployed LTE-U in the USA and is trialling an LTE-LAA network³⁴⁰. Currently the only mainstream consumer device which supports LTE-U is the Samsung Galaxy S8³⁴¹, but we would expect more devices to support LTE-U and LTE-LAA in future.
- A6.37 On the other hand, Wi-Fi, which uses the same spectrum, is a very mature technology and is already built into the vast majority of mobile devices. Many network operators, including O2, use Wi-Fi for 'mobile offload' and can switch users

³⁴⁰ <https://newsroom.t-mobile.com/news-and-blogs/lte-u.htm>

³⁴¹ <http://www.tmonews.com/2017/06/t-mobile-laa-testing-lte-u-rollout/>

to use the Wi-Fi network if the Wi-Fi network is currently providing a better quality of service than the mobile network.

- A6.38 NERA says that because LTE-LAA and Wi-Fi share the same spectrum there is unlikely to be ‘clean spectrum’ available for increasing a licensed operator’s effective spectrum holdings. We consider that this is pessimistic because there are currently 19 channels of 20 MHz available at 5 GHz and three non-overlapping channels available at 2.4 GHz. We are also working to make more spectrum available for Wi-Fi and LTE-LAA at 5.8 GHz which would increase the total number of 20 MHz channels to 28.³⁴²
- A6.39 NERA says that there is a risk an increase in loading in the 5 GHz band might displace traffic currently carried on Wi-Fi towards cellular as users seek a more reliable connection. It is not clear from its response how great this risk is, but, as we say above, we are making more channels available for Wi-Fi at 5 GHz which will reduce the risk of congestion at 5 GHz in the near future.
- A6.40 Finally, NERA says that LTE-LAA and Wi-Fi cannot substitute for a macrocell because they are much lower power and so have a much smaller coverage area. We acknowledge that LTE-LAA and Wi-Fi cannot fully substitute the macrocell, however, NERA also notes that Wi-Fi can be deployed indoors throughout a building as well as outdoors, providing coverage similar to a small cell or a picocell, and drawing traffic off the macrocell in these areas. NERA comments that *“the prevalence of (self-deployed) Wi-Fi within buildings is increasingly making cellular systems appear less relevant”*.³⁴³ The traffic drawn off the mobile network could be significant and the February 2017 CISCO VNI estimated that sixty percent of total mobile data traffic was offloaded onto the fixed network through Wi-Fi or femtocell in 2016 and that, in total, 10.7 exabytes of mobile data traffic were offloaded onto the fixed network each month.³⁴⁴
- A6.41 As we discussed previously in the section on small cells, O2 and Vodafone recently announced that they would be building new sites for small cells and Wi-Fi in street furniture across the Square Mile. We would expect this would relieve some of the demand for data over mobile networks in this area as more users are ‘offloaded’ onto the Wi-Fi network.
- A6.42 ✂ [REDACTED] .
- A6.43 In the first transitional period, we expect technologies which allow mobile networks to seamlessly handover to Wi-Fi networks, like EAP-SIM, O2’s “TU Go” app and H3G’s “In Touch” app, to continue to improve. In the second transitional period or later LTE-LAA may allow for greater integration between use of licensed and licence exempt spectrum.
- A6.44 In the second transitional period or later we expect the capacity available on Wi-Fi networks to continue to grow. This is through a combination of:
- **New Wi-Fi sites:** both private, like those used in the home and businesses, and carrier grade like those being deployed by O2 and Vodafone in central London;

³⁴² <https://www.ofcom.org.uk/consultations-and-statements/category-3/wireless-telegraphy-exemption-regulations-2017>

³⁴³ §5.4.1 NERA Report

³⁴⁴ <http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html>

- **New Wi-Fi technologies:** including MIMO and beam steering; and
- **Access to new spectrum:**
 - Possible improved access to 5150-5925 MHz through A.I. 1.16 at WRC-19;
 - Possible access to 5925-6425 MHz through new work starting in CEPT; and
 - 60 GHz WiGig supported in more devices, though this will likely only give in-room coverage.

In the second transitional period, we still consider that new technologies will enable MNOs to increase the capacity of their existing sites, but we recognise that these improvements could take some years to implement

- A6.45 Coordinated multipoint transmission (CoMP) allows multiple base stations to coordinate transmissions to devices operating at the edge of cell, where there is some overlap in coverage, and improve throughput to those users. NERA noted that CoMP required new technologies in both the network and mobile devices and dedicated fibre or microwave low-latency connections to a centralised RAN controller.
- A6.46 Advanced interference cancellation techniques such as FeICIC are a key enabler for denser networks because self-interference is a limiting factor in existing mobile networks³⁴⁵. Similar to CoMP, this will require new technology in the network and mobile devices and low-latency fibre connections between base stations.
- A6.47 However, H3G was less conservative and considered that some benefits from LTE-Advanced techniques could begin to be implemented as soon as 2017. LTE-Advanced could deliver up to 3x [REDACTED] capacity improvements in 2017 rising to 3x [REDACTED] in 2021.
- A6.48 We accept that these technologies and fibre or microwave enablers may not be available in the first transitional period, but consider that they could be available in the second transitional period or later. We recognise that installing a dedicated fibre or microwave network could be a particular challenge and could take many years to roll out to all the most congested sites. Many of the technologies in 5G will require dedicated fibre or microwave links between sites and so we might expect a dedicated fibre or microwave network to become essential for mobile networks in the longer term during the maturation of 5G.
- A6.49 MIMO uses multiple antennas to harness spatial diversity in mobile networks and increase throughput. Generally speaking, the greater the number of antennas used at a base station, the greater the possible throughput, but there are diminishing returns and the maximum gains can only be realised when mobile devices use two or more antennas. 3x [REDACTED]. Higher-order MIMO also requires more antennas as well as a minimum separation between antenna elements to fully take advantage of spatial diversity and not all sites have the space or the weight capacity to accommodate new, spaced-out antennas.
- A6.50 However, H3G was less conservative and considered some gains from higher order MIMO might be realisable from 2017. After accounting for device penetration rates,

³⁴⁵ "The 1000x Mobile Data Challenge: More cells, more spectrum, higher efficiency", Qualcomm, <https://www.slideshare.net/qualcommwirelessevolution/the-1000x-mobile-data-challenge-14120915>

it considered that MIMO could deliver 3x [REDACTED] spectral efficiency gain in 2017 rising to 3x [REDACTED] in 2021.

- A6.51 We consider that higher-order MIMO may become practical in the second transitional period, but we recognise that the capacity gains will be limited by the number of antennas in devices and there may still be a large population of devices using only one or two antennas. We also acknowledge that expanding the space and weight capacity of existing sites, or acquiring new, larger sites, to accommodate higher order MIMO could be a difficult and time consuming process.

We acknowledge that an MNO with a low spectrum share will have few options to further increase capacity in the first and second transitional periods without access to more spectrum

- A6.52 3x [REDACTED]³⁴⁶ .

- A6.53 In the **second transitional period**, we consider that mobile operators have more options to increase their network capacity without additional spectrum than in the first transitional period, but these options will not be possible at all sites. Ultra-dense indoor picocell deployments give greater capacity gains than small cells, but there are uncertainties around the scale of these gains when taking account of practicalities such as site acquisition and backhaul. It will also not be possible for some users to be covered by means other than macrocells, including high mobility users, and so the macrocell might be the limiting factor in mobile network capacity.

- A6.54 We expect there will be only incremental capacity improvements through techniques such as coordinated multipoint and advanced interference cancellation, but these will require dedicated fibre or microwave links between sites which we recognise will not be possible for all sites. We consider that higher-order MIMO will become practical in the second transitional period, but we understand that capacity gains will be limited by the number of antennas in devices and there will still be a large population of devices using only one or two antennas.

- A6.55 On the demand side, it is likely that Wi-Fi will continue to relieve demand growth on mobile networks to some extent. We acknowledge that Wi-Fi cannot substitute macrocells for all user scenarios, however, it can deliver capacity in the areas that it is needed.

- A6.56 For these reasons, we now consider that 3x [REDACTED] .

- A6.57 In the **longer term** there is greater uncertainty around the capacity gains possible from network investment, especially considering that 5G networks will be maturing during this period. However, we consider it is likely that the macrocell network will continue to be important to provide coverage to users who cannot be covered by small cells and picocells and so access to sufficient spectrum will continue to be important to serve all of an MNO's customers.

³⁴⁶ 3x [REDACTED] .

H3G's response and our updated position

H3G provided arguments for why spectrum is an essential input in a data centric market

A6.58 In this section we look at H3G's main arguments for why network investment cannot substitute for spectrum before moving on to look at its network demand and capacity modelling in more detail. H3G summarised its six main arguments as follows:

- i) Sites cannot substitute for spectrum in a data-centric market;
- ii) < [REDACTED] ;
- iii) An MNO with a smaller spectrum share has a much higher marginal cost of expanding capacity than an MNO with twice the spectrum;
- iv) < [REDACTED] ;
- v) < [REDACTED] ;
- vi) < [REDACTED] .

A6.59 These arguments are supported by annexes six to eight from the H3G response which we address next. H3G also submitted a capacity and demand model for its network which it developed alongside Frontier Economics - we discuss this in more detail after we have discussed the annexes to H3G's response.

H3G's response focussed on network densification but argued that there were cost and technical limits on possible capacity gains

A6.60 Annexes 6, 7a, 7b and 8 provided by H3G looked at the extent to which the H3G network could be densified and the capacity gains associated with that densification. These studies consider densification by building more macrocells, sector splitting and small cells, but with a clear preference for the first two of these techniques noting in annex 6, (the Real Wireless annex), that *"typically outdoor small cells are deployed when the use of cell splitting via macrocells has been exhausted ... most operators favour the use of macrocells, only turning to small cells as a last resort."*³⁴⁷ It is not clear from H3G's response and annexes at what point it would begin to prefer deploying small cells to cell splitting. However, we note that H3G has recently announced a small cells trial in south-west London.³⁴⁸

A6.61 **The Real Wireless annex** (annex 6) provides an analysis of the extent to which network densification can increase network capacity and how this compares to the capacity gains that can be made with additional spectrum. We first look at its analysis of possible network capacity enhancement techniques before moving onto its quantitative analysis.

A6.62 We summarise the H3G/Real Wireless responses on possible network capacity enhancements in the table below and summarise our updated position considering this response. We note that Real Wireless does not go into the granular detail of the

³⁴⁷ §7.1.4, "Site density vs spectrum investigation", Real Wireless Ltd, September 2016

³⁴⁸ <http://www.mobileeurope.co.uk/news-analysis/three-uk-dips-its-toe-into-small-cells-but-wants-more-action-from-wider-ecosystem>

O2/NERA report, in particular some of the likely future technological developments including beamforming massive MIMO, self-optimising networks, network management or LTE-LAA. We set out our position on these in our previous section on the O2/NERA response and we believe a similar position on these also applies to H3G.

	<i>H3G / Real Wireless position</i>	<i>Our updated position</i>
Network densification		
<i>Increasing network capacity by building more cells for greater spectrum re-use</i>		
Small cells <i>New, localised sites within a macrocell</i>	Small cells might capture 10% of network traffic in a macrocell and identifying the locations of traffic hotspots to cover with small cells is difficult along with site acquisition. It is expensive and time-consuming to get cable wayleaves for fibre backhaul and power. Small cells increase network complexity including management of high mobility users moving between Hetnet layers.	We still consider that small cell capacity gains can be significant in the first and second transitional periods and H3G recently announced a small cell trial in south-west London. < [REDACTED] .
6 Sector Sites <i>Splitting existing cells into more sectors</i>	Realistic capacity gains are limited to 50%. It is time consuming to re-engineer sites with additional antennas and landlord permission is often required.	We consider that possible capacity gains from sector splitting are significant < [REDACTED] .
New macrocells <i>Splitting existing cells by building new macrosites</i>	Most common and straightforward approach to densification, but it is very expensive and time consuming to acquire new sites and build new macrosites.	Changes to the Electronic Communications Code in the recent Digital Economy Act primarily benefit sites in rural areas, but may also make site acquisition easier in urban areas.

Using more spectrally efficient technologies

Increasing network capacity by using new technologies which increase bits / s / Hz / sector

Faster refarming <i>Upgrading existing 3G spectrum to 4G</i>	Refarming can be a way to increase spectral efficiency in existing spectrum holdings.	We agree < [REDACTED] .
MIMO <i>Multiple antennas harnessing spatial diversity</i>	Most sites use 2x2 MIMO today, but higher order MIMO might be possible in future.	We agree < [REDACTED] .
Interference cancellation <i>Improving throughput by enhancing SINR</i>	Can be used to mitigate self-interference when densifying a network.	We agree when using FeICIC in the second transitional period and later. Limited gains possible in the first transitional period.

Co-ordinated Multipoint <i>Enhanced edge-of-cell service</i>	Can improve spectrum efficiency	We agree in the second transitional period and later. Low-latency fibre or microwave links between sites are a prerequisite and limit possible gains in the first transitional period.
Radio layer improvements <i>Upgrading the radio layer</i>	Increases in spectral efficiency have slowed in recent times.	It is widely accepted that most future capacity gains will be through techniques other than improvements in the basic radio layer.
Carrier Aggregation <i>Increased peak speeds to individual devices</i>	Carrier aggregation offers higher peak speeds but also an improved overall broadband experience.	CA can give marginal capacity gains but is primarily a peak speed maximising technique and we consider network capacity to be much more important to the user experience than peak speeds.

Using licence exempt devices in shared spectrum

Decreasing demand for mobile networks by “offloading” users onto Wi-Fi and LTE-LAA

Wi-Fi <i>Short-range, high-capacity mobile broadband</i>	Wi-Fi offloading is not available for all types of traffic i.e. voice. Wi-Fi is low power with limited coverage.	We note that H3G does not have a large existing Wi-Fi network unlike some of the other operators. However, Wi-Fi can add capacity where it is needed and H3G's network can do VoWi-Fi.
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A6.63 Moving on to the quantitative analysis, Real Wireless modelled H3G's network and looked at the impact of densification of the network on capacity. It densified the existing H3G macrocell network by up to four times and then studied the impact this had on capacity. Real Wireless found that 3< [REDACTED] .

A6.64 3< [REDACTED] .

A6.65 **The H3G capacity annex** (annex 7a) presents H3G's own analysis of how many sites would be needed to match the capacity of a competing network with access to twice as much spectrum. 3< [REDACTED] .

A6.66 H3G also studied the minimum speeds that a network with less spectrum than a competitor could support saying that “*the network with smaller spectrum holding would require 3< [REDACTED] times the number of sites in order to match the competitor network in satisfying 95% of the users with the 2 Mbps minimum speed.*” However, in our previous annex (annex 5), we discuss how our Smartphone Cities data showed that all mobile networks have improved their throughput between 2015 and 2016 when serving users at the lower end of the data speed distribution. Indeed, 94% of the tests on H3G's network yielded download speeds of 2 Mbps or higher in 2016, although we recognise that not all of these tests will have been carried out in the ‘busy hour’.

A6.67 H3G additionally considered the number of sites a network would need to match the peak speed of a competitor with twice the spectrum in low-loaded cells. H3G found that the number of sites required was very much higher than the number of sites needed to match average speeds in heavily loaded cells. We agree that the

conclusions of this analysis are reasonable, but we still consider that the ability of the network to deliver the data speeds users require in heavily loaded cells are much more important to the network user experiences than peak data rates in low loaded cells because users tend to be much more sensitive to 'bad' experiences than 'particularly good' ones. We discuss this in more detail in annex 2.

- A6.68 **The Samsung annex** (annex 7b) considers the amount of spectrum H3G would need to match EE's quality of experience (QoE) and how site densification might substitute for spectrum. H3G summarises Samsung's findings by saying < [REDACTED] .
- A6.69 We consider that the conclusions that H3G have drawn from the Samsung annex are pessimistic because < [REDACTED]³⁴⁹ ³⁵⁰ .
- A6.70 Samsung considers < [REDACTED] .
- A6.71 For these reasons, < [REDACTED] we consider that the Samsung conclusion that < [REDACTED] is pessimistic.
- A6.72 **The Qualcomm annex** (annex 8) has a similar objective to the Samsung annex, but considers a scenario in the area around H3G's headquarters in Maidenhead. Qualcomm considers possible increases to capacity of doubling the spectrum available to H3G in this area (20 MHz vs. 10 MHz) compared with capacity increases possible when densifying sites. Qualcomm considered scenarios where the network loading was high, medium and low.
- A6.73 H3G summarises Qualcomm's findings: < [REDACTED] .
- A6.74 Whilst we disagree with the headline conclusion that < [REDACTED] we also consider that the Qualcomm results for the < [REDACTED] scenario are too optimistic. < [REDACTED] .

H3G supplied a demand and capacity model for its mobile network which it had developed with Frontier Economics

- A6.75 H3G developed a congestion model with the help of Frontier Economics which produces estimates of the number of sites and customers likely to be affected by congestion over time. < [REDACTED] .
- A6.76 The model compares demand and supply between 2017 and 2021 of each cell of about < [REDACTED] sites in H3G's UK network.³⁵¹ These represent the busiest 4G sites in December 2016. The model is developed on a **throughput-based approach**, i.e. it compares the cell capacity (the Mbit/s each cell can offer to customers roaming in that cell) with the customer demand in the busy hour.³⁵² In order to compare supply and demand, these must be expressed in similar terms. The model expresses demand based on the unconstrained aggregate demand, i.e. demand in the absence of congestion within a given area as a throughput in Mbit/s during the busy hour. The available capacity in the area is then expressed as a maximum achievable throughput in Mbit/s. A cell is considered congested if the

³⁴⁹ Physical Resource Block

³⁵⁰ < [REDACTED] .

³⁵¹ These sites had 4G spectrum in 1800 MHz band installed in December 2016. < [REDACTED] , meaning that in total there were < [REDACTED] cells as of December 2016.

³⁵² The busy hour is the hour during the day when Three's network experiences peak demand.

customers' demand has reached 95% of the cell capacity (referred to as the utilisation threshold).

- A6.77 The base year is based on observations performed on H3G's busiest 4G sites in December 2016 which includes both 3G and 4G traffic. When a cell becomes congested the model increases capacity in the following years by:
- a) \times [REDACTED] ;
 - b) **Densifying the network** \times [REDACTED] .
- A6.78 We have looked at the inputs, assumptions and results of the model. The model finds that H3G's network will have close to \times [REDACTED] and that the capacity upgrades as described above in the following years \times [REDACTED] .
- A6.79 The capacity assumptions of the model are based on H3G's performance measurements on its network and assign \times [REDACTED] . The model increases capacity by means of:
- a) **Carrier Aggregation**: when aggregating \times [REDACTED] .
 - b) **LTE-Advanced**: \times [REDACTED] .
 - c) **MIMO**: \times [REDACTED] .
- A6.80 Taking all into account, H3G estimates "*that capacity in its high-traffic 4G network increases by \times [REDACTED] in the next decade*".
- A6.81 We believe H3G's assumptions on future network capacity are reasonable. For example, we agree that carrier aggregation adds \times [REDACTED] capacity to cells in the busy hour, \times [REDACTED] LTE-Advanced and MIMO antennas can increase capacity \times [REDACTED] once deployed in the next few years. We note however that:
- a) \times [REDACTED] .
 - b) \times [REDACTED] . This is consistent with our definition of what it means for spectrum to be "useable" which we discuss in more detail in annex 3.
 - c) **Certain assumptions on demand growth seem unrealistic**: \times [REDACTED]
³⁵³ ³⁵⁴ This compares with a wholesale customer growth in 2016 of more than 500,000 subscribers.³⁵⁵ \times [REDACTED] .

³⁵³ Annex 10 of H3G's response, Analysis of H3G congestion modelling, Frontier Economics: "*Three estimates that per-user growth will be around \times [REDACTED] per annum over the next five years*"

³⁵⁴ This considers H3G had nearly \times [REDACTED] wholesale customers in 2016.

³⁵⁵ According to CK Hutchinson Holdings Limited 2015 and 2016 annual reports, there has been a retail customer growth of 213,000 between December 2015 and December 2016 (see page 58 of the 2015 report and page 54 of the 2016 reports available at <http://www.ckh.com.hk/en/ir/annual.php>). We understand that the main MVNO using H3G's network is iD, which according to the "Preliminary results 2016/17 and strategy update" by DixonsCarphone grew by ca. 300,000 subscribers over that same period (see page 21 of <http://www.dixonscarphone.com/~media/Files/D/Dixons-Carphone/documents/preliminary-results-201617-and-strategy-update-final.pdf>). \times [REDACTED]

A6.82 More specifically in relation to the demand assumptions, the model uses the demand function $\propto [\text{REDACTED}]$. This is shown in Figure A6.2 below together with $\propto [\text{REDACTED}]$.

Figure A6.2: $\propto [\text{REDACTED}]$

A6.83 $\propto [\text{REDACTED}]$

a) ³⁵⁶

b) ³⁵⁷

A6.84 $\propto [\text{REDACTED}]$

Figure A6.3: $\propto [\text{REDACTED}]$

Once a mobile network sector reaches capacity, traffic management can be used to maintain QoS for most users

A6.85 We also note that if a site is congested, i.e. the demand exceeds 95% of available capacity of a cell in that site, it is unclear how that would affect H3G's ability to compete. Congestion during the busy hour in a 4G network means that the quality experienced by customers will be somewhat worse: they will experience lower speeds on average. It will take longer to upload a picture, download a web page, watch a YouTube video etc. This may eventually constrain the demand on the cell, meaning that users will give up using a specific service during the time they experience congestion within the busy hour.

A6.86 As discussed in annex 7, mobile network operators can take commercial and technical steps to throttle traffic and constrain demand of the heaviest data users in the cell, making sure that a certain level of service quality is still guaranteed for all other users. This is possible by means of smart scheduling algorithms that can distribute the cell capacity more fairly or more efficiently among customers competing for capacity within the same cell.

A6.87 If during the busy hour service quality does not deteriorate significantly, congestion is unlikely to affect consumers to the extent that they decide to leave their mobile provider. As pointed out in annex 2, consumers' perception of the quality provided by the mobile operator depends on several factors and it is only partially driven by the level of congestion experienced in the busy hour in a certain site. Coverage, availability and reliability of the service are other important determining factors for consumers' experience.

A6.88 Most of the congested sites in mobile networks tend to be in non-residential, central locations, such as railway and tube stations, airports, shopping centres etc. Customers are affected by lower quality when using their mobile devices in these areas in busy hours. We recognise that if the quality experienced is consistently low

³⁵⁶ $\propto [\text{REDACTED}]$.

³⁵⁷ See Figure 14 of H3G's main response.

across several sites for a prolonged period of time, customers may consider switching to a different operator. > [REDACTED] .

Our updated position for H3G has improved, principally because of the earlier than expected useability of 1.4 GHz and H3G's recent acquisition of 3.4-3.6 GHz spectrum

A6.89 As discussed earlier, we had not undertaken a detailed assessment of whether H3G may struggle to add sufficient capacity to meet demand during in the next few years. However, we noted that the EC concluded in its decision on the O2/H3G merger that, *"based on the available evidence in its file, it could not be reasonably predicted that H3G's ability to compete would materially deteriorate due to capacity constraints in the next two to three years."*³⁵⁸

A6.90 In the **first transitional period** we continue to be of the view that H3G is unlikely to be capacity constrained. Whilst we acknowledge that there could be limits on the extent to which H3G could grow the capacity of its network through technical improvements and densification, we consider that the 1.4 GHz band will be available in devices earlier than we had previously thought and we include it as one of the bands we consider useable in the first transitional period. Moreover, we have now also looked in detail at the H3G demand and capacity model and we find that > [REDACTED] .

A6.91 In the **second transitional period**, H3G's recent acquisition of UK Broadband will allow it to use 40 MHz of 3.4 GHz spectrum. Some of the congestion experienced in this period could be addressed by deploying the 3.4 GHz band and, in the **longer term**, more than 80 MHz of 3.6-3.8 GHz, once devices can use these frequencies. > [REDACTED] .

³⁵⁸ Recital 775, EC merger decision on the O2/H3G merger, available online at http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6415_10.pdf

Annex 7

Commercial responses to managing data growth

Introduction

- A7.1 This annex describes how MNOs have choices over how they use their network capacity in terms of the prices and services they offer. This is relevant to our competition assessment because one reason we do not consider that MNOs need close to equal shares of spectrum for competition to be strong is that MNOs can choose to use their capacity in different ways. This diversity in commercial choices and spectrum holdings can benefit consumers.

Our position in November 2016 consultation

- A7.2 In the consultation, we said that there was no reason to expect rivals in any market to need the same *capacity* for competition to be strong. MNOs can have different market shares, may have compensating strengths in other areas (e.g. customer service), or may still be able to deliver services to many consumers by choosing commercial strategies that make best use of their capacity.
- A7.3 We also noted that H3G has higher data usage per subscriber than other MNOs. We said that in part this is likely to reflect H3G's choices about the tariffs it currently or has previously offered. For example, we said that only H3G still offers unlimited SIM-only post pay packages. If it needs to, H3G is probably able to change its commercial strategy to reduce usage by very heavy data users and make more capacity available for other users. To some extent it may already be doing this, as it has increased its prices for 'All-You-Can-Eat' (AYCE) packages while competing strongly for pre-pay consumers (who have lower usage).

Responses

- A7.4 BT/EE said that Ofcom must keep in mind that each MNO has chosen the spectrum portfolio it desires on the basis of its assessment of value, and specifically how any particular spectrum can help to deliver what are inevitably differentiated commercial strategies. It said that O2, for example, chose to pay similar sums to EE at the 2013 combined award auction to purchase (less, but more valuable and expensive) low frequency spectrum. BT/EE also said it was open to H3G to amend its commercial offers to manage demand, and that by improving its demand management techniques it would free up capacity to enable it to grow its customer base. It said a perverse consequence of offering support to H3G through the spectrum auction is that H3G's incentives to efficiently use existing spectrum would be undermined.³⁵⁹
- A7.5 H3G said that it was incorrect to assume that it could significantly increase data speeds for its customers by making changes to the data allowances it offers, or by adjusting its prices. It said that this was for two reasons. ✂ [REDACTED] . For these two reasons, it said that traffic management policies and ✂ [REDACTED]

³⁵⁹ Paragraphs 6, 24 and 97 of BT/EE response.

AYCE tariffs were not sufficient measures to address congestion and poor data speeds on its network 360 [REDACTED] .

A7.6 NERA said that, 361 [REDACTED] .

Ofcom's response

A7.7 We remain of the view that different MNOs can pursue different commercial strategies that make different use of their network capacity. This is consistent with the response of 362 [REDACTED] .

A7.8 We recognise that if some MNOs need to adopt very restrictive commercial strategies to cope with limited capacity, then competition for some segments of users may weaken. But there may be scope for commercial strategies to limit the adverse impact on competition whilst still having a material positive effect on the management of network capacity. Different MNOs may have more or less scope, depending on their specific circumstances, including the nature of their customer base.

A7.9 While H3G said that it cannot significantly increase data speeds for its customers by making changes to its prices, we continue to judge that there is scope 363 [REDACTED] .

A7.10 Our view is informed by 364 [REDACTED] .

Figure A7.1 365 [REDACTED]

A7.11 H3G said 366 [REDACTED] .

A7.12 We do not have similar evidence in relation to the scope for O2 to adopt such commercial strategies to limit the adverse impact on competition.

³⁶⁰ Paragraph 18 to 26 of Annex 2 of H3G response.

³⁶¹ Pages 109 and 110 of NERA report (confidential version).

³⁶² Footnote 31, page 18 of Annex 18 of H3G's response.

Annex 8

Future credibility of MNOs

Introduction and summary

- A8.1 This annex considers the role of spectrum holdings in the future ‘credibility’ of the four existing MNOs in the UK. By credible we mean that an MNO is able to exert an effective constraint on its rivals.
- A8.2 We first summarise what we said in the November 2016 consultation, then summarise responses and set out our final assessment on the future credibility of the spectrum holdings of each four MNOs in the market currently.
- A8.3 In our assessment of spectrum for the future credibility of the MNOs, we set out:
- The meaning of ‘credible’ MNO
 - Our framework for assessing credible spectrum portfolios
 - The minimum share of spectrum for credibility
 - The current commercial and financial position of O2 and H3G
 - Our conclusions on the future credibility of MNOs
- A8.4 We conclude that neither of BT/EE nor Vodafone needs to obtain spectrum in this award to retain credible spectrum portfolios in the first or second transitional periods or the longer term.³⁶³ It is unlikely that either O2 or H3G would cease to be credible MNOs in the first transitional period even if they did not obtain spectrum in this award. After the first transitional period, H3G has stronger spectrum holdings than was previously the case because of its purchase of UK Broadband. We consider that H3G is unlikely to need additional spectrum to enable it to be credible in the second transitional period and longer term. However, if O2 did not obtain any spectrum in this award, its share of spectrum would be below 10% in the second transitional period (when we expect the 3.4 GHz and 700 MHz bands to be useable). O2 might need more spectrum to remain credible in the second transitional period and the longer term.³⁶⁴

Summary of November 2016 consultation

Framework for assessing credible spectrum portfolios

- A8.5 In the November 2016 consultation, we set out a framework for assessing the spectrum portfolios of the existing MNOs, taking the framework we used for the assessment for the 2013 auction as our starting point. We considered four dimensions of capability:

³⁶³ See from paragraph 5.32 for an explanation of what we mean by the first and second transitional periods, and the longer term.

³⁶⁴ Without additional spectrum either in the Auction or future awards, such as for the 700 MHz or 3.6-3.8 GHz bands, O2’s spectrum share would be below 8% in the longer term.

- a) Capacity and average data speeds;
 - b) Quality of coverage;
 - c) Highest peak data rates; and
 - d) Other quality dimensions.
- A8.6 We considered that, at least for the next few years, it is only in terms of capacity and coverage that there are necessary minimum components which an MNO will need to be credible. Longer term, a route to 5G might also be important to credibility, but it is unclear what spectrum bands might be sufficient to achieve this.
- A8.7 Against these dimensions, we then considered the holdings of each of the existing four MNOs.

Minimum share of spectrum for credibility

- A8.8 We considered that it remains necessary to have sufficient spectrum for capacity to deliver a competitive average data rate and we considered what was the minimum share of spectrum required to achieve this.
- A8.9 We said we had not found clear evidence through any of our updated analysis to change the judgement reached for the competition assessment for the 2013 auction that there is a material risk of an MNO not having sufficient spectrum to be credible if it holds less than 10-15% of spectrum.

Assessment of future credibility of MNOs

- A8.10 We explained that BT/EE or Vodafone do not need to obtain spectrum in this award to retain credible spectrum portfolios.
- A8.11 For O2 and H3G, we noted that their shares of spectrum were within or slightly above the 10-15% range for currently allocated spectrum and for spectrum immediately useable after the auction, their performance to date was consistent with them being credible MNOs currently, and they are both strongly cash-flow positive. Given this, we considered it unlikely that O2 or H3G would cease to be credible MNOs in what we now call the first transitional period if they failed to obtain any additional spectrum in this award.
- A8.12 In the longer term, we concluded that O2 and H3G may need more spectrum to remain credible. They would both have a low share of spectrum, of around 10% or less, if they did not obtain any in this Auction. But this award will not be the only opportunity for them to obtain spectrum in the longer term. For example, we said there was a confirmed award at 700 MHz and a proposed award at 3.6-3.8 GHz.

Summary of responses

Framework for assessing credible spectrum portfolios

- A8.13 BT/EE considered that in assessing credibility, we must keep in mind the observable evidence of how competition has evolved to date. It noted that O2 has performed very well in retail and wholesale markets, for example recently winning the wholesale business of two potentially large MVNOs, Sky and TalkTalk. BT/EE quoted the Chairman and CEO of Telefónica saying that O2 had the lowest churn

and best quality mobile asset in the UK, and pointed to analysis by Enders Analysis showing that O2 had the lowest churn rate of the four MNOs. BT/EE said that H3G has a very strong spectrum holding on a per subscriber basis, and had recently been voted the best network for internet use by a YouGov survey.³⁶⁵

A8.14 On the dimensions of quality that Ofcom considered, BT/EE noted that:

- **Coverage:** MNOs with significant holdings of sub 1 GHz spectrum are able to offer better indoor coverage and more easily offer widespread geographic coverage. %< [REDACTED] . If there were a high value customer segment that demanded consistently high data speeds (which BT/EE says Ofcom has not shown), then BT/EE disputes that greater asymmetry of spectrum holdings would lead to a competition concern.³⁶⁶
- **Capacity:** In its decision on the proposed merger of H3G and O2, the European Commission conducted a detailed review of H3G's future network plans and its claims to be capacity constrained and concluded it was not capacity constrained.³⁶⁷ BT/EE also said that the EC had conducted an in-depth review of O2's arguments and that the EC concluded that "*it appears unlikely that O2's ability to compete would materially deteriorate ... in the next two to three years.*"³⁶⁸
- **Speeds:** BT/EE thought it was important to distinguish between peak and average speeds, as it argued that peak theoretical speeds are of less relevance to consumers. Even for average speeds, BT/EE argued that this was only one of a range of aspects of quality. %< [REDACTED] .³⁶⁹
- **Other competitive advantages:** BT/EE considered that other parameters that are important to competition include, amongst other things, brand, customer service and value added services (e.g. O2's 'Priority Moments').³⁷⁰

A8.15 BT/EE considered that Ofcom was wrong to simply calculate overall holdings of spectrum, as total volume of spectrum gave little indication of the nature of retail and wholesale competition. BT/EE said that spectrum shares may be informative of one aspect of capacity, but provided no insight into the many other aspects of quality including coverage. BT/EE provided estimates of spectrum shares by value in which it held around 33% of spectrum by value, which was similar to its share of network subscribers. We discuss this further from paragraph A11.51.³⁷¹

A8.16 The report by NERA, which is part of O2's response, considered that coverage was not relevant. It said that all four operators have made significant strides with respect to geographic coverage in recent years, and that Ofcom argues that all operators have at least the minimum spectrum necessary for coverage. It said that while customers often express dissatisfaction regarding coverage, such concerns primarily relate to the pace at which 4G networks have been rolled out, persistent

³⁶⁵ BT/EE's response, paragraphs 8 and 34.

³⁶⁶ BT/EE's response, paragraphs 18-19.

³⁶⁷ BT/EE's response, paragraph 20-21, which refers to paragraphs 774 and 2097 of the EC's H3G/O2 Final Decision.

³⁶⁸ BT/EE's response, paragraph 22, which refers to paragraph 869 of the EC's H3G/O2 Final Decision.

³⁶⁹ BT/EE's response, paragraphs 25-29.

³⁷⁰ BT/EE's response, paragraphs 32-34.

³⁷¹ BT/EE's response, paragraphs 36.

“not spots” within otherwise covered areas and poor performance of networks at cell edges. It considered that these problems were in large part due to lack of capacity spectrum.

A8.17 NERA considered there were three relevant dimensions in generating welfare benefits for consumers and supporting downstream competition:

- 4G capacity and average download speeds
- Headline speed
- 5G readiness

A8.18 It considered that the ability to provide adequate capacity and average data rates has emerged as the critical factor. It placed much less weight on headline speeds and 5G readiness.³⁷²

A8.19 H3G argued that speeds were now a critical dimension of competition, which are in turn a function of the amount of spectrum available. In its response³⁷³ H3G argued that nowadays customers use more data, are willing to pay extra for higher speeds and are more likely to leave if speeds reduce. We discuss some of this further in annex 2.

A8.20 Cityfibre said that Ofcom’s analysis of the ‘route to 5G’ was inconsistent. It said that on the one hand, Ofcom said that if BT/EE and Vodafone were hindered in their ability to enter this auction, then their 5G rollout will be harmed. On the other hand, it said that Ofcom argued that the risk of foreclosure of the market as a result of neither O2 or H3G being able to secure spectrum in the auction is limited because other spectrum may be available at some point in the future. It said that the reality was that the only parties that would have the option of still launching 5G even if they obtained no 3.4 GHz spectrum were BT/EE and Vodafone, given the extent of their existing holdings.

Minimum share of spectrum for credibility

A8.21 NERA argued that additional investment in networks was not a sufficient substitute for spectrum, especially in light of the expected growth in demand.³⁷⁴ It concluded that absent additional spectrum, these investments will not be sufficient to convey the expected growth in demand. We explain these arguments and assess them in annex 6.

A8.22 H3G argued that it faces a large disadvantage due to lacking economies of scale with respect to both coverage³⁷⁵ and capacity. H3G said that capacity has become critically important to competition in the light of the increasing relevance of data in the market.³⁷⁶

A8.23 H3G commissioned Professor Peha to analyse the implications of Ofcom’s assessment on 10-15% minimum spectrum shares. In annex 5 of H3G’s response,

³⁷² Section 6.1, NERA report.

³⁷³ Annex 3 of H3G’s response.

³⁷⁴ Section 5 of NERA’s report

³⁷⁵ H3G’s response, page 59.

³⁷⁶ H3G’s response, page 60.

Professor Peha argued that economies of scale with respect to capacity will make competition difficult to sustain in the presence of large disparities in spectrum holdings.³⁷⁷ We describe Professor Peha's analysis and conclusions in more detail below.

- A8.24 H3G also argued that an MNO cannot feasibly match the capacity and speeds of an MNO with twice the spectrum through network densification. We consider this argument in annex 6.
- A8.25 As discussed in annex 4, NERA noted that Ofcom identified six MNOs across Europe with a share of spectrum at or below 15%. It argued that a closer look at these six operators reveals they are poor comparators for the UK market, as in every case there are special circumstances (Free in France, Tele 2 and Ziggo in the Netherlands, T-2 and Telemach in Slovenia, and Yoigo in Spain).³⁷⁸
- A8.26 H3G also argued that the success rate of MNOs with a 10-15% spectrum share was very low.³⁷⁹ H3G said it had reviewed the countries that were used as reference points by Ofcom in 2012 and found that, at the time, ten MNOs fell within the 10-15% range. Most of the countries are considered in annex 4, but H3G also commented as follows on three further countries:
- Telenet Tecneo in Belgium has ceased operations;
 - Three Austria has merged; and
 - H3G UK and T-Mobile USA had their mergers blocked.
- A8.27 H3G argued that the only two operators that have escaped this fate are Free in France and Tele 2 in the Netherlands. However, H3G considered that, as a fixed line operator, Free does not rely principally on its mobile business. H3G also noted that Tele 2 started as an MVNO and only launched its own 4G service in 2015.
- A8.28 H3G rejected Ofcom's view that *"there are European operators within the 10-15% spectrum range which have apparently been able to compete"*. H3G argued that Ofcom only provided two examples of such MNOs (Free in France and Telemach in Slovenia) and that Slovenia was not included in the 2012 sample while it quoted an Enders Analysis report alleging that consolidation talks have restarted in France.
- A8.29 O2 considered that, even if there were a long-term alternative to obtaining spectrum that would allow it to increase capacity (and it considered that there was not), then it would not be < [REDACTED] . This is because there was a real risk that the competition effects of even a temporary loss of capacity could endure in the long term.
- A8.30 O2 also considered that Ofcom's view that 10-15% of spectrum was sufficient to support a credible competitor was not correct from a long-term perspective, and was not supported by international comparisons.³⁸⁰

³⁷⁷ Annex 5 of H3G's response, Section 7.

³⁷⁸ From page 43 of NERA report.

³⁷⁹ Page 63 of H3G's response.

³⁸⁰ O2's response, paragraphs 44 and 45, and section 5 of the NERA report.

- A8.31 NERA argued that congested networks can be expected to compete less vigorously for customers and may cease to be credible competitors for customers that place a high value on reliable network performance. In the worst case, NERA said that a congested network may suffer a consumer backlash that greatly diminishes its brand value and reduces its credibility across the entire market. NERA and O2 referred to the experience of Vodafone-Hutchison Australia (VHA) as an example of this.³⁸¹ We consider the experience of VHA from paragraph A11.109.
- A8.32 Responses also discussed the current state of competition in the UK and network performance comparison, which are discussed in annexes 1 and 5 respectively.

Current commercial position of H3G and O2

- A8.33 BT/EE said that H3G has boasted of consistent year on year growth in EBITDA, cash flows and subscribers over the period H1 2012 to H1 2016, and that H3G was the industry leader in terms of EBITDA and cash flow margins.³⁸²
- A8.34 H3G considered Ofcom's assessment of its financial position was ✂ [REDACTED]. It also noted that Ofcom had said it had the highest EBITDA margin, but that this was not a measure of absolute profitability or sustainability.³⁸³
- A8.35 H3G argued that it is still sub-scale despite its RAN sharing agreement with EE. It said that it has had to deploy thousands of sites in order to cover the UK's geography. It argued this is largely a fixed cost and independent of traffic or market share and quantified these costs using Ofcom's Mobile Call Termination model (MCT). It concluded that this cost puts H3G at a large cost disadvantage relative to its larger rivals.³⁸⁴
- A8.36 O2 argued that reliance should not be placed on its commercial success to date because that commercial success was explained by: ³⁸⁵
- O2's average customer data usage having lagged behind that of others, a position which will come to an end given the rate of traffic growth on O2's network;
 - ✂ [REDACTED] ; and
 - ✂ [REDACTED] .
- A8.37 In contrast to its current commercial success, O2 said that ✂ [REDACTED] .³⁸⁶

Assessment of credibility of four MNOs

- A8.38 BT/EE argued that Ofcom is right to find it unlikely that any of the four MNOs would cease to be credible in the next few years even if they did not obtain any spectrum in this award.³⁸⁷

³⁸¹ Page 91, NERA Report.

³⁸² Page 18 of BT/EE response.

³⁸³ Page 68-69 of H3G's response.

³⁸⁴ Page 56-58 and Annex 22 of H3G's response.

³⁸⁵ Paragraph 40, O2's response.

³⁸⁶ Paragraph 39, O2's response.

³⁸⁷ Paragraph 35, BT/EE's response.

- A8.39 O2 argued that in the period up to mid-2020, < [REDACTED] ³⁸⁸ .³⁸⁹
- A8.40 H3G argued that < [REDACTED] ³⁹⁰ .³⁹¹
- A8.41 Vodafone said that all four MNOs will remain credible players, regardless of the outcome of the auction for 2.3 GHz spectrum. Even if H3G and O2 did not acquire access to 2.3 GHz spectrum, they would remain credible players, with 10-11% of spectrum. It said that the EC had also reached the view during its investigation of the proposed H3G/O2 merger that neither H3G nor O2 are suffering from a spectrum deficit that could result in a loss of credibility.
- A8.42 Vodafone said that H3G's currently high spectrum utilisation is a result of its own commercial decisions and could be reversed by making different commercial decisions, either in the Auction or in setting its market strategy.
- A8.43 Vodafone said that if O2 feels that it is capacity-constrained, then the Auction would provide an opportunity to address this. Vodafone said there was no reason to suggest that O2 would require or merit special treatment in the Auction to facilitate the purchase of spectrum. It said if O2 were truly constrained, it would presumably value the spectrum more highly than other bidders. Vodafone also said that, like other operators, O2 has other options such as further increasing the volume of Wi-Fi sites and utilising further unlicensed bands.³⁹²
- A8.44 UK Broadband said that if one of the smaller MNOs did not acquire access to any 2.3 GHz or 3.4 GHz spectrum, that would be likely to pose a significant threat to their ability to compete in the market from 2018 onwards and could potentially discourage further network investment.³⁹³

Ofcom's response

Meaning of 'credible' MNO

- A8.45 A number of responses commented on the meaning of being a 'credible' competitor. As we said in the November 2016 consultation, by 'credible' we mean that a competitor is able to exert an effective constraint on its rivals - in terms of factors such as the provision of high quality services, competitive prices, choice and innovation - and so contribute to the overall competitiveness of the market.³⁹⁴ This is the same concept that we used in the July 2012 auction statement.³⁹⁵
- A8.46 We use the concept of 'credible' MNOs to refer, in effect, to the number of sustainable national 'network players' in the market. In these terms, the UK market is a four-player market, with four competing MNOs. This can be compared to some other European markets, which are now three-player markets, such as Germany, Austria and Ireland (in each of these countries, due to a merger between two of their MNOs). Therefore, the consequence if a UK MNO were to have a spectrum

³⁸⁸ O2's response, paragraph 42.

³⁸⁹ O2's response, paragraph 28.

³⁹⁰ Page 77 of H3G response

³⁹¹ Annex A, page 148 of H3G's response

³⁹² Pages 23 to 25, Vodafone's response

³⁹³ Page 3, UK Broadband's response

³⁹⁴ Paragraph 4.6, November 2016 consultation.

³⁹⁵ See from paragraph 4.25 of the July 2012 auction statement, https://ofcom-build.squiz.co.uk/_data/assets/pdf_file/0031/46489/statement.pdf

portfolio that meant that it would no longer be capable of being credible is that the UK would similarly become a three-player market.

- A8.47 In the context of spectrum auctions, our threshold for credibility is the *minimum* spectrum that an MNO needs to be capable of being credible and so maintaining a four-player market. We consider that an MNO can be a credible competitor even though it is not in a strong position in all dimensions of service, or in delivering particular services or to particular customers, or for a temporary period. And just because an MNO is credible, this does not mean it will necessarily have a leading market position. For example, an MNO with a low share of spectrum may have lower capacity than other operators, and may not be able to sustain a very high share of subscribers, or to compete strongly for all customer segments. But we would still regard such an operator as capable of being credible provided its spectrum allowed it to be able to exert a sufficiently effective constraint on rivals and contribute to the overall competitiveness of the market, and provided it could do this in a way that allowed it to be sustainable and financially viable.
- A8.48 Since MNOs remaining capable of being credible is a minimum requirement for a four-player market, even where this is satisfied, the strength of competition between those four MNOs can vary. The effective number of MNOs³⁹⁶ is an important influence on the competitiveness of the mobile market (especially given high barriers to entry at the national wholesale level). But it is not the only influence on market competitiveness. Therefore, in addition to the potential competition concern about credibility, we have identified a second type of concern about the strength of competition between credible MNOs.
- A8.49 We developed this framework of two types of competition concerns, including the concept of credible competitors, in the context of spectrum auctions because of its relevance to potential competition measures. Either type of competition concern could have significant adverse consequences for competition and consumers, and could imply a need for competition measures. But they vary in the scale of their potential adverse impact and might suggest different types of competition measures. This can be seen when we applied this framework to the 2013 auction, in which we imposed two categories of competition measures:
- a) Spectrum reservation to address our concern for that auction about the credibility of a fourth MNO; and
 - b) Safeguard caps (for both sub-1 GHz and overall spectrum holdings) to address our concern for that auction about the strength of competition between four credible MNOs.
- A8.50 For the 2.3 / 3.4 GHz award we have also assessed both types of competition concern. Importantly, just because there are four credible players in a market, it does not mean that all four MNOs are equally strong or that competition is as strong

³⁹⁶ A holding of mobile spectrum and expecting to enter as a network operator is not sufficient to be regarded as an MNO. For example, before the BT/EE merger, we did not regard BT as having sufficient spectrum to be a credible MNO, and did not consider its entry as a network operator would make it a five-player market (see paragraph 7.83, November 2014 consultation, https://www.ofcom.org.uk/data/assets/pdf_file/0025/78055/Public_Sector_Spectrum_Release_2-3_and_3-4_ghz_award.pdf). This is similar to the CMA's decision on the BT/EE merger that, without the merger, BT would have provided limited additional competition to MNOs, and that BT was not currently a strong competitor in retail mobile and that its market share forecasts were modest (see paragraph 11.81, *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016, <https://www.gov.uk/cma-cases/bt-ee-merger-inquiry>).

as it could be. We therefore disagree with BT/EE that, if it is unlikely that any of the four MNOs would cease to be credible, there can be no basis for intervening, as discussed further from paragraph A11.4 below.

- A8.51 Regarding O2's arguments about the position of VHA in Australia, while VHA's retail market share fell from 24% in 2011 to 18% in 2014, we note the comments of the ACCC, the competition authority and telecoms regulator in Australia. The ACCC said in 2016 that, although Telstra maintains a high market share, Optus and VHA have continued to invest in their mobile networks and that the mobile market in Australia remains competitive, with strong competition between operators. Based on this description of competition in the market, we consider that we would regard VHA as being a credible MNO under our framework.³⁹⁷ We also discuss VHA further from paragraph A11.109.below.

Framework for assessing credible spectrum portfolios

- A8.52 In our competition assessment for the 2013 auction, we compared the spectrum holdings of the existing four MNOs against a framework of what might be sufficient to ensure each MNO was capable of being a credible competitor in the future. We adopt a similar approach here.
- A8.53 Below we describe the framework we used for the 2013 auction, which we also set out in the consultation, and then update it, including considering responses. Figure A8.1 sets out the conclusions we reached in the 2013 auction on the four quality dimensions we considered when assessing whether a spectrum portfolio would be sufficient to allow an MNO to be credible.³⁹⁸

Figure A8.1: Conclusions on dimensions of capability (each considered in isolation) and spectrum for credibility from assessment for 2013 auction

Quality dimension	Necessary condition for credibility?	Important for helping provide sufficient capability for credibility?
Capacity and average data rates	Necessary to have enough capacity to deliver a competitive average data rate. Not necessary to have 25% of paired spectrum, partly because there are other ways of providing capacity. There is a material risk of not achieving the necessary minimum if hold less than 10-15% of paired spectrum after the Auction.	Greater spectrum share than 10-15% increases capability. A much larger holding than this is an important capability strength .
Quality of coverage	Necessary to have enough quality of coverage. Sub 1 GHz spectrum is unlikely to be necessary , given alternative ways of providing good quality coverage. Greater risk of not having the necessary minimum quality of coverage the higher the frequency on which the	While unlikely to be necessary, sub 1 GHz spectrum is likely to give some advantage and so is an important capability strength .

³⁹⁷ Pages 6 and 26 and Figure 2.7, Competition in the Australian telecommunications sector: Price changes for telecommunications services in Australia, February 2016, ACCC, https://www.accc.gov.au/system/files/ACCC%20Telecommunications%20reports%202014%E2%80%9315_Div%2011%20and%2012_web_FA.pdf

³⁹⁸ The table is reproduced from Figure 4.2 in our July 2012 statement.

	national wholesaler is relying for coverage.	
Highest peak data rates	Unlikely to be necessary to deliver highest peak data rates for credibility. So unlikely that access to 2x15 MHz or 2x20 MHz contiguous block of 800 MHz, 1800 MHz or 2.6 GHz spectrum is necessary to be credible.	Ability to deliver highest peak data rates may be a source of capability strength, but it is unclear how important this is as a contribution to credibility.
Other LTE advantages (e.g. better latency)	Unclear that it is necessary to deliver services with other LTE advantages, such as better latency, in the near term. So unclear that access to 800 MHz, 1800 MHz or 2.6 GHz spectrum is necessary to be credible. However, providing LTE services is more likely to be necessary longer term to be credible. In the longer term 900 MHz spectrum is likely to provide a route to LTE.	Other LTE advantages may be a source of capability strength, but it is unclear how important as a contribution to credibility. Longer term, the importance of this strength is likely to grow , and 900 MHz spectrum is likely to provide a route to LTE.

Dimensions of capability

- A8.54 **Capacity and average data rates:** It remains necessary to have sufficient spectrum for *capacity* to deliver a competitive average data rate to customers. We reconsider below the conclusion from the 2013 auction assessment about the appropriate share of spectrum required, taking account of responses.
- A8.55 **Quality of coverage:** We also consider that spectrum for sufficient *coverage* is necessary. As discussed below, all four MNOs currently have at least the minimum spectrum necessary for coverage. The technical characteristics of the spectrum which we are auctioning also mean that it is not an effective means of extending existing levels of mobile coverage.
- A8.56 **Highest peak data rates:** It is now possible to offer much higher peak data rates³⁹⁹ than at the time of the 2013 auction through the use of carrier aggregation with LTE-Advanced technology. This newer technology allows carriers to be aggregated across different spectrum bands and so reduces the benefits of having *contiguous* spectrum. However, our view on the importance of peak data rates is unchanged. We continue to consider it unlikely to be necessary for an MNO to deliver the highest peak data rates in order to be credible. It is average data rates that are more important for consumers' experience than peak data rates. The ability to deliver the highest peak data rates may be a source of capability strength, but it is unclear how important this is as a contribution to credibility. It might be argued that our view is inconsistent with the emphasis that BT/EE places on speed in its

³⁹⁹ The peak data rate is the data rate that can be delivered under ideal signal conditions and without contention between users (i.e. a single user occupying all of the resources of one cell and very close to the base station). This is distinct from the average data rate which is what users actually experience on average under realistic conditions in a network shared with other users, which we consider under capacity.

marketing. However, much of BT/EE's marketing relates to a particular measure of *average* speeds rather than peak speeds.⁴⁰⁰ We also note that there are few mobile applications that can make use of the very high peak speeds of over 300 Mbps, meaning that there would be little direct value for consumers in having the highest peak data rates. We discuss responses on the factors affecting competition, including average and peak speeds, and our assessment of responses in annex 2.

- A8.57 **Other LTE advantages:** The last quality dimension we considered for the 2013 auction no longer appears relevant as a distinction between MNOs, as all four MNOs are deploying LTE. We also note that there are now user devices that can use LTE with a wide range of spectrum bands (including 900 MHz and 2.1 GHz), and not just 800 MHz, 1800 MHz and 2.6 GHz.
- A8.58 We have also considered whether any new quality dimensions may be relevant. In particular, whether having an early route to deploying 5G services may be important. This is potentially relevant given the role that the 3.4 GHz band may play in providing 5G services. At this time we consider it unlikely that an early route to 5G will be a necessary requirement to having a credible spectrum portfolio in the second transitional period. However, in the longer term, MNOs are likely to need a route to 5G. The 3.4 GHz band is likely to provide one such route, as would other spectrum in the 3.6-3.8 GHz band. The 700 MHz band may also be used for 5G services. In addition, we expect that some of the existing bands will become useable for 5G services, and new bands might also become available. However, at present it is unclear which of the current bands will be useable for 5G and in what timeframe.
- A8.59 To summarise, for at least the first and second transitional periods, we consider it is only in terms of capacity and coverage that there are necessary minimum components which an MNO will need to be credible. Longer term, a route to 5G might also be important to credibility, but it is unclear what spectrum bands might be sufficient to achieve this. Neither the 2.3 GHz or the 3.4 GHz bands are likely to be used for the provision of coverage. As a result, the relevant considerations for credibility in the context of this award are capacity and, potentially, the relevance of 3.4 GHz as a route to 5G.

Applying judgement to assess the spectrum portfolio

- A8.60 We explained in our competition assessment for the 2013 auction that having only the bare minimum in each of the coverage and capacity dimensions may not be sufficient – an MNO might need to have more capability in at least one dimension to be credible.
- A8.61 For example, one MNO may have the necessary components together with much more than the necessary minimum capability in capacity, while another may have the necessary requirements and much more capability in terms of coverage. Alternatively, sufficient overall capability might be achieved through having only a little more than the minimum necessary in each of these two dimensions.

⁴⁰⁰ For example, EE's advertising that its network is "50% faster" than all other networks relates to *average* 4G download speeds based on information from Ookla speed tests by users (which we discuss further in Annex 8). <http://ee.co.uk/why-ee> While EE does also refer to its 'real-world' peak data rate of over 360Mbps at Wembley Stadium, this is a less prominent part of its advertising, <http://newsroom.ee.co.uk/ee-launches-next-phase-of-4g-for-the-worlds-fastest-smartphones/>

- A8.62 Another way of viewing this is in terms of risk. If an MNO does not have the necessary minimum capability in coverage or capacity, it is unlikely to be capable of being credible. However, it is not straightforward to specify these necessary minimum requirements with precision. We make a judgement in the light of the available evidence in the form of a range rather than a single threshold figure. Taking into account the uncertainty associated with our judgement, we consider that if an MNO is towards the lower end of the range in either capacity or coverage capabilities, there is a risk that it would not be capable of being credible.
- A8.63 As in our competition assessment for the 2013 auction, we do not consider that having a share of spectrum at or below the 10-15% range automatically means that an operator will not be a credible MNO. We recognise that share of spectrum is a simple measure that does not take into account the differences in spectrum of different frequencies and other factors.⁴⁰¹

Minimum share of spectrum for credibility

- A8.64 We have reviewed whether there are any reasons to revise our 2013 assessment of the minimum share of spectrum needed to be credible.

Professor Peha's report

- A8.65 We have analysed Professor Peha's report. We accept that it may be difficult to compete with a very low share of spectrum. But we do not find the report informative in terms of the limit for the minimum share of spectrum to be credible.
- A8.66 Professor Peha's analysis relates to what he calls a capacity-limited region, which he defines as "*where a carrier that merely deploys the minimum number of cell towers to bring adequate coverage to the region will not have enough capacity*".⁴⁰² For a capacity-limited region, he sets out a theoretical cost model for adding capacity by combining sites (which Professor Peha calls "towers") and spectrum, and then makes assumptions about how revenue relates to capacity to reach strong conclusions about auction outcomes.
- A8.67 In outline, Professor Peha's theoretical cost model assumes:
- "*a carrier's capacity increases linearly with the number of cell towers that the carrier uses, and linearly with the amount of spectrum it holds*";
 - operators can increase capacity by increasing expenditure on either cell sites or spectrum; and
 - operators minimise costs (having an optimal mix of spectrum and sites) for any given level of capacity.
- A8.68 Because Professor Peha assumes that operators have an optimal mix of cell sites and spectrum for minimising the costs of providing any given level of capacity, his model predicts that "*... capacity does not increase linearly with spectrum holdings as many people believe when a carrier minimizes its costs. In this case, capacity increases with the square of spectrum holdings. This is because a rational carrier will increase spectrum holdings and the number of towers in the capacity-constrained region together. ... the number of towers in the capacity-limited regions*

⁴⁰¹ See, in particular, paragraphs 4.69 to 4.73 of our July 2012 statement.

⁴⁰² Section 2.2, Annex 5 of H3G's response.

is proportional to spectrum holdings ...". The implication is that a 'large' operator with more spectrum and sites can increase capacity from a given amount of additional MHz of spectrum by more than 'small' operators.

- A8.69 Professor Peha also makes the strong assumption that revenues are roughly proportional to capacity. He does not give any explanation for why he is making this assumption (for example, on whether the direction of causality is that having extra capacity drives extra revenue, or whether higher data traffic drives higher revenues and this induces an operator to expand capacity). He then states that "*Since revenue tends to be proportional to capacity in a capacity-limited region, and large carriers can increase their capacity more than small carriers with every MHz of spectrum they obtain, large carriers will generally bid more in spectrum auction than their small competitors*". Professor Peha therefore considers that "*we can expect the big carriers to get bigger*".⁴⁰³
- A8.70 In our assessment of Professor Peha's analysis, we focus on two of his key propositions which do not fit well with the evidence from the UK, namely:
- That the number of sites operators have (in a capacity-limited region) is proportional to their spectrum holdings so operators have an optimal mix of spectrum and sites; and
 - Revenues are proportional to capacity.
- A8.71 For context, we first set out a comparison of the four MNOs by different metrics in the Figure A8.2 below.

Figure A8.2: Comparison of MNOs

	Share of spectrum ⁴⁰⁴	Share of mobile data traffic	Share of network subscribers	Approximate number of sites
BT/EE	42%	33%	33%	18,500
O2	14%	18%	33%	14,000-17,500
Vodafone	29%	13%	22%	14,000-17,500
H3G	15%	36%	11%	< [REDACTED]

Sources: The shares of mobile data traffic are taken from Enders Analysis' UK mobile market Q4 2016 – Nearly back to growth 13 April 2016 (slide 10). The shares of network subscribers are from Analysys Mason data and include the subscribers of hosted MVNOs, and are for Q3 2016. The number of BT/EE sites is taken from BT's 2017 annual report. The number of Vodafone's sites is taken from its web site, where it is reported as currently being 'more than 14,000' with a plan to increase this to 17,500.⁴⁰⁵ We have assumed O2 has the same number of sites as Vodafone. H3G's sites taken from Annex 5 of response.

- A8.72 It can be seen from this table that it is not straightforward to say which MNO in the UK is biggest, as it depends on what dimension is considered. If this is considered in terms of spectrum or sites, BT/EE is clearly biggest; but if it is considered in terms of data traffic, it is H3G; and if using shares of network subscribers, it is O2 that is the largest. Therefore, whilst H3G and O2 have the smallest shares of spectrum, they are the biggest in terms of data traffic and network subscribers respectively.

⁴⁰³ Section 7, Annex 5, H3G's response.

⁴⁰⁴ Including 800 MHz, 900 MHz, 1400 MHz, 1800 MHz, 2100 MHz and 2.6 GHz, but excluding 3.4 GHz and 3.6-3.8 GHz.

⁴⁰⁵ <https://www.vodafone.co.uk/our-responsibilities/our-network/index.htm>

- A8.73 We consider the first proposition (that operators always have an optimal mix of spectrum and sites) to be unrealistic, especially in the context of the UK currently.⁴⁰⁶ For example, spectrum auctions tend to occur at irregular intervals and represent long-term investments for operators at the time of the auction, reflecting expectations of future demand. Therefore, some MNOs may have acquired access to a high share of spectrum in the past and may be making relatively light use of some of that spectrum currently, because they do not have sufficient data demand today to justify deploying the spectrum more intensively (even if they expect to do so in the future as demand grows). Such MNOs can expand capacity over time through the use of their lightly used existing spectrum, broadly consistent with their plans when they acquired access to the spectrum in an earlier auction, rather than being reliant on acquiring more spectrum to add this capacity. We describe how BT/EE and Vodafone are not currently deploying all of their existing spectrum widely from A11.64 below, which suggests they will tend to have a lower value for incremental spectrum in this Auction. In contrast, expanding capacity with current spectrum holdings may be more expensive for MNOs with a low share of spectrum currently. They may be using that spectrum very intensively and may have a high valuation for additional spectrum to profitably meet expected future demand.
- A8.74 We also note that, as shown in the table above, the number of sites is relatively symmetric across the four MNOs in the UK, but their spectrum holdings are substantially more asymmetric. This contrasts to what is predicted by Professor Peha's cost modelling where the number of sites increases proportionally with spectrum holdings. Given their very different starting positions, operators with high shares of spectrum may consider it cost effective to expand capacity by adding sites, while MNOs with low shares of spectrum may rather expand capacity by acquiring spectrum.
- A8.75 Regarding the second proposition (revenues are proportional to capacity), it is not clear there is a strong relationship between revenues and capacity; and if there is some weak relationship between them, the nature of the causality is unclear. Competition between MNOs is much richer than just relating to capacity and average speeds. As explained in annex 2, while average speeds are one factor affecting competition, there are many other factors affecting retail competition including price, customer service and other aspects of network quality, such as coverage. This means that revenues are not necessarily proportional to capacity in a capacity-limited region. Even if an MNO only currently has a low share of spectrum and capacity, it may have a high valuation for additional spectrum if it expects to grow its customer base by, for example, offering competitive prices or good customer service. For example, O2 has a high share of (retail and wholesale) subscribers despite having a low share of spectrum, and H3G has the highest share of data traffic despite having a low share of subscribers and spectrum. In annex 1, we also show how Vodafone's share of subscribers has fallen over many years, despite it having a relatively high share of spectrum. This helps to illustrate that competition is more complex than just being about the amount of spectrum, capacity and average speeds.

⁴⁰⁶ We note that Professor Peha recognises that operators may not always have an optimal balance of sites and spectrum, but he says over the long term any "temporary effects should have little impact." However, we consider that in the context of this Auction that the impact of operators having a different balance in terms of spectrum and sites could be considerable.

- A8.76 In addition, a possible implication of Professor Peha's analysis is that operators with small spectrum holdings would be financially unviable. However, our analysis indicates that O2 and H3G are currently financially viable (see below).
- A8.77 We therefore do not consider that the two propositions fit with the evidence on operators' positions currently and the UK mobile market. Consequently we do not agree with the strong deterministic conclusion of Professor Peha that operators with large spectrum holdings will necessarily outbid operators with small spectrum holdings.

International comparisons of minimum shares of spectrum to be credible

- A8.78 In our competition assessment for the 2013 auction we noted that our analysis was consistent with evidence from other countries. This showed that while the shares of spectrum held by MNOs vary considerably, in general, it was unusual for an MNO to hold a share of paired spectrum amounting to less than 10%.⁴⁰⁷
- A8.79 We have reviewed the recent evolution of international spectrum shares in annex 4 and contrasted these with the evolution of market shares. As in our previous assessment, we have focussed mainly on other European countries which have four MNOs, as we consider these to be most comparable to the UK market.
- A8.80 Annex 4 shows that there are now fewer MNOs in Europe than previously that have shares of less than 10-15% of the spectrum useable for mobile services.⁴⁰⁸ This is in part due to the mergers that have taken place in recent years, and also because some operators that previously had low shares have since obtained a higher share of spectrum.⁴⁰⁹
- A8.81 That some operators who had spectrum in the 10-15% range have now merged could be interpreted as an indication that a share of spectrum in the 10-15% range makes it more difficult for an MNO to be credible in the longer term, but this is not necessarily the case. Furthermore, some of the recent mergers - such as the recently approved merger between H3G and Wind in Italy - are not between operators with small spectrum holdings.
- A8.82 Our updated comparison in annex 4 indicates some European operators with small spectrum shares that are not strong competitors currently (Ziggo in the Netherlands, T-2 in Slovenia, and Yoigo in Spain).
- A8.83 However, there are European operators within the 10-15% spectrum range which have apparently been able to compete, as they have increased their market shares - in particular, Free in France, Telemach in Slovenia, and Tele2 in the Netherlands.

⁴⁰⁷ Paragraph 4.73 of our July 2012 statement, and also Figure A2.28 of Annex 2 to the July 2012 statement and paragraphs A2.182 to A2.259.

⁴⁰⁸ Including 800 MHz, 900 MHz, 1800 MHz, 2.1 GHz paired, 2.6 GHz unpaired and 2.6 GHz paired bands. We now include unpaired 2.6 GHz spectrum despite excluding it in our previous assessment. Unlike in 2012, we now consider the unpaired 2.6 GHz spectrum can be considered as mainstream mobile spectrum. We have assumed that all spectrum awarded in these bands in other countries is for high power use.

⁴⁰⁹ For example, Free (Iliad) had a spectrum share of 11.6% at the time of our previous assessment in 2012, but today has a spectrum share of 16.7%, excluding 700 MHz spectrum, which is only now being deployed.

- A8.84 We also note that the merger in Italy between H3G and VimpelCom (Wind), which was approved by the EC in 2016, included spectrum divestment remedies (in addition to infrastructure sharing and transitional national roaming agreements) which will lead to the creation of a new fourth MNO. The spectrum divested to the new entrant amounts to 70 MHz across various bands, so that it will start operations with the equivalent of 12%⁴¹⁰ of the useable spectrum available (see annex 4 for further details).
- A8.85 The EC considered this was sufficient to enable the new MNO to develop and roll out its own mobile network and operate as an MNO, and that this would fully address the EC's concerns about the elimination of competition from the merger of two strong competitors. Iliad of France has already agreed to take these assets to become the fourth national operator after the merger.⁴¹¹ The EC considered that these remedies would *"(...) preserve effective competition, maintain incentives to invest in innovative technologies, and ensure that consumers will continue to benefit from effective competition"*.⁴¹²
- A8.86 In annex 4 we conclude that, based on the evidence from other European countries, there is not enough evidence to reach a reliable conclusion either that a spectrum share of 10-15% is enough to enable an MNO to be credible or that it is insufficient.
- A8.87 For completeness, we note that H3G also refers to Austria, Belgium and the USA, which we do not discuss in annex 4. H3G said that Telenet Tecneo in Belgium ceased operations, H3G Austria merged, and Three UK and T-Mobile USA had their merger prohibited.
- A8.88 With regards to Austria, the European Commission approved the merger between H3G Austria and Orange Austria in December 2012 with remedies intended to address the competition concerns identified.⁴¹³ While H3G Austria had a spectrum share in the 10-15% range before the merger, the European Commission considered it was *"an important, if not the most important, competitive force in the market"*, and that H3G Austria was not claimed to be a failing firm.⁴¹⁴
- A8.89 In the case of Belgium, it is worth noting that Telenet Tecneo never deployed the spectrum to become an MNO⁴¹⁵. When the EC approved the acquisition of the third mobile operator (Base) by Telenet in 2016, it considered the latter to provide mobile services as an MVNO rather than an MNO⁴¹⁶.
- A8.90 In the proposed merger between T-Mobile and AT&T, the FCC did not believe that T-Mobile was in a situation in which its viability was compromised unless it merged. Specifically, the FCC stated that *"T-Mobile has played an important role in the development of a more competitive mobile services marketplace by engaging in both pricing and technical innovation. Although T-Mobile faces challenges as the industry develops and responds to the increasing data demands of consumers, the*

⁴¹⁰ This is calculated including the 1400 MHz holdings of Telecom Italia and Vodafone. The new entrants share of spectrum would be around 13% when calculated excluding the 1400.

⁴¹¹ http://www.iliad.fr/presse/2016/CP_050716_Eng_.pdf

⁴¹² http://europa.eu/rapid/press-release_IP-16-2932_en.htm

⁴¹³ The proposed merger remedies were mostly focused on MVNO access.

⁴¹⁴ See especially paragraphs 283 and 390,

http://ec.europa.eu/competition/mergers/cases/decisions/m6497_20121212_20600_3210969_EN.pdf

⁴¹⁵ See <https://www.telegeography.com/products/commsupdate/articles/2013/08/08/bipt-fines-tecteo-telenet-bidco-over-alleged-rollout-infringement/>

⁴¹⁶ See http://europa.eu/rapid/press-release_IP-16-241_en.htm

*record does not support the bleak short-term outlook for T-Mobile that AT&T has portrayed in its submissions.*⁴¹⁷ Since the merger was abandoned (December 2011), T-Mobile's market share has grown from 10% to over 17% by Q1 2017.⁴¹⁸

- A8.91 Therefore, taking into account Austria, Belgium and the USA does not change our conclusion in annex 4.
- A8.92 Finally, we note that the international comparisons suggest that fairly symmetric spectrum distributions do not necessarily lead to more even market shares as we discuss in annex 4. For example, markets in Denmark, Sweden and Italy (pre-merger) have significant differences in subscriber market shares despite relatively symmetric distribution in spectrum. It is therefore clear that other factors affect the viability and market performance of an operator beyond spectrum holdings.

Conclusion on share of spectrum necessary to be credible

- A8.93 In a market where there are four MNOs holding all the spectrum, then symmetric holdings would imply each having 25% of spectrum. However, we do not consider that MNOs need close to equal shares of spectrum for them all to be credible. This is partly because spectrum is only one way of adding capacity, as there is some scope to trade off network investment and spectrum in terms of adding capacity (as discussed in annex 6). Moreover, it is not necessary for all MNOs to have the same capacity for them all to be credible. Different MNOs can have different market shares, and may pursue different commercial strategies and still be credible (as discussed in annex 7), especially given that average speeds are only one of the factors that drive competition (as discussed in annex 2). We therefore consider that an MNO could have a substantially lower spectrum share than 25% and be a credible competitor.
- A8.94 However, if an operator's spectrum holdings were too low, it might struggle to add sufficient capacity to be a credible competitor. It would tend to have higher marginal costs of adding capacity than an operator with a high spectrum holding, thereby limiting its ability to constrain rivals on a sustainable basis.
- A8.95 The link between spectrum holdings and market performance is not deterministic or mechanical. The international comparisons also suggest factors other than spectrum affect the viability and market performance of operators. Given this, we do not consider it surprising that we have not seen compelling evidence to provide a definitive view on the level or range of share of spectrum which is too low for an MNO to be capable of being credible. In our view, therefore, this is a matter for regulatory judgement, taking account of the available evidence.
- A8.96 For the 2013 auction, our judgement was that there is a material risk of an MNO not having sufficient spectrum to be credible if it holds less than 10-15% of spectrum.
- A8.97 In the UK, we find that O2 and H3G have been and remain credible competitors with spectrum shares in the 10-15% range, as discussed below.
- A8.98 On balance, we have not found clear evidence through any of our updated analysis to change the judgement reached for the competition assessment for the 2013

⁴¹⁷ See paragraph 22 at https://apps.fcc.gov/edocs_public/attachmatch/DA-11-1955A2.pdf

⁴¹⁸ Source: <https://www.statista.com/statistics/199359/market-share-of-wireless-carriers-in-the-us-by-subscriptions/>

auction. This judgement takes into account our analysis above, and also in other supporting annexes (especially in annexes 2, 6 and 7).

- A8.99 We have commented above and in annex 4 on international comparisons, and the consistency of that evidence with our judgement on the 10-15% range. Overall, in our view the evidence neither strongly supports nor contradicts our judgement.

Current commercial and financial position of O2 and H3G

- A8.100 In the November 2016 consultation, we said that O2 and H3G had performed well to date, during a period when they have had a share of spectrum in the 10-15% range. We focus on O2 and H3G as they are the operators with low spectrum shares. Below we have updated our assessment of the current commercial and financial position of O2 and H3G with more recent data, and taking account of responses.

- A8.101 In terms of their financial performance, we focus on EBITDA minus capex, which is a measure of the current operational earnings of their mobile businesses less capital expenditure. This measure abstracts from different forms of financing the business by ignoring interest payments and provides an indication of the underlying financial strength of the business. In addition, we also consider the EBITDA margin, especially to compare between the MNOs.

- A8.102 We also consider information on recent market trends, including on mobile service revenue growth, contract ARPU growth, contract net adds and churn. This is to assess whether there is evidence that O2 and H3G's commercial position has weakened recently relative to other MNOs.

- A8.103 We conclude that currently both O2 and H3G are commercially and financially viable.

Current commercial and financial position of O2

- A8.104 Figure A8.3 below shows O2's EBITDA minus capex for the period 2012 to 2016 (calendar years).

Figure A8.3: O2's financial results⁴¹⁹

£millions	2012	2013	2014	2015	2016
Revenues	5,711	5,682	5,692	5,690	5,605
EBITDA	1,298	1,390	1,406	1,400	1,396
Capex (including spectrum)	607	1,176	609	641	761
EBITDA minus capex (including mobile spectrum purchases)	693	214	797	759	636
EBITDA minus capex (excluding mobile spectrum purchases)	693	824	797	759	636

- A8.105 We show EBITDA minus capex, both when mobile spectrum purchases are included within capex and when such purchases are excluded. We do this because

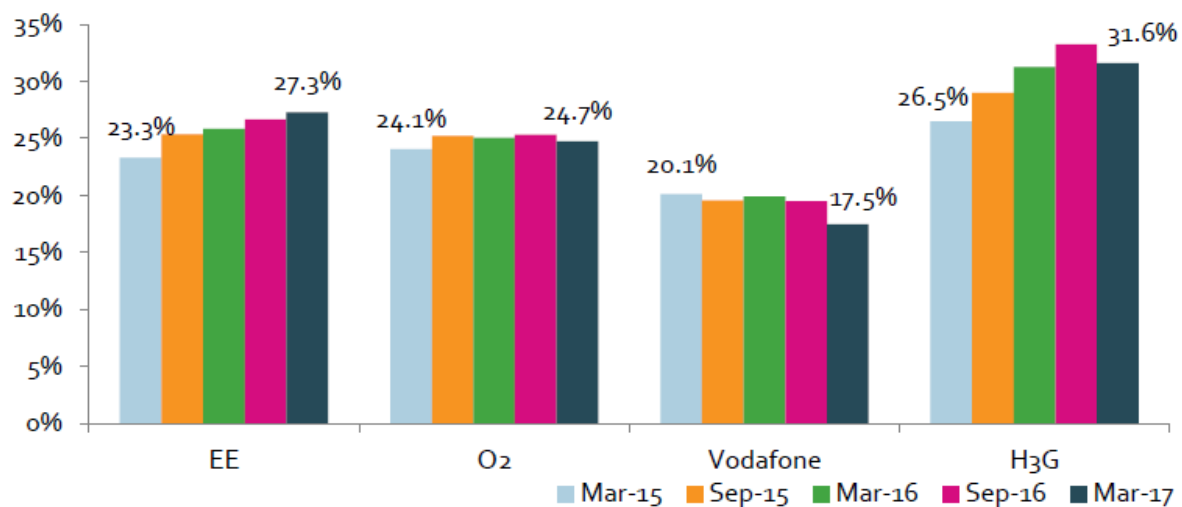
⁴¹⁹ From Telefónica's audited annual reports for 2012, 2013 and 2014, and Telefónica's unaudited quarterly financial updates for 2015 and 2016. Using €/£ exchange rate published by Telefónica, namely, 0.811 for 2012, 0.849 for 2013, 0.806 for 2014, 0.726 for 2015 and 0.817 for 2016.

mobile spectrum purchases tend to be infrequent and the underlying trend can be obscured when such purchases are included. For O2, there is a large increase in its capex in 2013 due to the £550 million (or €719 million) that it spent in the 2013 auction to obtain 2 x 10 MHz of 800 MHz spectrum. This was for a licence with a 20 year initial term. It can be seen that O2's EBITDA minus capex is significant over the whole period even when spectrum purchases are included in capex.

EBITDA margin

A8.106 Below we show a chart from Enders Analysis comparing the EBITDA margin for the four MNOs. This shows that H3G has the highest EBITDA margin, followed by BT/EE. O2 currently has the third highest EBITDA margin, above Vodafone. O2's EBITDA margin has been broadly flat over the period.

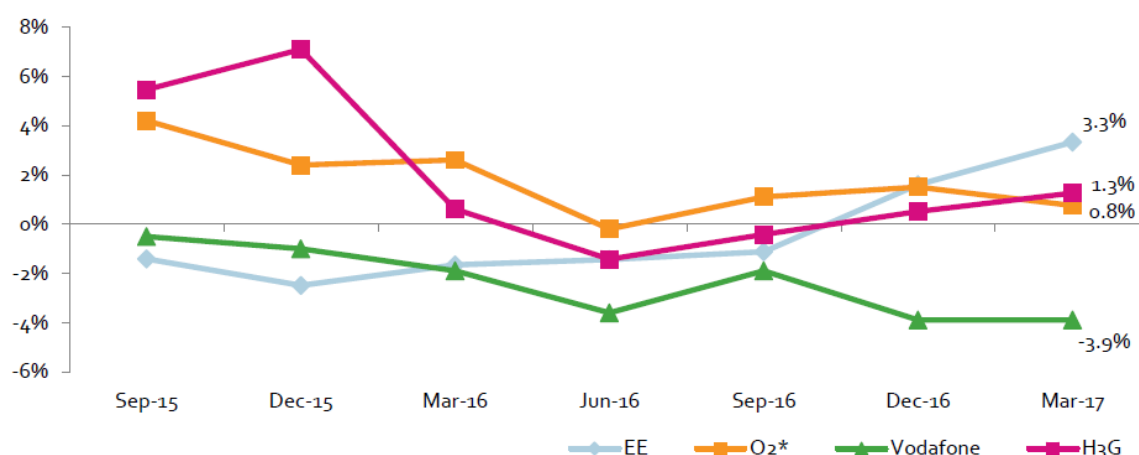
Figure A8.4: EBITDA margin by operator last 12 months



Source: Enders Analysis

Revenue growth, contract net additions and churn

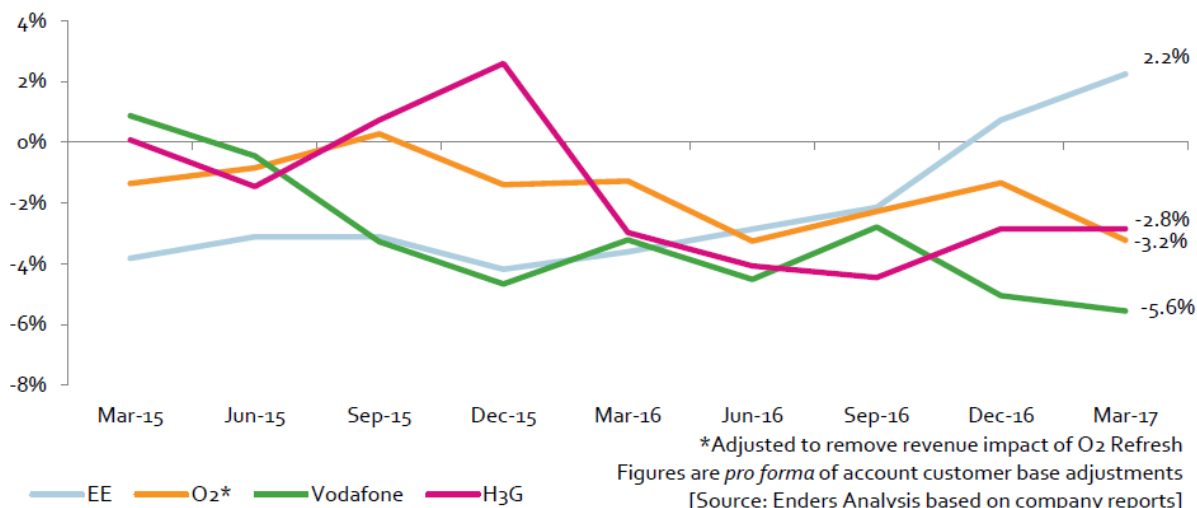
A8.107 According to Enders Analysis, from Q2 2015 to Q4 2016, O2's mobile service revenue growth has been reported to be at or above Vodafone's and EE's. While O2's mobile service revenue growth remained positive in Q1 2017, it fell behind EE's and H3G's.

Figure A8.5: Reported mobile service revenue growth by operator

Source: Enders Analysis – Adjusted to remove revenue impact from O2 Refresh⁴²⁰

A8.108 As shown in the chart below, although O2 is reported to have generally experienced a reduction in contract ARPU over the Q1 2015 to Q1 2017 period, the decline was not as pronounced as EE's until Q2 2016. However, since Q2 2016, EE has had the strongest contract ARPU growth, turning positive from Q4 2016. Vodafone has experienced a stronger contraction in ARPU than O2 since Q2 2015.

A8.109 It is worth noting that all MNOs have experienced a decrease in the share of pre-pay subscribers as a proportion of total subscriber. As a result, in 2016 pre-pay subscribers represented 3% [REDACTED] of the total retail subscribers of Vodafone, O2, EE and H3G, respectively.

Figure A8.6: Contract ARPU growth

Source: Enders Analysis

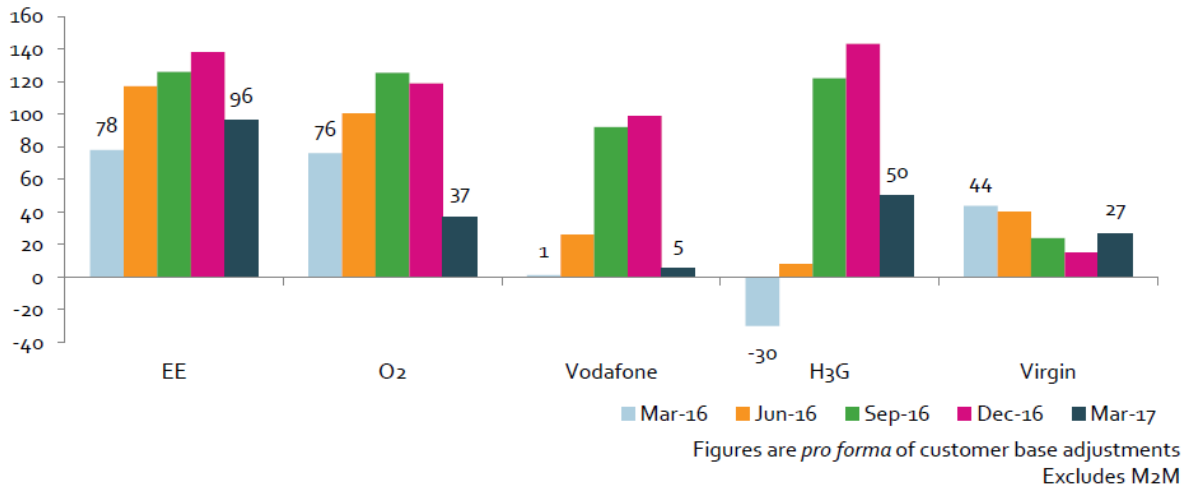
A8.110 As shown in annex 1, O2's retail subscriber shares have remained relatively stable between 3% [REDACTED]. While O2 has lost pre-pay subscribers, its loss of

⁴²⁰ O2 Refresh plans separate the airtime and handset prices so that users can upgrade their handsets early if they so wish

subscribers in this segment has been less pronounced than for EE or Vodafone over the 2011-2016 period. On the other hand, 3< [REDACTED]⁴²¹.

A8.111 According to Enders Analysis, O2's net contract additions were below EE's and H3G's for Q4 2016 and Q1 2017 but had been at a comparable level to EE's over previous quarters and consistently higher than Vodafone's. However, there was a noticeable decrease in the contract net additions for O2 for Q1 2017. However, it should be noted that in Q1 2017 O2 disconnected 228,000 inactive contract accounts⁴²².

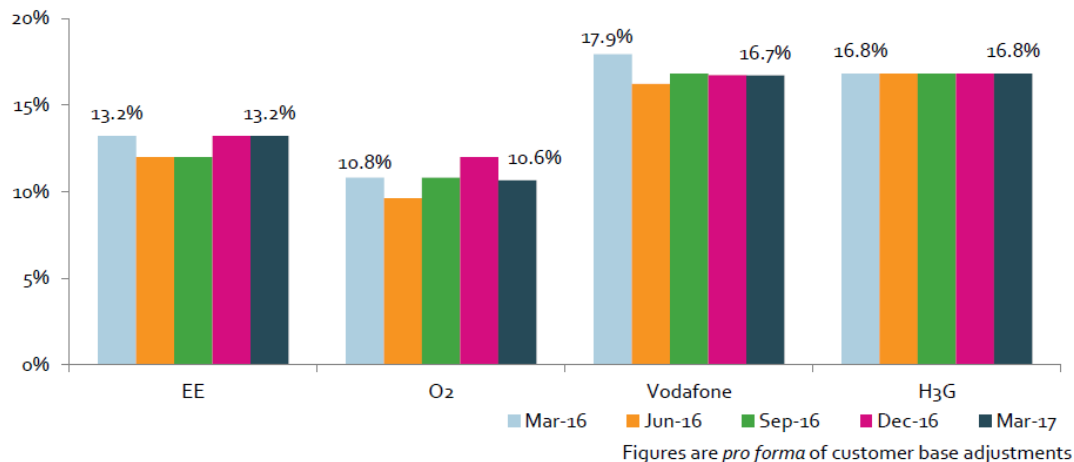
Figure A8.7: Contract net additions (thousands)



Source: Enders Analysis

A8.112 Enders Analysis also reports that O2 has the lowest annualised contract churn of all MNOs including Q1 2017 where O2's churn was 10.6% compared to 13.2% for EE, 16.7% by Vodafone and 16.8% for H3G.

Figure A8.8: Annualised contract churn



⁴²¹ 3< [REDACTED] .

⁴²² See page 22 of <https://www.telefonica.com/documents/162467/138879215/rdos17t1-eng.pdf/ccb1826a-f588-4232-b8db-398e444e428b?version=1.1>

Source: Enders Analysis

A8.113 At the wholesale level, we also note that O2 won two important MVNO deals, with Sky in 2015 and TalkTalk in 2014, with the former launching its service in January 2017 and the latter currently in the process of transitioning from Vodafone⁴²³.

A8.114 O2 remains as the MNO with the < [REDACTED] .

Current commercial and financial position of H3G

A8.115 H3G's EBITDA minus capex over the period 2012 to 2016 is shown in Figure A8.9. As with O2, we show this separately for when the capex includes spectrum purchases and when it is excluded. This shows that the underlying financial position of H3G's business has strengthened over this period.

Figure A8.9: H3G UK's financial results⁴²⁴

£million	2012	2013	2014	2015	2016
Revenues	1,948	2,044	2,063	2,195	2,276
EBITDA	281	417	547	686	719
Capex (including spectrum)	250	509	323	570	352
EBITDA minus capex (including mobile spectrum purchases)	31	(92)	224	116	367
EBITDA minus capex (excluding mobile spectrum purchases)	31	146	224	328	367

A8.116 H3G has told us that < [REDACTED] .

A8.117 We are interested in the underlying financial strength of H3G in terms of its ability to generate money from its mobile operations. < [REDACTED] EBITDA minus capex is a reasonable measure for this, < [REDACTED] .

A8.118 < [REDACTED] .

A8.119 < [REDACTED] .

A8.120 < [REDACTED] .

A8.121 < [REDACTED] .

⁴²³ See <https://www.talktalkgroup.com/dam/jcr:b55a1d43-aa3a-4515-9f59-3b88d89d5fec/TalkTalk%20Network%20Overview.pdf>

⁴²⁴ Sources: CK Hutchison Holdings Limited annual results presentation (operations analysis) – page 27
http://www.ckh.com.hk/upload/assets/downloads/en/e_CKHH_AR_Supplementary_info_20170322.pdf
 f Three UK Results – CKKH 2015 Annual summary,
<http://www.threemediacentre.co.uk/~media/Files/T/Three-Media-Centre/Three%20UK%20FY15%20Results.pdf>
<http://www.threemediacentre.co.uk/news/2017/fy-2016-results.aspx>
 Hutchison Whampoa Limited annual reports, 2014 and 2013, <http://www.hutchison-whampoa.com/en/ir/annual.php>

A8.122 We therefore remain of the view that H3G is currently financially viable. Given the strength of its underlying EBITDA minus cashflow currently, we do not see strong reasons to expect H3G's financial viability to weaken in the immediate future.

EBITDA margin and economies of scale

A8.123 As shown in Figure A8.4 above, H3G's EBITDA margin is higher than that of other MNOs, though did decline slightly in the last six months of 2016. We agree with H3G that the EBITDA margin is not a measure of absolute profitability, and we recognise that H3G's absolute profits are lower than the other MNOs. However, we consider that it is still relevant to consider the EBITDA margin, as explained below.

A8.124 We agree with H3G that there are economies of scale in the mobile industry. In terms of network costs, the volume of data traffic and coverage are the main drivers. In terms of retail costs, the number of subscribers affects retail costs and revenue. Compared to its rivals, H3G has a low share of subscribers, a low share of revenue but a high share of data traffic.

A8.125 If there are economies of scale in terms of retail costs, then having a low share of subscribers will tend to increase cost per subscriber and depress the EBITDA margin. Similarly for the costs of coverage, which may not vary significantly with the number of subscribers, so that, everything else equal, the fewer subscribers an operator has, the higher the cost per subscriber for the coverage layer. This again tends to depress the EBITDA margin.

A8.126 As H3G has a higher EBITDA margin relative to rivals who have higher subscriber numbers and revenue, this suggests it is generating sufficient other cost efficiencies or revenue to overcome economies of scale in providing coverage and in retail costs. In turn, this suggests that H3G has sufficient scale to compete effectively, and that it is not sub-scale.

A8.127 We also note that, in its annual report, H3G's parent company (CK Hutchison Holdings Limited) highlights the EBITDA margin of its UK telecommunications business (i.e. H3G) stating that it has a "*Healthy EBITDA margin of 41%*".⁴²⁵

Revenue growth, contract net additions and churn

A8.128 As shown in Figure A8.5 above, H3G's mobile service revenue growth rates are reported to have generally been above those of EE and Vodafone, though have been behind EE since Q4 2016. Also, as shown in Figure A8.6 above, H3G's contract ARPU growth has varied relative to other MNOs. For Q4 2016 and Q1 2017, Enders Analysis report it as being above Vodafone, but below EE.

A8.129 As discussed in annex 1, in 2016 H3G had < [REDACTED] ⁴²⁶ .

A8.130 As shown in Figure A8.7 above, H3G has had positive net contract additions since Q2 2016. Its net additions from Q3 2016 to Q1 2017 have been broadly comparable to EE and O2, and above Vodafone.

⁴²⁵ See

http://www.ckh.com.hk/upload/assets/downloads/en/e_CKHH_AR_Supplementary_info_20170322.pdf
f page 10

⁴²⁶ < [REDACTED] .

- A8.131 As shown in Figure A8.8, according to Enders Analysis, H3G's contract churn is higher than O2's and EE's but it is generally comparable to Vodafone's.
- A8.132 As we showed in annex 1, H3G⁴²⁷ retail subscriber market share has shown a steady upward trend over recent years from 3% [REDACTED] .
- A8.133 In its annual report, CK Hutchison Holdings Limited has also highlighted that H3G has "*Competitive propositions in the domestic consumer market*".

Conclusions on current commercial and financial position of O2 and H3G

- A8.134 Based on the evidence above, we conclude that O2 and H3G are currently commercially and financially viable.
- A8.135 This conclusion is consistent with the EC's findings in its decision on the proposed H3G/O2 merger. The EC found that H3G's financial position was "healthy" and that several short term forecasts of H3G's financial position absent the proposed H3G/O2 merger projected improved financial performance as well as further growth of the business. The EC also considered that H3G was unlikely to face problems in raising capital for future investments in the coming years. For O2, the EC found that "*given the positive financial outlook and the growing customer base, O2 is likely to remain a formidable competitor in the retail market*". It found that in the absence of the proposed H3G/O2 merger, O2 "*would continue to be financially sound and to invest in profitable projects*".⁴²⁸
- A8.136 However, we recognise that it is possible that the commercial and financial position of H3G and O2 could change in the future. The fact that they have been credible competitors to date whilst having a share of spectrum in the 10-15% range is relevant but it does not remove the risk that they may lose their credibility in the future.

Our conclusions on spectrum for the future credibility of MNOs

- A8.137 We consider below each MNO's spectrum holdings and whether it enables it to be a credible competitor. We start by considering the spectrum portfolios of BT/EE and Vodafone. Then we assess H3G's spectrum holdings, initially in the first transitional period and then in the second transitional and the longer term. Thereafter we set out a similar assessment of O2's spectrum portfolio. Finally, we comment on the consistency of our conclusions with the EC decision on the proposed H3G/O2 merger, which was raised in some responses.

BT/EE and Vodafone already have strong spectrum portfolios

- A8.138 In terms of spectrum for coverage, BT/EE has more than the minimum necessary, with a small amount (2x5MHz) of sub 1 GHz spectrum, namely the 800 MHz and 900 MHz bands, and a large amount of 1800 MHz spectrum.

⁴²⁷ See page 10 of

http://www.ckh.com.hk/upload/assets/downloads/en/e_CKHH_AR_Supplementary_info_20170322.pdf

⁴²⁸ See for example paragraphs 727, 723, 741, 744, 747, 763, 846, 849, 851 and 858 of the EC's Decision on proposed H3G/O2 merger.

http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6415_10.pdf

- A8.139 In terms of spectrum for sufficient capacity, BT/EE has a very large amount of spectrum - 255 MHz or 42% of current spectrum (including 1400 MHz), greatly in excess of the minimum necessary.
- A8.140 Given its advantages in terms of such a high share of spectrum, we consider BT/EE's spectrum portfolio overall would be sufficient for it to be credible even if it did not obtain spectrum in this Auction. As shown in Figure 6.2, it will still have 30% of mobile spectrum if we include the 2.3 and 3.4 GHz spectrum in the calculations (but exclude other future mobile spectrum, such as at 700 MHz and 3.6-3.8 GHz). Even including the 700 MHz spectrum, BT/EE's current holdings would still amount to 28% of mobile spectrum.
- A8.141 Vodafone has more than the minimum required to be credible in terms of both coverage and capacity. It has a large amount of sub 1 GHz spectrum (2x27.4 MHz) providing good spectrum for coverage, allowing it to provide good capacity even in hard to reach places, such as indoors. For capacity in general, it has a fairly large amount of spectrum overall - 176 MHz, representing 27% of immediately useable spectrum, including 1400 MHz and 2.3 GHz spectrum (see Figure 6.2).
- A8.142 As shown in Figure 6.2, Vodafone would still have 19% of mobile spectrum if we include the 2.3 GHz, 3.4 GHz and 700 MHz, and it did not obtain any of those frequencies. As with BT/EE, we therefore consider Vodafone's spectrum portfolio as a whole would be sufficient for it to remain a credible competitor in the first and second transitional period. Even in the longer term, when we also consider the 3.6-3.8 GHz spectrum, Vodafone's existing holdings would represent 16% of spectrum.
- A8.143 In summary, we do not consider that BT/EE or Vodafone need to obtain spectrum in this award to retain credible spectrum portfolios. If significantly more spectrum were to become available in the future, or a route to 5G were to become important and their existing holdings were not suitable for this, then at some point BT/EE and Vodafone might need to obtain additional spectrum.

H3G likely to remain credible in the first transitional period without additional spectrum

- A8.144 Given that we expect the 1400 MHz band to become available during 2018, H3G's spectrum share will be 14% during most of the first transitional period. It has more than the minimum necessary for coverage with 2x5 MHz of 800 MHz spectrum, and 2x15 MHz of 1800 MHz spectrum. Furthermore, given that it does not offer 2G services, it is the only MNO that can use all of its spectrum for 3G and 4G services, which it uses to carry a high (albeit declining) share of data compared to other MNOs.
- A8.145 From a commercial perspective, its retail subscriber market share has shown a slow but continuing upward trend over recent years. In addition, it has been growing in the wholesale market, as a host of MVNOs < [REDACTED] . Its financial position has improved over time and its mobile business appears commercially and financially viable. Given H3G's spectrum portfolio and position in the market currently, we consider it unlikely that H3G would cease to be credible in the first transitional period.

H3G likely to have sufficient spectrum to be credible in the second transitional period and longer term

- A8.146 H3G's position in the second transitional period and longer term has been strengthened due to the spectrum it acquired access to as a result of the purchase of UK Broadband. In the second transitional period, when we expect the 3.4 GHz and 700 MHz bands to be useable, H3G will have a minimum of 14% of useable spectrum, due to the 40 MHz of 3.4 GHz spectrum it now holds. In the longer term, we expect the 3.6-3.8 GHz spectrum to also be useable and when that happens H3G will have at least 19% of useable spectrum, because of the 84 MHz of 3.6-3.8 GHz it now holds.
- A8.147 With only 40 MHz of 3.4 GHz spectrum, H3G will not be able to launch 5G services, but can probably deploy the new 5G radio interface and latest antenna techniques to offer improved customer experience. The 1400 MHz spectrum is likely to be valuable spectrum given its relatively low frequency and the ability to use it at higher power than some other bands. Therefore, the useability of its 1400 MHz spectrum will strengthen H3G's ability to provide capacity in hard to reach areas (although it would still have much less low-frequency spectrum than O2 and Vodafone).
- A8.148 We therefore consider that H3G is now unlikely to need additional spectrum to enable it to be credible in the second transitional period and longer term.

O2 likely to remain credible in the first transitional period without additional spectrum

- A8.149 If O2 did not win any 2.3 GHz spectrum, its spectrum portfolio would represent 13% of mobile spectrum during the transitional period, once the 1400 MHz band becomes useable. O2's spectrum includes 2x27.4 MHz of sub 1 GHz spectrum giving it an important strength in terms of coverage, as it is able to provide good capacity even in hard to reach areas, such as deep indoors. However, we recognise that some of O2's spectrum is currently being used for less efficient 2G technology, though over time it is likely to refarm spectrum to more efficient 3G and 4G technologies.
- A8.150 We recognise that < [REDACTED] . Despite this, we consider it unlikely that the impact of this on O2 could be so severe that it would cease to be credible during the first transitional period. This is because:
- O2 has a strong position in both the retail and wholesale markets currently, < [REDACTED] ;
 - It has industry-leading churn as shown in Figure A8.8 and is currently strongly cash-flow positive; and
 - The first transitional period is not indefinite, being expected to last for around two to three years.
- A8.151 As we have emphasised above, when discussing the meaning of being a credible MNO, there can be a concern about a weakening of competition in the mobile market without the loss of a credible MNO. < [REDACTED] .

O2 may need more spectrum to remain credible in the second transitional period and longer term

- A8.152 Beyond the first transitional period, when considering credibility, we attach less weight to current market position, as this can change over time. We therefore focus on the spectrum portfolios and what MNOs can achieve with those portfolios. We consider these portfolios and the capabilities they provide in the round.
- A8.153 O2 would have less than 10% of spectrum (9.4%) in the second transitional period if it obtained no spectrum in this award. This is calculated including the 3.4 GHz and 700 MHz spectrum in the pool of spectrum considered. In the longer term O2's existing spectrum holdings would represent less than 8% of spectrum (also including 3.6-3.8 GHz in the pool of spectrum). The capability of its portfolio is strengthened by its large amount of sub 1 GHz spectrum. Nevertheless, with such a low share of spectrum, just below the 10-15% range, there would be a risk to O2's credibility.
- A8.154 If a route to 5G were to become important to credibility, and its existing spectrum was not suitable for this, then O2 might also need spectrum that would enable it to offer 5G services.
- A8.155 O2 may therefore need more spectrum to remain credible in the second transitional period and longer term.

Consistency with EC decision on proposed H3G/O2 merger

- A8.156 Regarding comments in some responses that the EC had concluded that both O2 and H3G would continue to be viable regardless of the outcome of the auction, Vodafone and BT are understandably and inevitably relying upon the heavily redacted public version of the EC's merger decision. Further, when setting out the framework and context for its decision, the EC clearly took into account a letter from Ofcom of 10 March 2016 (see paragraph 133 of the EC's merger decision). In that letter, Ofcom had submitted to the EC that it "*would propose including competition measures in the PSSR award where we considered it to be necessary and proportionate to promote effective and sustainable competition*".
- A8.157 When considering the ability of O2 and H3G to acquire access to spectrum in the future, the EC also expressly noted at paragraphs 2593 to 2595 of its decision that "*Ofcom has the duty and powers to design spectrum auctions in such a way that anti-competitive outcomes, such as strategic bidding, are not possible or made more difficult or unlikely...[i]t can thus be expected to ensure that strategic bidding is unlikely to materialise in particular in the upcoming PSSR auction.*" The EC's conclusions in the merger decision therefore took into account Ofcom's ability to impose competition measures, where necessary, in the Auction. We do not therefore agree that our conclusions about the capacity of O2 and H3G *in the absence of any competition measures* are inconsistent with those of the EC.

Annex 9

Responses on likelihood of strategic investment in the Auction

Introduction and summary

- A9.1 In this annex we consider the responses we received to the November 2016 consultation on the likelihood that some MNOs' bids for spectrum will be based not on the value they expect to obtain from using the spectrum (intrinsic value), but from the value they obtain by preventing rivals obtaining the spectrum and weakening competition (strategic investment value).
- A9.2 The responses include the reports and models submitted by H3G and O2 which they claim show that some MNOs have an incentive to engage in strategic investment in this auction, and that strategic investment is likely. We assess each of these below. In annex 10 we then set out our assessment of strategic investment, having considered these responses.
- A9.3 The structure of this annex is as follows:
- We summarise what we said in the November 2016 consultation on the risk of bidding based on strategic investment value in the auction.
 - We provide a high level summary of the responses we received.
 - We provide a high level comparison of the three models we received that aim to compare intrinsic value and strategic investment value for spectrum. These three valuation models are by Frontier Economics (for H3G), Analysys Mason (for H3G) and NERA (for O2). This includes considering the similarities and the differences in the design of these models, comparing some of the input assumptions to the three valuation models that are common to more than one model, and comparing the results that the models produce.
 - We assess Frontier Economics' report for H3G, which considers whether [strategic investor(s) has/have] \geq [REDACTED] incentives to bid strategically and foreclose [target(s)] \geq [REDACTED] .
 - We assess NERA's report and model for O2, which estimates both intrinsic and strategic investment value for all MNOs.
 - We assess Analysys Mason's report for H3G, which also estimates intrinsic and strategic investment values for all MNOs.
 - We assess Power Auctions' report for H3G, which builds on Analysys Mason's estimations of spectrum value, and makes inferences on likely auction outcomes.
 - We comment on BT/EE's response on the likelihood of strategic investment.

- A9.4 Our overall assessment of the models is that they provide quantified illustrations of how there can be an incentive for some companies to engage in strategic investment, when comparing the cost and pay-off of strategic investment. That is, for the total value of the strategic bidder(s), including strategic investment value, to sufficiently exceed the intrinsic value of the intended victim(s). However, for the reasons set out in detail below, we do not consider any of these models or reports are sufficiently reliable to draw clear-cut conclusions from them on the likelihood of strategic investment in the Auction. We do not consider this conclusion to be surprising, given the difficulty of the task of accurately modelling intrinsic and strategic investment values, and auction bidding, for all MNOs for a wide range of different amounts of spectrum in each band in the Auction.

Summary of November 2016 consultation

- A9.5 In the November 2016 consultation, we assessed whether there was a risk that competition concerns could arise if we did not impose competition measures in the Auction. In doing so, we distinguished between two sources of value that drive bids in the auction: intrinsic and strategic investment value.
- A9.6 In our assessment, we considered the risk that a bidder could win spectrum based on its strategic investment value, as a way to weaken downstream competition. In assessing this risk, we took into account both the pay-offs and the costs associated with bidding on the basis of strategic investment value.
- A9.7 In addition, we explained that there were features of the auction design that might mitigate the risk of strategic investment, by increasing the potential costs of engaging in it.
- A9.8 The first auction design feature is the uniform price rule. The consequence of this is that by bidding on a larger quantity of spectrum for strategic reasons, the strategic bidder will also be increasing the cost of any smaller amount of spectrum it would wish to acquire access to for intrinsic value reasons.
- A9.9 The second auction design feature is related to the nature of bidding in the Auction, which is for individual lots and not for packages of lots. As a result of this, a strategic investor may be “stranded” in an amount of spectrum which is insufficient to achieve its strategic goal, and be forced to buy that spectrum at a price that exceeds its intrinsic value.
- A9.10 The third auction design feature is related to the limited information policy we are adopting in the Auction. This makes some aspects of strategic investment – both unilateral and coordinated - much more difficult, as strategic bidders may lack sufficient information.
- A9.11 In assessing the risk of strategic investment affecting auction allocations, we considered each band separately and both together:
- a) Risk of strategic investment in the 2.3 GHz band: We provisionally concluded that the possibility of strategic investment in the 2.3 GHz band was a significant concern. This could be either unilateral strategic investment by one bidder, or tacitly coordinated investment between two strategic bidders.
 - b) Risk of strategic investment in the 2.3 GHz and 3.4 GHz bands together: When the specific effect of denying 2.3 GHz spectrum to competitors during

the transitional period is ignored, we considered it unlikely that a single bidder would have the incentive to engage in unilateral strategic investment in relation to all or almost all of the spectrum available in the Auction in order to weaken competition. We reached this view because we considered the pay-offs were uncertain while the costs and risk of failure were likely to be high. We also considered that coordinated strategic investment was unlikely due to a lack of clear focal points as to how the spectrum would be split.

- c) Risk of strategic investment in the 3.4 GHz band: We noted that strategic investment could arise in the band to deny competitors' access to a band suitable for an early 5G launch. However, we considered the pay-offs from such strategy were uncertain, and the costs would be potentially high due to the amount of spectrum available. We also considered that coordinated strategic investment was unlikely due to a lack of clear focal points as to how the spectrum would be split.

Summary of responses

- A9.12 Vodafone considered there was a risk that BT/EE could have an incentive to acquire access to 2.3 GHz spectrum, even though it might not need it.⁴²⁹ It said that the benefits to BT/EE of bidding strategically were at least twice as high as the supposed benefits to Vodafone. Based on evidence on diversion ratios, < [REDACTED] .
- A9.13 Vodafone also argued that < [REDACTED] .⁴³⁰
- A9.14 In Vodafone's view, there was a risk that BT/EE could have an incentive to engage in strategic investment for 2.3 GHz, but that it would obtain no value from such strategic investment. Vodafone also noted that it has significantly less spectrum than BT/EE, so is not able to build any lead in overall spectrum holdings.
- A9.15 We consider the above arguments by Vodafone in paragraphs A10.79 and from 0 in the next annex.
- A9.16 O2 said that, while Ofcom was right to focus on competition concerns, it had failed to have proper regard to the potential for huge losses in static welfare for consumers.⁴³¹ NERA's report for O2 said that maximising intrinsic value was implicitly linked to maximising static welfare and dynamic innovation benefits. It said that bidding on the basis of intrinsic value should be a good proxy for the benefits that their deployment will generate for consumers.⁴³²
- A9.17 NERA included indicative estimates of the potential scale of welfare losses when bidding was not based on intrinsic value. It assumed that BT/EE would be prevented from bidding for 2.3 GHz spectrum by a spectrum cap, but that if Vodafone obtained all 2.3 GHz spectrum by bidding based on strategic investment, there would be a welfare loss of £2.2 bn. In NERA's analysis this is largely driven by a reduction in network quality for O2 and H3G. In a scenario where there is strategic investment in both the 2.3 GHz spectrum and the 3.4 GHz spectrum (such

⁴²⁹ Page 14 of Vodafone's response.

⁴³⁰ Page 18 of Vodafone's response.

⁴³¹ Paragraph 28 of O2's response.

⁴³² NERA report, section 6.

that Vodafone obtains all the 2.3 GHz spectrum and BT/EE and Vodafone together obtain all 150 MHz of 3.4 GHz spectrum), NERA forecasts a welfare loss of £3.1 bn.

A9.18 NERA sought to measure both intrinsic and strategic investment value for MNOs. NERA's assessment assumed that we impose a cap that would exclude BT/EE from 2.3 GHz spectrum. NERA concluded that there is a risk that strategic investment could affect auction outcomes.⁴³³

- 2.3 GHz: There is a real risk that [strategic investor(s)] < [REDACTED] could have sufficient strategic investment value to block [target(s)] < [REDACTED] .
- 3.4 GHz and overall shares: It cannot be ruled out < [REDACTED] .

A9.19 NERA considered that the auction design rules do not eliminate incentives for engaging in strategic investment bidding.⁴³⁴

A9.20 Taking these arguments into account, NERA concluded that a 255 MHz cap on immediately useable spectrum *"leaves open the possibility of an outcome that is grossly inefficient and harmful to downstream competition"*.⁴³⁵

A9.21 H3G also expressed concerns on the likelihood of strategic investment affecting auction outcomes. H3G submitted several reports supporting its arguments. These are:

- Analysys Mason (AM) report (annex 16 of H3G's response) estimating intrinsic and strategic investment values. The report concluded that < [REDACTED] .⁴³⁶ < [REDACTED] .
- Power Auctions report (annex 19 of H3G's response), develops theoretical results demonstrating that value complementarities < [REDACTED] . Power Auctions builds on its theoretical results and uses the results of AM's model to make inferences on likely auction outcomes. It argues that *"[s]trategic value from the 2.3 GHz band alone, together with strong value complementarities for [certain packages] < [REDACTED] , make foreclosure likely"*.⁴³⁷
- Frontier Economics report (annex 18 of H3G's response), which assesses whether [a strategic investor has/strategic investors have] < [REDACTED] incentives to bid strategically and foreclose [a target/targets] < [REDACTED] . Relying on an oligopoly model based on diversion ratio data, Frontier Economics concluded that < [REDACTED] .⁴³⁸

A9.22 Based on this evidence, H3G concluded that < [REDACTED] .⁴³⁹ Moreover, it argued that < [REDACTED] .⁴⁴⁰

⁴³³ NERA report, pages 113-114.

⁴³⁴ NERA report, page 117.

⁴³⁵ NERA report, page 120.

⁴³⁶ Annex 16 of H3G's response, page 44.

⁴³⁷ Sub-section 5.3 of the confidential version of Power Auctions' report.

⁴³⁸ Annex 18 of H3G's response, page 28.

⁴³⁹ H3G Response, page 120.

⁴⁴⁰ H3G Response, page 128.

- A9.23 We consider the modelling of strategic investment by each of NERA, Analysys Mason, Power Auctions and Frontier Economics in detail below.
- A9.24 Some responses also argued that strategic investment has occurred before, both in the UK and elsewhere. We consider these from paragraph A11.133.
- A9.25 BT/EE said that Ofcom overestimated the incentive to, and ability of, MNOs to bid strategically for the 2.3 GHz spectrum. BT/EE referred to Ofcom's November 2014 Consultation and May 2015 Statement on the 2.3 and 3.4 GHz award, pointing out that we considered in those documents that strategic investment in spectrum is unlikely in this award. BT/EE said the key reasoning that supported this conclusion still holds, in particular it said that there was no evidence that strategic investment would have an associated pay-off, never mind whether that pay-off would exceed the likely substantial cost of such investment.⁴⁴¹ BT/EE said Ofcom had not carried out a proper analysis including the costs and risks faced by a would-be strategic bidder. BT/EE also referred to the auction design mitigations that we discussed in the November 2016 consultation.⁴⁴²

High level comparison of valuation models by Frontier Economics, Analysys Mason and NERA

Overview of approaches to estimating intrinsic and strategic value

- A9.26 Below we provide an overview of the models provided by Frontier Economics (FE), AM and NERA, and then discuss each in turn in more detail. We comment on certain aspects of each model in terms of their methodology and assumptions. Thereafter, in subsequent sections we comment on each of the models in greater detail. However, given the very large number of issues that arise, the discussion in this annex does not attempt to cover all aspects of the models. As such, an absence of comment by us should not be taken as indicating our agreement.
- A9.27 These models share a similar goal in that they attempt to provide estimates of intrinsic and strategic investment values and inform the likelihood of strategic investment in the Auction or the incentives for a bidder to engage in it. In particular:
- AM and NERA estimate valuations for each possible package to each operator.⁴⁴³ By package we mean a combination of amounts of 2.3 GHz and 3.4 GHz spectrum for which an operator could acquire licences. Both AM and NERA models make assumptions on how spectrum holdings affect downstream competitive outcomes. These assumptions include the role of spectrum in the ability to retain or gain subscribers and the scale of any increases in prices/margins due to weaker competition.
 - FE's model is different in that it does not attempt to model valuations for each possible package. In contrast, the model compares a scenario where [target obtains "sufficient spectrum" to avoid being weakened as a competitor with a scenario where it fails to do so/targets obtain "sufficient spectrum" to avoid being weakened as competitors with a scenario where

⁴⁴¹ BT/EE response, paragraph 6.

⁴⁴² Paragraphs 86-89 BT/EE response

⁴⁴³ In strict terms, the models provide value estimates for most but not all possible packages. NERA model considers 10 MHz blocks of 3.4 GHz rather than 5 MHz blocks. AM does consider 5 MHz lots for blocks of up to 80 MHz. With respect to larger blocks of 3.4 GHz spectrum, AM only provides values for the following block sizes: 100 MHz, 120 MHz and 150 MHz.

they fail to do so] & [REDACTED] . It then considers how competition would be affected in each scenario, and derives intrinsic and strategic investment values for this “sufficient” amount of spectrum. As opposed to AM and NERA’s models, the effect of spectrum holdings on changes in prices/margins is partly endogenous through use of an oligopoly model.

- A9.28 Figure A9.1 below provides an overview of the main methodological aspects underpinning the sources of intrinsic and strategic investment value in each of these models. We refer to annex 11 for definitions of technical and commercial values.

Figure A9.1: Overview of FE, NERA's and AM's models

	FE's model for H3G	AM's model for H3G	NERA's model for O2
Intrinsic Value			
- Technical value (network cost avoidance)	FE does not explicitly distinguish between technical and commercial value, but its modelling implicitly includes the two aspects. FE assumes that without spectrum there is increased spending on the network to compensate (technical value). And FE also assumes that some segment of the market %< [REDACTED] cannot be served without spectrum (commercial value)	Technical value forms part of intrinsic value.	No technical value, as "operators with limited spectrum have few costs they can avoid from acquiring access to more spectrum because they lack the frequencies they need to take full advantage of network improvements" ⁴⁴⁴
- Commercial value (extra revenue from better network performance)		The share of downlink spectrum is assumed to drive the performance of the network of each operator, which in turn affects their ability to gain new customers and retain existing customers. The size of the segment that is likely to be sensitive to changes in network performance is 13% of post-paid subscribers. Two thirds of that segment is influenced by network performance.	As data consumption grows, operators need to increase their capacity (through expanding downlink spectrum holdings) to avoid losing customers due to congestion and inability to provide high speed services. From the pool of customers that would need to leave the network to remove congestion, 20% switch away each year. The model also assumes that if the speed of the network falls below %< [REDACTED] of the average speed of all networks then %< [REDACTED] of subscribers churn away
Strategic investment value			
- Switching consumers pay higher ARPU	In estimating strategic investment values, all three models assume that subscribers will switch from constrained to unconstrained (or higher quality) networks. In doing so, all three models assume that subscribers cease paying the average ARPU of the constrained network (often lower) and start paying the often higher average ARPU of the unconstrained network (this is in addition to any assumed price increase arising from a softer competitive environment). For example, %< [REDACTED] .		

⁴⁴⁴ NERA's report, page 90.

- Increased price/margins	Price increase is determined by an oligopoly model. < [REDACTED] .	Price increase is an exogenous assumption. When [victim operator's/victim operators'] < [REDACTED] share of downlink spectrum falls below < [REDACTED] , ⁴⁴⁵ [strategic investor(s) is/are] < [REDACTED] able to increase ARPU's < [REDACTED] below the acceptable performance threshold (APT).	Exogenous assumption for increase in cashflow margins. When one or more networks are capacity constrained, strategic investors are able to increase their cashflow margins depending on the number of constrained networks.
- Increased subscriber base	FE assumes that when [victim operator(s) lose/loses] < [REDACTED] subscribers other operators will benefit in accordance with diversion ratios.	When an MNO's spectrum share falls below < [REDACTED] , subscribers churn away from it. Other networks capture these subscribers in proportion to their share of gross market adds, assuming that the MNO that falls below the APT would not pick up any of the subscribers in that pool.	Subscribers lost by constrained MNOs flow to unconstrained networks in proportion to their spare capacity.

A9.29 At a high level, there are some similarities in the approaches adopted in these models, such as strategic investment value arising from a combination of obtaining more subscribers and being able to increase prices due to weaker competition.⁴⁴⁶ However, there are also differences. For example, while NERA does not consider that spectrum has a relevant technical value, AM and FE do. Other examples include the treatment of MVNOs in the analysis. While NERA and FE incorporate them in assessing intrinsic and strategic values, AM only analyse values arising from MNOs' own retail businesses.

A9.30 There are also important differences in the way each of these models incorporate the context of the auction, including the differences between bands (availability, useability, etc.) and < [REDACTED] :

- FE does not distinguish between spectrum bands, and only refers to the ability of a strategic investor's victim(s) to acquire access to "sufficient spectrum". < [REDACTED] .

⁴⁴⁵ This corresponds to the assumed acceptable performance threshold. See Annex 16 of H3G's response, footnote 43.

⁴⁴⁶ In addition, none of these models explicitly model a 5G value for the spectrum. AM said that it "assumed that 2.3GHz and 3.4GHz bands will be used in the macrocell layer for 4G, as there is insufficient information to build an accurate 5G valuation model" (H3G's response, page 119). NERA, said that its model does not capture all sources of value, such as the launch of 5G services (NERA report, page 90). While FE links its results to 5G technology, this is not explicit in its modelling approach.

- AM does not incorporate longer term spectrum in the analysis. It assumes that both 2.3 GHz and 3.4 GHz are immediately useable (with an adjustment to take account of lower coverage capability if 3.4 GHz spectrum). AM does not incorporate the effects of the UK Broadband acquisition.
- NERA explicitly models differences in useability and availability of 2.3 GHz, 3.4 GHz and longer-term spectrum. NERA also provided an updated version of its analysis which incorporates the effects of the UK Broadband acquisition.

Average revenue (ARPU) versus marginal revenue of switchers

- A9.31 As described in Figure A9.1, all three models adopt the approach that when subscribers switch from constrained (or losing) networks to the higher quality (or gaining) networks their ARPU goes from the average for the losing network to the average for the gaining network. This common approach is likely to overstate strategic investment value relative to intrinsic value, as it is not clear that such a large increment in price for the switching consumer and revenue for the networks is appropriate.
- A9.32 Differences in average ARPUs may reflect differences in the mix of subscribers each MNO has, as well as other factors. Especially given the scale of the differences in ARPUs generally assumed in these models as between losing and gaining networks (see Figure A9.1), the common approach in the models is, in effect, assuming that switching consumers generally face a large *increase* in their bills when switching. We are concerned that this is not a reasonable assumption (especially as it has not been properly justified in the reports).
- A9.33 The approach also means that the loss in profit to the losing network from a consumer switching away is significantly smaller than the gain in profit to the gaining network from acquiring the same consumer. This embeds a feature in these models which tends to depress intrinsic value of the potential victims of strategic investment compared to the strategic investment value to the potential strategic bidders.
- A9.34 Another assumption which may be more reasonable, would be to assume that when a subscriber switches from one MNO to another it purchases a similar package and its ARPU is similar. In our view, the approach adopted in all three models fails to distinguish between the average revenue of existing users and the marginal revenue of switchers.

Comparison of common inputs to valuation models

- A9.35 A key challenge with any valuation model is to ensure the inputs are reasonable and the model correctly calibrated. In this section, we illustrate the challenges in obtaining reliable input data by comparing some of the inputs which are common to more than one model. We also highlight differences between the input data and data provided to Ofcom. We do this for:
- a) ARPU
 - b) Profit margins
 - c) Post-paid subscriber numbers

A9.36 We observe sometimes large differences in some of these assumptions. These differences highlight the difficulties in obtaining reliable input data which may have considerable implications for the results of the models. In the following sub-sections we take each of these input variables in turn.

ARPU

A9.37 Figure A9.2 below compares the ARPUs assumed in the three valuation models. These are also compared with data reported to us by MNOs.

Figure A9.2: Comparison of monthly ARPU figures in the models

	FE's model for H3G	AM's model for H3G	NERA's model for O2	Data from MNOs
Basis of ARPU figures	Post-paid subscribers	Post-paid handset subscribers/ Blended average*	All* subscribers	Post-paid / All subscribers
	Excluding MVNO	Excluding MVNO	Weighted average of MNOs' and MVNOs' ARPU	Excluding MVNOs
	Excluding handset revenues	Excluding handset revenues	Unknown whether it includes handset revenues	Excluding handset revenues
Source	Analysys Mason's data	Analysys Mason, 2016; GSMAi.	O2's data	MNOs
Year	Not known	2015	2016	2016
BT/EE	£27.53	£29.03 (post-paid) / £19.89 (blended)	£18.35	⌘ [REDACTED]
H3G	£19.74	£20.81/£14.56	£19.30	⌘ [REDACTED]
O2	£27.77	£29.27/£18.49	£14.25	⌘ [REDACTED]
Vodafone	£25.72	£27.12/£19.18	£16.41	⌘ [REDACTED]
Virgin	£19.74			
Tesco Mobile	£19.74			

Source: FE model, NERA model, AM model and operator data.

* AM's model also uses ARPU for each of contract handsets, PAYG handsets, contract mobile broadband and PAYG mobile as well as a blended average of all of these.

**NERA does not explicitly state in its report whether the ARPU relates to the MNO/MVNOs' total subscribers or a subset of subscribers e.g. post-paid only. However, given that these figures are closer to AM's blended average ARPU than the ARPU of post-paid subscribers it may be the former.

A9.38 As illustrated by the table above, the models use considerably different ARPU inputs for the same MNOs. These differences can in part be explained by differences in what they represent. For example, NERA's is the only model to use a weighted average of the ARPU from MNO and MVNO customers.⁴⁴⁷ Furthermore, NERA appears to be using ARPU for all subscribers whereas FE uses ARPU from post-paid customers only. AM's model uses different ARPU for four different subscriber groups as well as a blended average of these. In Figure A9.2 we have

⁴⁴⁷ Footnote 61, page 91 of NERA's report. It is not clear from NERA's report whether the average ARPU is an average of the MNO's retail ARPU and the retail ARPU of the MVNO it hosts or it is an average of the MNO's retail ARPU and the wholesale ARPU it receives from the MVNO it hosts.

presented AM's ARPU figures for post-paid handset subscribers as this category of subscriber is the main driver of results in AM's model.

- A9.39 While we recognise there is a different treatment of MVNOs and the figures are therefore not directly comparable, we note that NERA's model for O2 assumes that H3G has the highest ARPU out of the MNOs and O2 has the lowest ARPU, while AM's and FE's models for H3G assume that H3G has the lowest ARPU. Furthermore, the post-paid ARPUs used by the FE and AM models are different from the ARPU figures reported to us. For example, post pay ARPU for BT/EE in FE's and AM's models are 3x [REDACTED] than the information BT/EE has reported to us.

Profit margins

- A9.40 In addition to differences in ARPUs across the models there are also significant differences in their approach to estimating profit margins, even before any assumed price increase arising from a softer competitive environment:
- In FE's model for H3G, FE takes 3x [REDACTED]⁴⁴⁸.
 - In NERA's model for O2, NERA assumes a 'symmetric cash flow margin', that is, NERA assumed that *"20% of ARPU is retained as contribution to fixed costs and profits whereas the rest is spent on customer-related costs"*.⁴⁴⁹ Not only is this figure (in %) the same across MNOs, but it is much lower than FE's figures (in %).
 - In Analysys Mason's model for H3G, the profit margins are the consequence of a complex modelling exercise, involving different margins for different types of subscribers and based on assumptions about spectrum holdings. This makes it difficult to compare the profit margins used by AM with those used by NERA and FE.

Subscriber numbers

- A9.41 Figure A9.3 below compares the subscriber numbers assumed in the three valuation models and also compares these with the subscriber numbers that MNOs have reported to us.

⁴⁴⁸ FE says that it relied on 3x [REDACTED].

⁴⁴⁹ Page 85 of NERA's report.

Figure A9.3: Comparison of subscriber numbers (million) in the models

	FE's model for H3G	AM's model for H3G	NERA's model for O2	Data from MNOs
Basis for figures	Number of retail post-paid subscribers	Number of retail post-paid subscribers / total retail subscribers	Total subscribers including retail and hosted MVNO subscribers	Number of retail post-paid subscribers / total retail subscribers
Source	Telegeography	Analysys Mason, 2016	Unknown	MNO data submitted to Ofcom, 2016
H3G	6.2m	⌘ [REDACTED]	⌘ [REDACTED]	⌘ [REDACTED]
O2	13.3m	⌘ [REDACTED]	⌘ [REDACTED]	⌘ [REDACTED]
BT/EE	18.0m	⌘ [REDACTED]	⌘ [REDACTED]	⌘ [REDACTED]
Vodafone	13.6m	⌘ [REDACTED]	⌘ [REDACTED]	⌘ [REDACTED]
Virgin	2.3m			⌘ [REDACTED]
Tesco Mobile	0.9m			⌘ [REDACTED]

Source: FE model, NERA model, AM model and operator data.

- A9.42 While not all the subscriber numbers in the table are comparable, some of them are intended to estimate the same thing. For example, FE assumes ⌘ [REDACTED] . AM assumes ⌘ [REDACTED] .

High level comparison of NERA's and AM's valuation results

- A9.43 As discussed, the NERA and AM models estimate intrinsic and strategic investment values for each operator. In this sub-section, we provide a high level comparison of the results of each model.
- A9.44 In both cases, NERA and AM make clear that their models do not reflect the operators' own view of the value for the spectrum available in the Auction.⁴⁵⁰ Hence, even if we were to accept the methodology of these models, the submissions indicate such models will not necessarily reflect the MNOs' valuation for the spectrum in the Auction. Thus, it is unclear whether these models are good predictors of the likely bidding drivers or outcomes in the auction.
- A9.45 Although the outputs of these models may look similar in terms of predicting a risk of strategic investment, on a closer inspection, the outputs of the two models are substantially different. For example,⁴⁵¹ the allocations that would maximize total

⁴⁵⁰ NERA clarifies that: "we were tasked by O2 to develop our own model (which is separate from the model that O2 is developing to support its bidding strategy)". NERA further notes that the model is "not [designed] as a tool to forecast actual bids in the auction" (NERA report, page 89). H3G requested Analysys Mason to "develop a model of strategic investment based on its understanding of Ofcom's view of the market" (H3G's response, page 121). Moreover, AM's report (page 2) clarifies that "In making assumptions underpinning our calculations we have been asked by H3G to reflect as far as possible our understanding of Ofcom's view of the market, as set out in its relevant consultations and statements, even where this conflicts with H3G's views on the market (i.e. so that our conclusions are based on modelling reflecting our understanding of Ofcom's view of the market)".

⁴⁵¹ In these examples, we use NERA's original model, which does not incorporate the effects of UK Broadband acquisition. This is to make it comparable with AM's model. We also use upper bound estimates in both models, given that these are the figures that H3G and O2 use to express the risk of

intrinsic values differ in each case, as shown in Table A9.4.⁴⁵² According to the NERA model, this allocation is attained [REDACTED]. In contrast, according to AM's estimates, [REDACTED].

Figure A9.4: Auction outcomes that maximise intrinsic value in NERA and AM models (in MHz by operator)

[REDACTED]

A9.46 [REDACTED].⁴⁵³ Figure A9.5 below compares both the levels and breakdown of total values for the package 40 MHz of 2.3 GHz (and 0 MHz of 3.4GHz).

Figure A9.5: Comparison of estimated values for the package 40 MHz of 2.3 GHz and 0 MHz of 3.4 GHz in NERA and AM's models (in £m)⁴⁵⁴

[REDACTED]

Source: Ofcom from NERA and AM models

A9.47 As can be seen in the figure, there are substantial differences as to:

- Levels of intrinsic value: O2's intrinsic value of 40 MHz of 2.3 GHz (and 0 MHz of 3.4GHz) is [REDACTED] according to NERA's model, but [REDACTED] according to AM's model. In contrast, Vodafone's intrinsic valuation for the same package is [REDACTED] according to NERA's model but [REDACTED] according to AM's model. Hence, NERA's intrinsic value estimate for the package is [REDACTED].
- [REDACTED].
- [REDACTED].

A9.48 Outputs of models of this type are generally sensitive to the specific assumptions and construction of the models, and the examples above illustrate that this also seems to be the case when comparing the NERA and AM models. Even though the NERA and AM models share some high level characteristics and a common goal, they do not appear to generate consistent valuation estimates.

Conclusions from high level comparison

A9.49 The models of FE, NERA and AM share a similar goal and, at a high level, there are some similarities in their approaches. However, there are also significant

strategic investment. However, we note that using lower bound estimates do not alter our conclusions substantially.

⁴⁵² NERA reports intrinsic value allocations in page 101 of their report. AM does not report such allocations. Hence, in the case of AM, we calculated intrinsic value allocations by taking the full set of intrinsic values available in the AM model and maximizing total values among feasible allocations.

⁴⁵³ While NERA provides a strategic value estimate for each package, AM only provides these values for selected packages and argues that the rest of the packages would be within a certain range. Both AM and NERA report strategic investment values for the package shown, so we use this package to compare results.

⁴⁵⁴ Excludes BT/EE given that NERA does not provide an estimate for the relevant package.

differences, such as the treatment of different spectrum bands and the H3G's acquisition of UK Broadband.

- A9.50 One common approach in all three models is that, when subscribers switch from constrained (or losing) networks to the higher quality (or gaining) networks, their ARPU goes from the average for the losing network to the average for the gaining network (which is generally assumed to be significantly higher). In our view, this is likely to overstate strategic investment value relative to intrinsic value, by failing to distinguish between the average revenue of existing users and the marginal revenue of switchers.
- A9.51 Our comparison of inputs that are common to the three models (ARPU, profit margins, and post-paid subscriber numbers) shows the sometimes large differences in input assumptions. This highlights the difficulties in obtaining reliable input data which may have considerable implications for the results of the models.
- A9.52 Although the outputs of the NERA and AM models may look similar in terms of predicting a risk of strategic investment, on a closer inspection, the outputs of the two models are substantially different.

Frontier Economics' Model

Overview of methodology and assumptions in Frontier Economics' model

- A9.53 As annex 18 of its response, H3G submitted a report by Frontier Economics (FE) aimed at assessing [strategic investor's/investors'] < [REDACTED] incentives to engage in strategic investment in the Auction, and the risk that [strategic investor(s)] < [REDACTED] strategic investment value may affect the outcome of the Auction.
- A9.54 FE does this by estimating [strategic investor's/investors'] < [REDACTED] strategic investment value for spectrum and comparing it to [target's/targets'] < [REDACTED] intrinsic value for the spectrum.
- A9.55 The FE model assumes that if [the target(s) fail/fails] < [REDACTED] to acquire access to sufficient spectrum in the Auction, [it/they] < [REDACTED] would face the consequences. For this purpose, the FE model distinguishes between two categories of post-paid subscribers: < [REDACTED] and the rest of the post-paid market < [REDACTED].⁴⁵⁵ The consequences are assumed to be:
- a) [The target(s)] < [REDACTED] would be excluded from < [REDACTED].
 - b) < [REDACTED] increase in incremental network costs across the rest of the post-paid market < [REDACTED] [The target(s)] < [REDACTED] would be able to pass on this cost increase to customers to some extent (as described below), but [the target(s)] < [REDACTED] would lose some customers as a result of the higher price.
- A9.56 FE uses a static model of oligopoly competition (Bertrand differentiated model with linear demands⁴⁵⁶) to explain how higher costs would translate into higher prices,

⁴⁵⁵ FE does not include pre-pay customers in its model because it says < [REDACTED].

⁴⁵⁶ Annex 18 of H3G's response, page 34.

not only for [target(s)] < [REDACTED] , but also for other operators < [REDACTED] MNOs plus the two main MVNOs, Virgin and Tesco).⁴⁵⁷ We understand that FE calibrates the model by assuming each firm profit maximises, has linear demand and using data on ARPU, incremental costs, subscriber numbers and diversion ratios. The model generates equilibrium prices in scenarios where [target(s)] < [REDACTED] either fail(s) or succeed(s) in acquiring access to sufficient spectrum. It does this separately for the < [REDACTED] and for the rest of the post-paid market. < [REDACTED] FE estimates new equilibrium prices based on [target(s)] < [REDACTED] no longer competing in the segment. For the rest of the post-paid market, this involves obtaining new equilibrium prices when [target(s)] < [REDACTED] compete(s) with higher incremental costs. Given the price changes derived by comparing equilibrium prices in the oligopoly model with and without [the target(s)] < [REDACTED] acquiring access to spectrum, FE estimates both [the target(s)] < [REDACTED] intrinsic value and [the strategic investor's/investors'] < [REDACTED] strategic investment value.

A9.57 [The target's/targets'] < [REDACTED] **intrinsic value** for the spectrum reflects the difference in present value of expected profits between the scenario where it wins sufficient spectrum to avoid incremental cost increases and the scenario where it does not.⁴⁵⁸ This includes both the effect on the < [REDACTED] (where incremental cost increases are assumed to exclude [the target(s)] < [REDACTED] from the market) and in the rest of the post-paid market < [REDACTED] .

A9.58 [Strategic investor's/investors'] < [REDACTED] **strategic investment value** for the spectrum reflects the benefits [strategic investor(s)] < [REDACTED] obtain(s) from weakening [target(s)] < [REDACTED] . This can be broken down into three components:

- a) [strategic investor(s)] < [REDACTED] gain(s) customers from < [REDACTED] It is assumed to acquire access to < [REDACTED] of the customers that [target(s)] < [REDACTED] is/are assumed to lose. These diverted customers are made up of both < [REDACTED] and also the rest of the post-paid market.
- b) Even before any price increases, < [REDACTED]
 - 1.
 - 2.
- c) [strategic investor's/investors'] < [REDACTED] prices increase, for both the < [REDACTED] and the rest of the post-paid market due to weaker competition (as derived from the oligopoly model described above).

A9.59 Both [target's/targets'] < [REDACTED] intrinsic value and [strategic investor's/investors'] < [REDACTED] strategic value are based on the net present value of change in profit.⁴⁵⁹ The results are presented in relative terms, i.e. [strategic investor's/investors'] < [REDACTED] strategic value as a percentage of [target's/targets'] < [REDACTED] intrinsic value. FE says that the length of the

⁴⁵⁷ FE said the model takes account of MNOs hosting the two large MVNOs. For example, < [REDACTED] .

⁴⁵⁸ Annex 18 of H3G's response, page 22.

⁴⁵⁹ While the FE model includes four MNOs and two MVNOs, FE's report focuses on the incentives of [strategic investor(s)] < [REDACTED] to prevent [target(s)] < [REDACTED] from acquiring spectrum, and does not discuss the role of < [REDACTED] in the Auction.

time period for the NPV does not affect these results expressed in percentage terms, as the same discount rate is applied to both operators.

- A9.60 We discuss FE's assumptions on ARPU, incremental margins and post-paid subscriber numbers above. FE also makes an assumption about diversion ratios showing where subscribers move when they leave a given operator. These ratios also capture closeness of competition, and drive how an operator would react in the oligopoly model to a price increase from a rival. FE says that the diversion ratios used are based on switching data from Kantar.

Frontier Economics' results

- A9.61 The results from FE's model are shown in Figure A9.6 below for [target's/targets'] \times [REDACTED] intrinsic value relative to [strategic investor's/investors'] \times [REDACTED] strategic value for the "sufficient spectrum" that [target(s) need/needs] \times [REDACTED] to acquire access to in the Auction to avoid competition weakening. It can be seen that \times [REDACTED] .

Figure A9.6: Valuation results from FE's base case

\times [REDACTED]

- A9.62 \times [REDACTED] .

- A9.63 \times [REDACTED] .

- A9.64 As shown in Figure A9.1, FE's report also says that [strategic investor(s)] \times [REDACTED] will have some intrinsic value for the spectrum, but this has not been modelled.

- A9.65 FE concludes that its analysis \times [REDACTED] ⁴⁶⁰ ⁴⁶¹ .

- A9.66 H3G relied on this conclusion to argue that there is a \times [REDACTED] .

Frontier Economics' sensitivities

- A9.67 FE reports sensitivities around its base case for two inputs:

- a) **Incremental cost increase:** In the base case, FE assumes that if [the target(s)] \times [REDACTED] did not acquire access to sufficient spectrum, then its incremental costs increase by \times [REDACTED] . In the sensitivity, a higher incremental cost increase of \times [REDACTED] is assumed.
- b) **Size of \times [REDACTED] :** FE assumes that if [target(s)] \times [REDACTED] did not acquire access to sufficient spectrum, then it/they would be excluded from the \times [REDACTED] which is assumed to be \times [REDACTED] of post-paid customer in the base case. In the sensitivities, FE assumes \times [REDACTED] .

- A9.68 Raising the incremental cost increase from \times [REDACTED] to \times [REDACTED] has the effect of \times [REDACTED] the incentive to engage in strategic investment.

⁴⁶⁰ Annex 18 of H3G's response, page 28.

⁴⁶¹ Annex 18 of H3G's response, page 28.

For this sensitivity, the model predicts that [the strategic investor's/investors'] \propto [REDACTED] strategic value is likely to be around \propto [REDACTED] of [the target's/targets'] \propto [REDACTED] intrinsic value. FE say that this reflects the fact that [the target's/targets'] \propto [REDACTED] intrinsic value from avoiding the \propto [REDACTED] .

A9.69 In terms of the size of the \propto [REDACTED] , FE argues that its assumption that this is \propto [REDACTED] .

Ofcom's response to FE's analysis

A9.70 In this section, we provide our comments on FE's model and conclusions on the likelihood of strategic investment in the Auction. First, we discuss the stylised nature of FE's model. Second, we highlight that the FE model is not specific about the spectrum [target(s)] \propto [REDACTED] might need, in terms of either amount or band, to avoid being weakened as a competitor. Third, we draw out the implications for FE's analysis of its failure to take account of auction design features and, in particular, the uniform price rule. Fourth, we explain that FE's model fails to take account of the \propto [REDACTED] . Fifth, we discuss the reasonableness of FE's input assumptions. Sixth, we comment on the very limited sensitivity analysis that FE has undertaken.

Stylised model

A9.71 The model that FE has developed is highly stylised, more so than NERA's model and AM's model. While a highly stylised model can be useful, to rely on the outputs of such a model for the conclusions that FE and H3G seek to draw, we would need to be confident that it sufficiently captures relevant factors, and that the inputs and calibration are appropriate. FE's report does not give us this confidence for the reasons set out below.

A9.72 The following provide some examples of the stylised nature of FE's model:

- a) FE's model makes a binary assumption that either [the target(s) obtain(s)] \propto [REDACTED] sufficient spectrum or it does not, without being specific about either the amount of spectrum or the bands. We expand on the limitations of this below.
- b) The effects on [the target(s)] \propto [REDACTED] of not winning sufficient spectrum are imposed as assumptions, such as the assumed exclusion of \propto [REDACTED] . This is different to AM or NERA's models, which attempt to model the effect of not obtaining different amounts of spectrum on operators' commercial performance.
- c) Whilst FE models the consequences of the assumed effects on [the target(s)] \propto [REDACTED] for the scale of price changes by [the strategic investor(s)] \propto [REDACTED] (whereas the AM and NERA models make assumptions about price changes), this is done using a static oligopoly model. As we understand it, FE models future years simply as if they were identical to the initial year and so it apparently makes no allowances for changes in market demand or cost trends in future years. Spectrum is a long-term, strategic asset (e.g. the spectrum licences acquired in the Auction are not time-limited), and the mobile market is subject to significant changes over time, such as rapid growth in demand and technological developments.

- d) In FE's model there is a hard distinction between the \mathbb{X} [REDACTED] and the rest of the post-paid subscribers, which we understand are treated as entirely separate markets with independently-determined prices. In addition, FE's model assumes that [target(s)] \mathbb{X} [REDACTED] is/are completely excluded from the \mathbb{X} [REDACTED] if its/their incremental network cost increases, so that it becomes a two/three-player market, whilst there remains a four-player market (with weaker competition) for the rest of the post-paid subscribers. We recognise the scope for different customer segments and potential for weaker competition in one or more of these segments. However, in reality, we would expect less rigid separation of products, competition and prices between FE's two market segments.

No explanation of what "sufficient spectrum" means

- A9.73 FE assumes that [target(s)] is/are a weaker competitor/weaker competitors when it/they fail(s)] \mathbb{X} [REDACTED] to acquire access to "sufficient spectrum to avoid network cost increases". With respect to what is meant by sufficient spectrum, FE only mentions that "this could mean [target(s)] fail(s)] \mathbb{X} [REDACTED] to acquire access to any spectrum or insufficient spectrum to avoid adverse consequences on its cost or market position".⁴⁶² It is unclear what amount of spectrum this might be and there is no distinction between the 2.3 GHz and 3.4 GHz bands. We consider this is an important limitation of the analysis that restricts the conclusions that can be drawn from it.
- A9.74 As FE's model does not distinguish between the 2.3 GHz and 3.4 GHz bands, FE makes no distinction on how pay-offs and costs associated with 2.3 GHz and 3.4 GHz are modelled. It is thus unclear whether the results (if true) would hold only with respect to immediately useable spectrum, or also with respect to the totality of the spectrum. FE's conclusions that Ofcom should be concerned about strategic investment both in 3.4 GHz and 2.3 GHz are a consequence of FE considering both bands without making any distinction between them, rather than an analysis accounting for the specific characteristics of each band.

Failure to take account of the uniform price rule and the associated multiplier effect

- A9.75 FE's analysis compares [the strategic investor's/investors'] \mathbb{X} [REDACTED] strategic investment value to [the target's/targets'] \mathbb{X} [REDACTED] intrinsic value – as such, it treats the costs of strategic investment as being the same as the intrinsic value of the victim (\mathbb{X} [REDACTED]) for "sufficient spectrum".⁴⁶³ This fails to take account of the uniform price rule which we discuss in Annex 10. This is especially relevant where a strategic investor, to ensure foreclosure is effective, has to purchase more spectrum than the "sufficient" amount the victim needs.
- A9.76 This results in a 'multiplier effect' which can be illustrated with the 2.3 GHz band. There are 40 MHz available in this band in four lots of 10 MHz each. If the victim's "sufficient spectrum" is 10 MHz to avoid network cost increases, the strategic investor needs to buy all 40 MHz to be sure of denying 10 MHz to the victim. In such circumstances, the strategic investor's value would need to be greater than victim's intrinsic value to ensure that strategic investment was successful. Given our uniform price rule in the Auction, the strategic investor's value would need to be four

⁴⁶² Annex 18 of H3G's response, page 6.

⁴⁶³ The cost of strategic investment would subtract the strategic bidder's own intrinsic value for the spectrum from the victim's intrinsic value, but this is not estimated in FE's model. For simplicity, in the discussion below, like FE, we compare \mathbb{X} [REDACTED] .

times larger than the victim's intrinsic value for 10 MHz. That is, using FE's relative percentage metric to report the results of its model (see Figure A9.6 above), [the strategic investor's/investors'] \times [REDACTED] strategic investment value would need to be 400% of [the target's/targets'] \times [REDACTED] intrinsic value.

A9.77 There are further possibilities:

- If [the target's/targets'] \times [REDACTED] "sufficient spectrum" is 20 MHz, [the strategic investor(s) need(s)] \times [REDACTED] to acquire access to 30 MHz for successful strategic investment, implying a multiplier and required relative percentage value of 150%.⁴⁶⁴ In this case, [the strategic investor(s)] \times [REDACTED] would need to have a larger strategic investment value than [the target's/targets'] \times [REDACTED] intrinsic value \times [REDACTED].
- If [the target's/targets'] \times [REDACTED] sufficient spectrum is 30 or 40 MHz, [the strategic investor(s) need(s)] \times [REDACTED] less spectrum than [the target(s)] \times [REDACTED], implying multipliers of 67% and 25%. In these cases, successful foreclosure can occur even if [the strategic investor's/investors'] \times [REDACTED] strategic investment value is/are \times [REDACTED] lower than [the target's/targets'] \times [REDACTED].

A9.78 The multiplier effect is likely to be even more important when considering the 3.4 GHz band, as there is 150 MHz of spectrum in this band in the Auction (in lots of 5 MHz each). For example, if [the target's/targets'] \times [REDACTED] sufficient spectrum is 20 MHz, [the strategic investor(s) need(s)] \times [REDACTED] 135 MHz for successful (unilateral) strategic investment, implying a very large multiplier of 675% (or multiplier of 287.5% for [the strategic investor(s)] \times [REDACTED] to foreclose [the target(s)] \times [REDACTED] from 40 MHz by winning 115 MHz).

A9.79 This effect may be even more important again when considering all the spectrum together, if [target(s)] \times [REDACTED] could obtain "sufficient spectrum" from either band.

A9.80 Even if the sufficient spectrum that [the target(s) need(s)] \times [REDACTED] is a large amount, the multiplier effect can still apply. For example, if [the target(s) need(s)] \times [REDACTED] 60 MHz of spectrum across either band, with 190 MHz of spectrum in the Auction in total, to be sure that [the target(s)] \times [REDACTED] did not obtain 60 MHz of spectrum, [the strategic investor(s)] \times [REDACTED] would need to obtain 135 MHz of spectrum. Therefore, [the strategic investor(s)] \times [REDACTED] may need a strategic investment value more than double [the target's/targets'] \times [REDACTED] intrinsic value.

A9.81 Since FE is silent on the amount of spectrum or the spectrum bands that are "sufficient" for [target(s)] \times [REDACTED] to avoid a weakening of competition, the size of the multiplier effect in FE's analysis is unclear. However, given the amount of spectrum in the Auction, this multiplier effect is likely to be important, and even larger for the risk of strategic investment involving the 3.4 GHz spectrum. Therefore, even if FE had correctly modelled the ratio of [the strategic investor's/investors'] \times [REDACTED] strategic value to [the target's/targets'] \times [REDACTED] intrinsic

⁴⁶⁴ We are assuming that [the target(s)] \times [REDACTED] would in these examples bid up to its full intrinsic value for the "sufficient spectrum" it requires. This seems a reasonable assumption especially if [the target(s)] \times [REDACTED] really requires the whole of the "sufficient spectrum" to remain a strong competitor.

value, that would be insufficient to support a reliable conclusion about strategic investment in the 2.3 GHz or 3.4 GHz bands.

No account of 3< [REDACTED]

A9.82 FE's analysis was prepared without assuming 3< [REDACTED] ⁴⁶⁵ ⁴⁶⁶ .

A9.83 3< [REDACTED] .

A9.84 3< [REDACTED] .

Input assumptions may not be reasonable

A9.85 Given the issues set out above, we have not assessed the reasonableness of FE's inputs in detail. However, from a high level assessment, we consider there are likely to be concerns over some of the important inputs, including some of the parameters discussed in the previous sub-section on inputs common to different models.

A9.86 As shown in Figure A9.6 above, 3< [REDACTED] . The inputs for ARPU, incremental margin and subscriber numbers also affect the results.

A9.87 In FE's base case it assumes that if [the target(s)] 3< [REDACTED] did not obtain "sufficient spectrum" it/they would be excluded from all 3< [REDACTED] of subscribers that constitute the 3< [REDACTED] , which it argues is a conservative estimate. It considered sensitivities of 3< [REDACTED] .

A9.88 We do not consider that there is any clear evidence on the size of any 3< [REDACTED] from which [the target(s)] 3< [REDACTED] (in FE's model) would be completely excluded if it/they did not obtain sufficient spectrum. While FE refers to consumer research 3< [REDACTED] , this does not provide any direct evidence on the share of the market from which [the target(s)] 3< [REDACTED] would be excluded if it does/they do not obtain spectrum. We believe that the 3< [REDACTED] ⁴⁶⁷ . As described in Annex 2, while speed is one factor affecting retail competition, it is far from being the only factor.

A9.89 The assumption on the size of this market segment also needs to be considered in the context of the ARPUs in FE's model. Even some customers who place 3< [REDACTED] .

A9.90 FE assumes that [the target's incremental cost increases/targets' incremental costs increase] 3< [REDACTED] by 3< [REDACTED] for the rest (3< [REDACTED]) of the post-paid subscribers. The source for the 3< [REDACTED] is described simply as a "Frontier assumption".⁴⁶⁸ There is no explanation of why this might be a reasonable assumption.

A9.91 As well as the explicit input assumptions described above, there are also important assumptions that are implicit in the design of FE's modelling approach. There is often little explanation in FE's report about why it has made these assumptions and the basis on which it considers them justified. These include:

⁴⁶⁵ This is clear, for example, from page 17 of the (confidential version) of the FE report, where FE refer to 3< [REDACTED] .

⁴⁶⁶ Even if 3< [REDACTED] .

⁴⁶⁷ 3< [REDACTED] .

⁴⁶⁸ Page 33 of Annex 18 of H3G's response.

- As described above, we understand that FE's model assumes that when a subscriber switches from [the target(s)] < [REDACTED] to [the strategic investor(s)] < [REDACTED] .
- FE implicitly assumes that while the quality of the network for the < [REDACTED] of subscribers can be recovered at a reasonable cost, there is nothing that can be done to lift the quality of the network for the other < [REDACTED] representing < [REDACTED] . This is despite the two market segments using the same network. For instance, it is not clear why the investment made to bring the network quality up to pre-congestion levels for the < [REDACTED] of subscribers does not also improve the quality for the other < [REDACTED] .
- FE's model seems to implicitly assume that [target's/targets' competitive weakness(es) is/are enduring] < [REDACTED] , as FE say that the length of the time period for the NPV does not affect these results expressed in relative percentage values. However, if the advantage that [the strategic investor(s)] < [REDACTED] enjoyed were only for a transitional period and did not apply in the longer term, this could change the results (though we recognise that this would change both [the strategic investor's/investors'] < [REDACTED] strategic value and [the target's/targets'] < [REDACTED] intrinsic value). The lack of distinction between 2.3 GHz and 3.4 GHz spectrum in the model means it is not possible to assess the impact properly for different time periods.

Very limited sensitivity analysis

- A9.92 Where there are uncertainties about some inputs (as we consider is the case), sensitivity analysis would need to establish whether the results were consistent with plausible ranges for the different inputs. We consider the very limited sensitivity analysis in the FE report is insufficient to assess this.
- A9.93 FE only reports changes to two parameters (the incremental cost increase and the size of < [REDACTED]) and only changes the base case assumptions for these parameters in one direction.
- A9.94 In our view a more complete sensitivity analysis would involve changing base case parameter assumptions in both directions, and undertaking sensitivity analysis for a larger number of the many assumptions. A few examples of the sensitivity analysis that FE could have undertaken on its inputs include:
- a) reducing the base case proportion of the < [REDACTED] from which [the target(s) is/are] < [REDACTED] assumed to be excluded, and the increase in incremental network cost;
 - b) varying the assumptions on ARPU, incremental margins and subscriber numbers; and
 - c) varying the implicit assumption that when customers switch MNO their ARPU changes from the average of the MNO they were previously with to the average for the MNO they are switching to.

Conclusions on FE's model

- A9.95 In our view, FE's analysis provides an illustration of how the strategic investment value of a potential strategic bidder, such as [the strategic investor(s)] < [REDACTED] , can exceed the intrinsic value of a potential victim of strategic investment, such as [target(s)] < [REDACTED] .
- A9.96 However, for the reasons set out above, we do not consider that FE's analysis is sufficiently robust to provide a reliable indication of the likelihood of strategic investment by [the strategic investor's/investors'] < [REDACTED] against [target(s)] < [REDACTED] in the Auction. In summary:
- FE's model is highly stylised and does not attempt to model some relevant considerations;
 - FE's model is not explicit about the spectrum [the target(s)] < [REDACTED] may need, either in terms of the amount or the bands, which means it is of little use in exploring the likelihood of strategic investment in specific bands;
 - FE's model fails to take account of the < [REDACTED] ;
 - FE's model fails to incorporate in its analysis that, for successful strategic investment, a strategic investor may have to purchase more spectrum than the amount the victim needs;
 - FE gives little justification for some of the important inputs in its model and it is not clear that they are all reasonable; and
 - The sensitivity analysis that FE reports on input assumptions is very limited.

NERA's model

Overview of methodology and assumptions in NERA's model

- A9.97 NERA developed a high-level model which it categorises as a "subscriber avoidance model". According to NERA, the purpose of the model was to support high-level inferences on the efficiency, competition and welfare impact of particular outcomes to the PSSR consultation but not as a tool to forecast actual bids in the auction.
- A9.98 O2 provided us with a copy of the model supporting NERA's report, and an updated version of that model which incorporated the effects of H3G's UK Broadband acquisition ("the updated model"). O2 also submitted a report that describes the original model, but no updated version of this report was provided to us. In this section, when we summarise the outcomes of the model, we do so using the updated model which incorporates H3G's acquisition of UK Broadband.
- A9.99 The model estimates intrinsic values for the 4 MNOs and strategic investment values for Vodafone and BT/EE. Based on this model, NERA concludes that there is a risk of < [REDACTED] . In its letter to Ofcom dated 4 April 2017, O2 states that < [REDACTED] . O2 also notes that the model shows that it should have

*“exceptionally high value for the first 40-60 MHz of spectrum”*⁴⁶⁹. Equally, rivals would benefit substantially if O2 is blocked.

- A9.100 The model considers some high level technical parameters of each of the mobile networks in the UK, including: spectrum holdings of each operator; usage of spectrum for 2G/3G services and refarming forecasts; spectral efficiency for 2G, 3G and 4G; downlink profile for each band; carrier aggregation limit forecast; and date from which each of the new bands will be useable. The model also takes into account the expected growth in data traffic - using NERA's own data growth forecast - and then estimates the growth in data consumption for subscribers of each MNO using an S-curve function.
- A9.101 NERA assumes that bands will be available and useable with handsets widely from the following years:
- 2.3 GHz: 2017
 - 3.4 GHz: 50% in 2019 and 100% in 2020
 - 1400 MHz: 2019
 - Longer term spectrum (3.6 GHz and 700 MHz): 2021
- A9.102 NERA defines 3 periods based on the availability of bands: transitional period 1 (TP1) from now until early/mid 2019; transitional period 2 (TP2) from 2019 to mid-2020 or later, and the long-term from 2021 onwards.
- A9.103 In determining both intrinsic and strategic investment values, the way spectrum holdings trigger subscriber movements across operators plays a key role:
- For every MNO in every year the model estimates whether the network is congested by estimating downlink traffic being conveyed by the network and comparing it to its capacity. If it is congested, it estimates the number of subscribers that would have to be dropped for the network not to be congested any more. It then assumes that 20% of these subscribers churn away every year.
 - The model also assumes that if the speed of the network falls below \propto [REDACTED] of the average speed of all networks then \propto [REDACTED] of subscribers churn away. These subscribers are different and in addition to those lost because of congestion.
- A9.104 The number of subscribers that would leave a congested network (and margin derived from those subscribers) is the source for intrinsic values. The destination networks of those subscribers is one of the sources for strategic investment in the model.
- A9.105 In what follows, we explain in turn how NERA estimates intrinsic and strategic investment values.

⁴⁶⁹ Page 9 of O2's 2.3 3.4 award letter submitted on 4 April.

Intrinsic values

- A9.106 The NERA model assumes that, absent capacity constraints, market shares would remain static. However, increasing demand for speed creates congestion. If congestion is not addressed through increased capacity, subscribers would leave the MNO. The model assumes that each specific spectrum band would enable operators to increase their capacity starting from the moment the band becomes available and useable. Expanding capacity would allow operators to avoid losing subscribers and to retain cashflows.
- A9.107 The model estimates the intrinsic value that each MNO would have for a given amount of spectrum by obtaining the loss in cash flows with and without such spectrum. For this purpose, NERA estimates the enterprise value (over the period 2016-2026) that an MNO would obtain if it wins a certain package of spectrum in the Auction. It then estimates the enterprise value of that MNO without any spectrum licences being won in the Auction (which we call the null package). The value of the package of spectrum is determined as the incremental enterprise value that such spectrum would generate over the enterprise value with the null package.
- A9.108 In estimating intrinsic values, NERA's model assumes only the amount and type of spectrum access acquired by the operator in question is relevant and not the spectrum access acquired by other operators. Therefore, NERA's approach to intrinsic value does not depend on gaining subscribers from other networks, only the risk of losing subscribers. Hence, it is a "subscriber avoidance model".
- A9.109 For each year, the model estimates the number of subscribers that each network would be unable to serve given its capacity and speeds. In estimating intrinsic values, NERA assumes that a proportion of those subscribers would leave the constrained network and not join any other network (even if there are networks that have spare capacity as this would be influenced by what spectrum licences other operators have acquired – whereas, as noted above, when deriving intrinsic value, spectrum licences acquired by other operators is ignored). The result of this approach is that the number of subscribers in the market, when modelling intrinsic value, falls over time (although it is assumed to be static when modelling strategic value, as discussed below). This is due to there being insufficient spectrum for all networks to cover their growing demands for capacity, which causes networks to become constrained and lose subscribers.⁴⁷⁰
- A9.110 For each subscriber that an MNO retains, it obtains a margin which is assumed to be 20% of the annual ARPU assumed for that operator. NERA relies on ARPUs supplied by O2 which are a weighted average of the MNO's retail ARPU for its own retail subscribers and ARPUs of the MVNOs it hosts at the wholesale level. Specifically, the assumed monthly ARPUs are: £18.35 (BT/EE), £19.30 (H3G), £14.25 (O2) and £16.41 (Vodafone).
- A9.111 In NERA's model, the availability of bands determines when these are useful to address capacity issues. The 2.3 GHz band would allow operators to address capacity concerns during all three periods (TP1, TP2 and the long-term), 3.4 GHz spectrum in TP2 and the long-term, and 700 MHz and 3.6 GHz in the long-term only. In particular, given the pre-existing spectrum holdings of each operator and their forecasted traffic, NERA's model suggests that:

⁴⁷⁰ In the intrinsic value part of the model, there is no scenario possible where all operators retain all their subscribers, given that there is a limited amount of spectrum available. > [REDACTED] .

- Only O2 and H3G are willing to pay an intrinsic value premium for 2.3 GHz spectrum over 3.4 GHz or long-term spectrum. This is because these operators would otherwise lose customers during TP1. Other operators hold sufficient spectrum to meet demand growth during TP1.
- After incorporating the effects of UK Broadband acquisition, £< [REDACTED] .
- £< [REDACTED] .

A9.112 Figures A9.7 and A9.8 summarise the result of intrinsic value estimates in NERA's updated model. The model estimates intrinsic values for all possible packages combining 2.3 GHz, 3.4 GHz, 3.6 GHz and 700 MHz spectrum. Hence, the figures below are only a subset of the estimated values.

A9.113 In the figures below, each column is a 10 MHz block showing the marginal intrinsic value for 2.3 GHz or 3.4 GHz to an operator. The first column for a specific operator represents the value of 10 MHz to that operator. The second block represents the value of a second 10 MHz, given that the operator already has 10 MHz and so on. The figures represent values in descending order of marginal intrinsic value from highest to lowest. The darker colour on a column represents the value that cannot be substituted by another band of spectrum.⁴⁷¹ For example, in Figure A9.7 £< [REDACTED] the darker value represents the marginal intrinsic value for 10 MHz that is specific to 2.3 GHz spectrum and cannot be substituted. The lighter part of the column can be substituted using 3.4 GHz spectrum.

Figure A9.7: NERA's estimation of 2.3 GHz marginal intrinsic values for 10 MHz blocks (single band)

£< [REDACTED]

Source: NERA's updated model

Figure A9.8: NERA's estimation of 3.4 GHz marginal intrinsic values for 10 MHz blocks (single band)

£< [REDACTED]

Source: NERA's updated model

A9.114 As can be seen in the charts above, £< [REDACTED] .

A9.115 Given that only O2 and H3G have intrinsic value during TP1, NERA argues that excluding BT/EE and Vodafone from bidding for this spectrum would not

⁴⁷¹ In Ofcom's response section below, we do not discuss how NERA has modelled the value of spectrum that cannot be substituted by another band. However, we note that there are alternative approaches that result in different breakdowns of the intrinsic value between substitutable and non-substitutable values. One approach for the 2.3 GHz band would be to input enough spectrum in the 3.4 GHz band such that an operator doesn't lose subscribers in the second transitional period and limit the model to the end of 2019. Then adding 2.3 GHz spectrum to an operator's holding could estimate the benefit to an MNO that cannot be substituted by 3.4 GHz. The result of this analysis shows that £< [REDACTED] , as opposed to NERA's analyses which claims £< [REDACTED] .

compromise the allocative efficiency for this band. However, NERA suggests that BT/EE would have a high incremental value for additional spectrum in the long-term if it maintains its market share, which would make it a strong contender for spectrum in the PSSR auction. On the other hand, it concludes that Vodafone has no business case for acquiring access to substantial amounts of spectrum in the PSSR auction, unless it plans to recover market share (which is assumed not to occur in NERA's model, since market shares are completely static apart from the effects of capacity constraints).

Strategic Investment Values

A9.116 NERA then proceeds to estimate the strategic value to MNOs of acquiring access to spectrum. There are two sources of strategic investment value in NERA's model:

- Subscriber movements: it assumes that the subscribers that a congested network loses are acquired by the other MNOs as a proportion of their spare capacity⁴⁷². However, it is often the case that there is not enough spare capacity to absorb those customers. In this case, NERA assumes that subscribers return to their initial MNO. In determining strategic investment values, the model ensures that the total number of subscribers in the market remains constant throughout the years modelled. For each subscriber switching between networks, NERA assumes that the acquiring network earns, and the departed network loses, the (different) assumed ARPU for that network.
- Margin increases: The model also assumes that congestion leads to an increase in the cash flow margins of unconstrained networks due to weaker competition. This will depend on how many congested networks there are. NERA presents two scenarios: (i) a "mild" scenario where the margins of unconstrained networks increase by 2.5%, 5% and 7.5% if there are three, two or one unconstrained networks, respectively; and (ii) an "strong" scenario where the boost to margins are 10%, 20% and 30% respectively.

A9.117 The model estimates the NPV of the cash flows (i.e. enterprise value, over the period 2017-2026) for all MNOs under all possible spectrum allocation combinations, including the scenarios where MNOs do not acquire access to any spectrum in the Auction (i.e. null package). NERA estimates the *total value* for a given package by considering the incremental enterprise value in excess of the enterprise value with the null package. It then deducts the intrinsic value from the total value estimate, to obtain the value attributed to strategic investment for a given package. This is represented in the two equations below.

$$\text{Total Value (package } x) = \text{Enterprise value (package } x) - \text{Enterprise value (null package)}$$

$$\begin{aligned} \text{Strategic investment value (package } x) \\ = \text{Total value (package } x) - \text{Intrinsic value (package } x) \end{aligned}$$

A9.118 While in estimating intrinsic values, NERA's model assumes only the amount and type of spectrum access acquired by the operator in question is relevant, in the estimation of strategic investment values it is also relevant what other bidders purchase. In NERA's model, the strategic investment value for any given package differs depending on how the rest of the spectrum is allocated. This means that the

⁴⁷² The model takes into account acquisition costs.

model has multiple enterprise value estimations for a given package and a given operator. For example, there are 136 different enterprise value estimations for an MNO which acquires access to 40 MHz of 2.3 GHz and 0 MHz of 3.4 GHz. This is because the enterprise value depends on how the 3.4 GHz spectrum is split among the remaining three MNOs, and there are 136 ways in which such spectrum can be split among three bidders.⁴⁷³

A9.119 Such multiplicity even applies when considering the enterprise value when no spectrum is obtained in the Auction (i.e. null package). For example, an MNO that does not win any spectrum may still see its enterprise value grow substantially if another strategic investor is successful in denying spectrum unilaterally to an operator that may face capacity constraints. This multiplicity applies exclusively to the estimation of strategic investment values, and does not apply to the estimation of intrinsic value. Intrinsic values to an operator are unaffected by a different network being capacity constrained or not.

A9.120 In order to obtain a single estimate of strategic investment value for each package, NERA uses two criteria to select the relevant enterprise value associated with that package among all possible values:

- Null package: NERA consistently selects the minimum possible enterprise value for the package without any spectrum (we call this criterion 1).⁴⁷⁴
- Packages with spectrum licence acquisition (i.e. packages other than the null package): NERA selects the minimum possible enterprise value for package with spectrum (applying criterion 1 again) in most of the results discussed in their report.⁴⁷⁵ However, where it discusses a coordinated strategic investment outcome, it selects the enterprise value that would arise if such coordinated outcome was achieved successfully (we call this criterion 2).⁴⁷⁶

A9.121 NERA obtained estimates for 2.3 GHz and 3.4 GHz packages presented in NERA's report by applying criterion 1 to both enterprise value with the spectrum and without it. Table A9.9 below summarises strategic investment values for Vodafone and BT/EE using NERA's updated model. The figures below are only a subset of the values estimated by NERA. We also note that NERA did not provide estimates of packages containing 2.3 GHz for BT/EE.

Table A9.9: NERA's strategic investment value estimates for selected single band packages (in £m)

⌘ [REDACTED]

Source: Ofcom based on NERA's updated model

⁴⁷³ Although the number of scenarios could be potentially larger considering possible allocations of long-term spectrum as well, NERA simplifies the valuation exercise by assuming a fixed allocation of this spectrum. In particular, it assumes that Vodafone, EE and H3G are allocated 2x10 MHz of 700 MHz each and that O2, EE and H3G are allocated 30 MHz of 3.6 GHz and Vodafone 20 MHz.

⁴⁷⁴ The application of this criterion to the null package is not discussed in NERA's report, but can be clearly identified in the model.

⁴⁷⁵ Page 111 of NERA's report.

⁴⁷⁶ Such results are reported in page 113 of NERA's report.

A9.122 NERA concludes that \propto [REDACTED] .

A9.123 With respect to the 3.4 GHz band, NERA \propto [REDACTED] .

A9.124 Finally, NERA estimates the value for BT/EE and Vodafone of collectively blocking H3G and O2 from acquiring access to any spectrum. \propto [REDACTED] . The total value of each of those packages is obtained by applying criterion 2 to the enterprise value with the spectrum, and criterion 1 to the null package. Based on this, Vodafone would have a total value in the range of \propto [REDACTED] and BT/EE would have a total value in the range of \propto [REDACTED] . NERA therefore argues that such a coordinated scenario is plausible.

Ofcom's response to NERA's model

A9.125 In this section, we provide our comments on NERA's model and conclusions for the purpose of our assessment of the likelihood of strategic investment in the Auction. In doing so, we first discuss the methodological approach of the model. Next, we look at whether the conclusions drawn from this model are likely to be sensitive to assumptions. Finally, we discuss whether NERA's conclusions are likely to hold when considering our auction design.

Methodology

A9.126 NERA's model has some desirable properties for estimating values for the spectrum in the Auction. For instance, it incorporates assumptions on timing of useability of each band, and the effect of this on the value of each of the two bands for addressing capacity constraints in different timeframes. It also takes into account the role of spectrum becoming available in future awards (700 MHz, 3.6-3.8 GHz) as an alternative way to address longer term capacity constraints. On the basis of this methodology, the model illustrates the extent to which different operators would be willing to substitute certain type of spectrum for others, depending on when they are likely to become capacity constrained.

A9.127 However, in our view, the model also has a number of questionable high level methodological assumptions in its approach to determining values for spectrum, which can have a substantial effect on the results. Some of these assumptions were discussed above⁴⁷⁷, when we compared this model with other models submitted by stakeholders. In this sub-section, we discuss methodological issues that apply exclusively to NERA's model. These are: 1) whether the drivers of churn on NERA's model are realistic; 2) the effects of the subscriber base considered in the model; 3) the methodology for computing strategic investment values; and 4) the way NERA model discounts cashflows.

Modelling of capacity constraints and churn is not in line with market data

A9.128 First, one of NERA's model fundamental assumptions is that when a network becomes capacity constrained, it starts to lose subscribers due to congestion or inability to provide high speeds in a mechanical way. This is the key source of intrinsic and strategic investment values in NERA's model. We consider that, although network congestion may affect an MNO's ability to retain customers, this relationship is likely to be complex. In order for NERA's approach to be an accurate representation of reality, both forecasted congestion and the relation between congestion and churn should be reasonable. One way to evaluate whether NERA's

⁴⁷⁷ Discussed in: High level comparison of valuation models by Frontier Economics, Analysys Mason and NERA

model assumptions are reasonable is to look at whether the outputs are consistent with actual data, at least directionally. We have examined NERA's model and noticed some basic outputs which are not in line with market data. 3< [REDACTED]

Weakened competition may only affect customer segments

A9.129 Second, NERA considers all subscribers (pre-paid, post-paid, MVNOs and MNOs) are equally sensitive to network quality. This has two main consequences:

- a) In determining both intrinsic and strategic investment values, NERA uses highly averaged ARPUs which may not accurately reflect the incremental revenue at stake.
- b) In determining strategic investment values, NERA's model assumes that the effects of a weaker competitive environment on margin increases will be widespread rather than focused on a particular segment. This might have the effect of overstating strategic investment values, since by denying spectrum to a victim, the strategic investor would be able to increase prices to all its subscribers rather than just a portion of them. In our competition assessment, we are more concerned about the effect of a very asymmetric distribution of spectrum on a weakening competition for certain customer segments. We also note that both Frontier Economics and Analysys Mason assume prices would increase only in the post-paid segment.

NERA's criteria for selecting from the multiplicity of enterprise values are not conservative

A9.130 Third, we have concerns with the way NERA computes strategic investment values. We agree with NERA's view that the strategic investment value for an operator can depend not only on the particular package, but also on how the rest of the spectrum is allocated. Where there is more than one potential strategic investor, the extent to which one of them (strategic investor 1) succeeds in denying spectrum to a victim is likely to impose externalities on the pay-offs of the other strategic investor (strategic investor 2). This view is consistent with the coordination and free-riding problems associated with strategic investment we highlight in Annex 10. Hence, we understand the rationale for there to be a multiplicity of enterprise value estimations in NERA's modelling of strategic investment.

A9.131 However, NERA relies on two criteria to translate such multiplicity of enterprise value estimations into a single relevant value. One way to interpret these criteria is that they indicate what a strategic investor would expect about how the rest of the spectrum is likely to be allocated. We note that the criteria NERA uses for selecting the relevant enterprise values among the possible ones have a substantial impact on the estimated strategic investment values. Figure A9.10 below illustrates the potential impact of this for a hypothetical package (which we call package X):

Figure A9.10: Illustration of NERA's selection of enterprise values

A9.132 Figure A9.10 illustrates the effects of NERA's criteria for selecting enterprise values in the estimation of total values. As explained, NERA's model estimates multiple enterprise values for every package, including the null package. In the figure above, an MNO's enterprise value without any additional spectrum can be as low as £20 (minimum enterprise value, in purple), but up to £50 (maximum enterprise value, considering additional enterprise value, in green) in the case, for example, when another strategic investor denies spectrum to the victim MNO. A similar logic applies to the enterprise value with package X: it can be as low as £60 but as high as £80, depending how spectrum is allocated among the remaining bidders. The higher end for the enterprise value with package X could correspond to a situation of coordinated strategic investment.

A9.133 Based on these purely illustrative values, the MNO's total values (for package X) may be as high as £60 ($=£80-£20$), but as low as £10 ($=£60-£50$), depending on what other bidders do. NERA's criterion for the null package (criterion 1 – the minimum possible enterprise value) would imply selecting the enterprise value of £20 as the relevant one. Regarding the enterprise value for package X, NERA's criterion 1 would imply a value of £60, and criterion 2 (the enterprise value that would arise if such coordinated outcome was achieved successfully) a value close to or at £80. Hence, NERA's methodology would estimate a total value for package X of either £40 ($=£60-£20$) or £60 ($=£80-£20$),⁴⁷⁸ despite the fact that the range of possible values is £10 to £60.

A9.134 The example above illustrates that NERA's criteria for selecting enterprise values does not necessarily result in conservative estimations of total values. In addition, these criteria have the effect of underestimating the risk associated with strategic investment, as they select a single value as relevant for decisions from a range of

⁴⁷⁸ It might not be exactly £60, as that depends on what is the outcome that maximizes strategic investment value as compared to the outcome that NERA sets out in criterion 2. % [REDACTED] .

possible values arising from situations outside a bidder's control.⁴⁷⁹ We note that NERA has not provided any justification for these selection criteria in its report.

A9.135 In particular, our view is that:

- Applying criterion 1 for any package other than the null package appears to be a conservative approach. This is because the minimum enterprise value for a package is the minimum that the bidder can control through its own bids, since higher enterprise values would depend on bids made by other bidders. This criterion may reflect, for example, the fact that coordination can turn out to be unsuccessful.
- However, selecting the minimum enterprise value associated with the null package (i.e. applying criterion 1 to the null package) appears to be an aggressive assumption. This is because, as explained above, the value of a package is derived in the NERA model as the enterprise value with that package less the enterprise value of the null package. Therefore, the lower the selected enterprise value of the null package, the larger the value derived by the model for the package with spectrum, as illustrated in the example above. But assuming the lowest enterprise value is likely to underestimate the value of the null package, and is thus capable of giving rise to artificially large strategic investment values. For example, this approach may underestimate the possibility that another strategic investor 1 may raise the bidder's enterprise value for the null package if that strategic investor engages in strategic investment bidding. In other words, this approach underestimates the role of free riding in a bidder's decisions.
- In addition, when evaluating a coordinated strategic investment outcome, we consider it is unreasonable to apply criterion 2 for selecting the enterprise value for the packages with spectrum and criterion 1 to select the enterprise value for the null package. This would imply that:
 - a) Strategic investor 1 is certain that strategic investor 2 would pursue the package that would enable a coordinated outcome if strategic investor 1 engages in strategic investment bidding. This would imply certainty about coordination, thereby ignoring the risks associated with coordinated strategic investment (which we discuss in annex 10).
 - b) Strategic investor 1 is certain that strategic investor 2 would not engage in strategic investment bidding at all if strategic investor 1 does not win any spectrum. This implies that, in evaluating the null package, a strategic investor would expect victims not be denied spectrum, i.e. that if the bidder itself does not engage in strategic investment, no other bidder will do so either.
 - c) In other words, it involves a very optimistic expectation on how the rest of the spectrum may be split if strategic investor 1 bids for a package, but a very pessimistic expectation if it does not bid for that package. This leads to high estimations of strategic investment values.

⁴⁷⁹ This aspect of NERA's methodology is only relevant for strategic investment value estimates, as intrinsic value estimates are non-strategic (i.e. do not depend on what other bidders do).

A9.136 To illustrate the impact of NERA's selection criteria on value estimation, we consider Vodafone's total value for the package with \pounds [REDACTED], which we call "package A"; and BT/EE's total value for "package B" which comprises \pounds [REDACTED]. NERA proposes these packages as potentially relevant for strategic investment in the auction.⁴⁸⁰ Figure A9.11 below provides ranges of enterprise values in NERA's model for each of the bidders with and without the packages.⁴⁸¹

Figure A9.11: Ranges of enterprise values with selected packages in NERA's model (in £m)

\pounds [REDACTED]

A9.137 When discussing coordinated strategic investment NERA argues that the value of these packages could be as high as \pounds [REDACTED] for Vodafone and \pounds [REDACTED] for BT/EE. This is obtained by applying criterion 2 to the enterprise value with packages A and B, and criterion 1 to the enterprise value without these packages. These values are \pounds [REDACTED] intrinsic value for the same packages \pounds [REDACTED].⁴⁸²

A9.138 However, if criterion 1 (rather than criterion 2) was applied to select the enterprise value with packages A and B (as NERA does for all other value estimations in its report), this would bring down BT/EE's value for package B by \pounds [REDACTED], and Vodafone's value for package A by \pounds [REDACTED].

A9.139 This gap has a simple interpretation: BT/EE would gain an additional \pounds [REDACTED] from winning package B if coordination was successful (i.e. if Vodafone wins package A), but would face the risk of not getting that 'value premium' if Vodafone fails to win package A and wins no spectrum, with the rest of the spectrum being \pounds [REDACTED].⁴⁸³ BT/EE does not therefore control whether or not it obtains the value premium, as that depends on the actions of other bidders. The gap in values illustrates the effect that the selection criteria can have in NERA's estimation of the value for spectrum. \pounds [REDACTED].

A9.140 In addition, as discussed, the criterion to select the enterprise value with a null package is also likely to have a substantial effect on the estimation of values. For the case of BT/EE's enterprise value with the null package, the minimum enterprise value, which NERA selects, would arise when \pounds [REDACTED]. But there are many possible alternative outcomes, such as where Vodafone successfully wins package A, but \pounds [REDACTED]. If BT/EE was confident that Vodafone would win package A – as NERA assumes for BT/EE's enterprise value with package B in the coordinated outcome – this scenario would be perhaps a more consistent and reasonable assumption on what BT/EE would expect when considering its value for the null package. This is because the information policy in the Auction (the third auction design feature we discuss above) means that Vodafone will only receive approximate aggregated bid information during the Auction and will not see the bids made by BT/EE or any other bidder. Therefore, Vodafone might be unable to adjust

⁴⁸⁰ Page 113 of NERA's report.

⁴⁸¹ We use the "strong strategic value" assumptions in NERA's model for running the sensitivities below.

⁴⁸² O2's intrinsic values were computed assuming NERA's standard assumption on long term spectrum.

⁴⁸³ In particular, BT/EE's minimum enterprise value with package B arises where \pounds [REDACTED]

its bid from package A to another package, depending on the bids made by BT/EE (and vice versa), even if it wished to do so.

A9.141 By selecting the enterprise value related to this outcome rather than the most unfavourable outcome, BT/EE's enterprise value with the null package would go up from £ [REDACTED] . If this enterprise value is selected instead of NERA's approach, it would have the effect of reducing BT/EE's modelled incremental value of package B by £ [REDACTED] . For example, if criterion 2 was used for BT/EE's enterprise value with package A (i.e. including the value premium discussed above), this alternative criterion for the null package would come down from £ [REDACTED] .

A9.142 The examples above illustrate that NERA's estimates are sensitive to the selection criteria, and that NERA's choices are not particularly conservative nor, in our view, necessarily superior to other choices. In addition, we note that there are many other possibilities to select the relevant enterprise value, like selecting other allocations (as in the examples above), or selecting weighted combinations of other allocations (for example, taking the average of all possible allocations with a given package). Here are some additional examples of the impact of alternative assumptions:

- The most conservative approach to estimating total values would be to take the minimum enterprise value for package A or B minus the maximum enterprise value for the null package. In this case, £ [REDACTED] . Although this criterion may appear excessively conservative, it illustrates how large a difference the choice of criteria can make to the resulting package values. In addition, values derived under the most conservative approach are the only ones that are in bidders' own control.
- Another option would be to take the average enterprise value for both the null package and the package with spectrum. This would be a reasonable approach if the strategic investor assigned equal probability to all possible allocations of the spectrum it does not win. In this case, Vodafone's total value for package A would reduce to £ [REDACTED] and BT/EE's total value for package B would fall to £ [REDACTED] . £ [REDACTED]

A9.143 In summary, in the NERA model a bidder's total value, including strategic investment value, is modelled as the difference between its enterprise value with the specific package of spectrum and its enterprise value without it (the null package). There is a wide variety of possible criteria to select a single enterprise value for a bidder - for each of the cases with the spectrum package and without it - from the multiplicity of possibilities (given that enterprise value is affected by the way other operators bid in the Auction). NERA uses specific criteria (without providing a clear justification for the choice of criteria). In our view, NERA's criteria are not particularly conservative nor necessarily superior to other possible criteria. We have illustrated above that different criteria can lead to very different value estimates, and, in some cases, conclusions as to the risk of strategic investment.

Other aspects of the methodology may not be appropriate

A9.144 Fourth, there are other methodological aspects, some of which may have a smaller impact on results, but which we nevertheless consider may be inappropriate.

A9.145 For example, NERA has used different years to compare intrinsic values and strategic values. Both values are based on enterprise value estimations up to the year 2026, but for the purpose of intrinsic value, cashflows in the model start at

2016 while strategic value cashflows start at 2017. Given that this applies both to the enterprise value with and without spectrum and 2016 cashflows in the model do not change with the spectrum, the 2016 cashflow nets out (when subtracting the enterprise value without spectrum from the enterprise value with the spectrum package) and does not affect the *total* value estimates for a package.

A9.146 However, the NERA model applies an additional year of discounting to the intrinsic value, discounting intrinsic value to 2015 prices but strategic investment values to 2016 prices. This inappropriately decreases the intrinsic value estimations relative to strategic investment value. It is more appropriate to discount intrinsic and strategic investment values to the same year, 2016, in order to make the comparison to strategic value more consistent. Such a change has the effect of raising intrinsic values for all operators which causes:

- H3G and O2 to have higher valuations for packages as they only have intrinsic value;
- BT/EE and Vodafone's total package values to remain the same but within the package they would have a decreased strategic investment value; and
- Overall, strategic investment is less likely in NERA's model.

A9.147 Another example of an aspect of the methodology that may not be appropriate is the underlying static nature of NERA's model, such as the assumption that, apart from the effect of capacity constraints, market shares are unchanged over the entire period modelled of about 10 years. As we discuss in annex 2 the speeds experienced by consumers (and constraints on speeds due to capacity constraints and network congestion) are an aspect of retail competition, but there are also many other considerations.⁴⁸⁴ The mobile market is subject to rapid change both in terms of consumer demand and technology, and market shares can and do change over time (see annex 1) and in ways that do not appear to be explained solely by capacity constraints. Operators' values for spectrum can be significantly affected (in either direction) by their future commercial and competitive plans.

Sensitivity to assumptions

A9.148 In addition to questions about methodology, the results in the NERA model are sensitive to the particular assumptions made. Some of these assumptions have a significant effect on the results, in our view are not properly justified or discussed, and may not be reasonable.

A9.149 One example of this is the extent to which the conclusions NERA draws from its analysis rely on upper end assumptions about the size of cashflow margin increases occurring when one or more networks become constrained. NERA claims there is a risk \propto [REDACTED]⁴⁸⁵. NERA's assertions are based on the scenario labelled as "strong", where cashflow margins are assumed to increase by 10%

⁴⁸⁴ We also note that, in modelling strategic investment value, NERA's model assumes that customers lost by weakened competitors are acquired by other networks in proportion to their spare capacity. This does not take into account the many other considerations that affect the closeness of competition between networks, as reflected, for example, in diversion ratios.

⁴⁸⁵ NERA report, page 112. This result continues to hold in the updated model, in which \propto [REDACTED], whereas an allocation based on intrinsic value \propto [REDACTED].

when one network is capacity constrained, 20% when two are constrained and 30% when three networks are constrained. However:

- The assumption of margin increments in this scenario appears to be aggressive, in particular when considering that these apply to all subscribers (i.e. post-paid, prepaid and MVNOs). If margins increased exclusively due to price rises (and costs remained constant), prices would need to increase 2%, 4% and 6% when one, two or three networks are constrained respectively.⁴⁸⁶ If costs were to increase as well, prices would need to increase even further to explain the assumed changes in cashflow margins. We note that, amongst other evidence submitted by stakeholders, these are the most aggressive assumptions as to price increases when competition softens. Both FE and AM assume that prices would only increase for post-paid customers, and consider smaller price increases in their upper bounds.
- In the only other scenario discussed by NERA, with “mild” assumptions (for which margins increase by only a quarter of the increments in the “strong” scenario), the risk of strategic investment in the auction reduces significantly. For example, O2’s standalone value⁴⁸⁷ for \mathcal{K} [REDACTED] , while Vodafone’s total value for the same package would be much lower at \mathcal{K} [REDACTED] with strong scenario). Similarly, O2’s intrinsic value for \mathcal{K} [REDACTED] (package A) is \mathcal{K} [REDACTED]⁴⁸⁸, while Vodafone’s total value for that package with mild assumptions is \mathcal{K} [REDACTED] with strong assumptions).
- We also modified the model to create an intermediate scenario, where margin assumptions are in between the two scenarios that NERA assumed (i.e. margins increase by half of the increments in the strong scenario). \mathcal{K} [REDACTED] .

A9.150 We thus conclude the ranking of valuations described by NERA is sensitive to assumptions, and the conclusions about strategic investment values of strategic investors exceeding intrinsic values of victim operator(s) only hold in the NERA model under aggressive assumptions on softening of competition.

Auction design features

A9.151 We now assess whether NERA’s conclusions on the likelihood of strategic investment are likely to hold when considering our auction design. Purely for the purpose of the discussion in this sub-section, we take NERA’s model results on values at face value.

A9.152 As discussed, NERA concludes that there is a risk of \mathcal{K} [REDACTED] . We disagree that this conclusion about strategic investment is likely to hold when considering the first auction design feature we have identified as mitigating the risk

⁴⁸⁶ We derived these implied price increases from NERA’s assumption that the initial cashflow margin is 20% of the initial price, with the remaining 80% being the cost. For example, if initial monthly ARPU is £20, the initial margin in NERA’s model is £4 and cost is £16. If it increases by 10%, the new margin is £4.40. At unchanged cost of £16, this new higher margin implies a price (ARPU) of £20.40, which is 2% higher than the initial price.

⁴⁸⁷ We note that intrinsic values are unaffected by the potential effects of softening of competition, and thus remain the same in the mild and strong scenarios.

⁴⁸⁸ This value is calculated using long term spectrum acquisition (30 MHz of 3.6 GHz spectrum for O2) to be consistent with the NERA model for calculating Vodafone’s strategic value.

of strategic investment, the uniform price rule. This is due to the multiplier effect discussed from A9.76 above.

- A9.153 In a context of \propto [REDACTED] , consistent with NERA's model results, the multiplier effect is particularly powerful. This is because the strategic investor would need to outbid multiple times its victim's \propto [REDACTED] block of spectrum.
- A9.154 Continuing with the example of \propto [REDACTED] according to NERA's model with strong price increments. Despite the fact that this amount \propto [REDACTED] , we would expect the uniform price rule of the auction to prevent \propto [REDACTED] from being successful in strategic investment. This is because, according to NERA's model, \propto [REDACTED] for the spectrum. This illustrates that NERA's conclusions do not incorporate important aspects of our auction design.
- A9.155 This observation also holds in the scenario of coordinated outcomes discussed above. As discussed, NERA's estimation of \propto [REDACTED] .

Conclusions on NERA's model

- A9.156 NERA's model has interesting features displaying the extent to which operators can view different bands as substitutes. In addition, the model provides a useful illustration of how strategic investment can arise. It can also be used to show the risks associated with engaging in strategic investment, such as incentives for free riding and coordination issues (although NERA does not do so).
- A9.157 However, as set out in annex 10, for an exercise of the kind NERA attempts, we consider it is challenging to provide reliable estimates of both intrinsic and strategic investment value for every possible package and every operator. NERA's model illustrates that this task may not only be sensitive to the assumed forecasts of business parameters, but also on other uncertain issues such as a bidder's expectations on bids by other operators and auction outcomes.
- A9.158 For the reasons set out above, we do not consider that NERA's model is sufficiently robust to provide a reliable indication of the likelihood of strategic investment in the Auction. In summary:
- The results of the model, and the conclusions that NERA draws from those results are sensitive to the choice of methodology. The effect of variations to the original model which appear reasonable to us have large effects on the results.
 - The results of the model are also sensitive to assumptions on parameters. In particular, we found that NERA's conclusions on the risk of strategic investment rely on strong assumptions on price increments when competition softens, \propto [REDACTED] .
 - NERA's conclusions as to the risk of strategic investment do not incorporate the features of our auction design, such as the uniform price rule. We have verified that incorporating this feature can change the results on which NERA depends for its conclusions.

NERA's welfare analysis

Overview of NERA's welfare analysis

- A9.159 Building on its model, NERA carries out an estimation of the potential welfare effects of inefficient spectrum allocation. It focuses on two aspects that it considers translate into welfare loss: switching costs and reduction in network quality⁴⁸⁹.
- A9.160 As previously discussed, the NERA model estimates the number of subscribers that churn out of each network as a result of congestion. NERA considers that there are switching costs associated with moving from one network to another. These include: search costs related to the time spent researching how to carry out the switch; other transaction costs related to the time spent doing the switch; early termination charges paid to the losing operator; contract overlap; and lost consumer welfare as a result of temporary loss of service while switching.
- A9.161 NERA also estimates the welfare loss as a result of lower network quality⁴⁹⁰. It assumes that consumers' willingness to pay (WTP) for mobile data is £31.4 per month⁴⁹¹ and that the loss in consumer surplus for each subscriber is proportional to the loss in network quality, i.e. $WTP \times (1 - \text{quality})$ ⁴⁹². NERA's model estimates congestion as a function of capacity (in Gbps) compared to traffic during the busy hour (which is assumed to account for 3% [REDACTED] of total traffic during the day).
- A9.162 The model then calculates the total welfare loss for the subscribers of each network but assumes that only subscribers in urban areas (49% of the total) are affected.
- A9.163 NERA estimates the total welfare loss under four spectrum allocations:
- The scenario where spectrum is allocated efficiently as per intrinsic value, 3% [REDACTED]. In this scenario there are still welfare losses of £316m in TP1 and £0 in TP2, but NERA argues that this is the result of the existing inefficient allocation of spectrum.
 - In the second scenario Vodafone acquires access to all 2.3 GHz spectrum and then the 3.4 GHz is allocated based on intrinsic value, 3% [REDACTED]. Total welfare losses are estimated to be £2.2bn in TP1 and £0 in TP2.

⁴⁸⁹ NERA also argues that O2's subscribers place significant value on the other aspects of O2's service which they would lose if they move to another network. However, NERA has not tried to quantify the value of these services to consumers.

⁴⁹⁰ Network quality is measured as $\ln(\text{quality}) = \min(1, \text{capacity}/\text{demand}) - 1$, i.e. $\text{quality} = e^{\min(1, \frac{\text{capacity}}{\text{demand}}) - 1}$. This corrects a typo in NERA's report which states that the figure used is the maximum, not the minimum as is done in the model. As discussed before, the model already estimates the level of demand and capacity for each operator in each year and each spectrum allocation scenario. Therefore, if capacity is greater than demand, *quality* will be equal to 1. If capacity is less than demand then *quality* will be less than 1.

⁴⁹¹ It is unclear how NERA arrives at this estimation of the WTP. On page 101 of its report it mentions a £90 WTP for mobile data as per a Plum report for the GSMA (see footnote 70). NERA simply states that "we assume that the willingness to pay for mobile data is £31.40 per month and that network congestion will only affect customers living in urban areas".

⁴⁹² Given that *quality* is 1 when there is no congestion, $1 - \text{quality}$ represents the degradation in the network quality that translates into a loss of welfare for the consumer, i.e. 0 if there is no congestion and more than 0 if there is.

- c) In the third scenario BT/EE and Vodafone jointly acquire access to the 3.4 GHz band but the 2.3 GHz is awarded according to intrinsic value. As a result, Δ [REDACTED] . Welfare loss in TP1 is the same £316m as in scenario 1 but there is a £2bn welfare loss in TP2.
- d) The fourth scenario assumes that BT/EE and Vodafone acquire access to all the spectrum, i.e. Δ [REDACTED] . This leads to the same welfare loss for TP1 of £2.2bn as in the second scenario plus an additional welfare loss of £2.6bn for TP2.

A9.164 Of the welfare losses estimated above only 5-6% correspond to losses as a result of switching costs, with the bulk of the losses being the result of lower network quality.

Ofcom's response to NERA's welfare analysis

- A9.165 If there were an inefficient allocation of spectrum, we would generally expect it to lead to adverse effects on consumers (although in some cases there could be a combination of adverse effects and partially offsetting benefits). However, reliably quantifying the scale of this effect raises significant challenges.
- A9.166 NERA's approach relies on (amongst other things) there being an inefficient allocation, accurately measuring the resulting change in network quality, and a range of assumptions such as about the value consumers derive from quality (e.g. the figure for average WTP, the assumption that welfare losses are proportional to reductions in quality, etc.).
- A9.167 Here we focus on just one aspect, relating to the difference between the busy hour and other times of day. Subscribers' willingness to pay would reflect the monthly value that they would derive from the service as they use it throughout the whole month, not just the busy hours in the month. On the other hand, NERA's model measures congestion (i.e. decrease in quality) during the busy hour. It therefore seems to be a significant overstatement to assume, as NERA appears to, that the entire monthly value of the data service for the subscriber is affected in proportion to the loss of quality during the busy hour.
- A9.168 While users would experience the effects of congestion during the busy hour, at other times they might not suffer any drop in quality and, therefore, no loss of welfare. Even if we assume that there is congestion at other times beyond the busy hour, we would expect that the average loss in quality would be lower than in the busy hour and so accordingly would any welfare loss.
- A9.169 NERA assumes that a certain proportion of traffic takes place during the busy hour. Using a simple illustrative assumption that consumers value each MB of data equally, only the willingness to pay corresponding to that proportion of traffic conveyed during the busy hour would be affected by congestion. As a result, welfare losses due to congestion would only relate to that proportion of traffic being conveyed during the busy hour.
- A9.170 Even when affected by congestion, some subscribers may still be able to obtain some of the services they expect, e.g. receiving e-mails, browsing webpages, sending messages, etc. These users may not experience a significant loss in welfare. Furthermore, for some users the hours in which they demand higher quality are times when there is no congestion.

A9.171 Therefore, we have reservations about NERA's quantified estimate of welfare losses, both because of the challenges of the exercise and the specific point discussed above about the busy hour. Nonetheless, we agree that if consumers experienced a significant loss in network quality as a result of spectrum asymmetry this is likely to have a material detrimental effect on consumer welfare.

Analysys Mason's models

Overview of methodology and assumptions in AM's models

A9.172 H3G commissioned AM to analyse potential ranges of values for PSSR spectrum for UK MNOs. The scope of AM's work involved modelling both intrinsic and strategic values for each MNO. In deciding on assumptions, H3G asked AM to take a conservative approach and to reflect as far as possible Ofcom's view of the market, as set out in the relevant documents, even where this conflicts with H3G's own view of the market.

A9.173 H3G states that *"AM has found that [operator(s)] < [REDACTED] could find it difficult to win sufficient spectrum to remain competitive without appropriate measures in the PSSR auction, even if Ofcom were correct in its assumptions about relative technical values between MNOs."*⁴⁹³

A9.174 The main conclusions that H3G draws from the AM models are as follows:

- More capacity-constrained MNOs may have a lower intrinsic value.
- [Strategic investor(s)] < [REDACTED] would significantly increase [its/their profit(s)] < [REDACTED] by keeping PSSR spectrum out of [victim operator(s')] < [REDACTED] hands and have a large strategic investment value in the PSSR auction.

A9.175 The main outputs of AM's models are estimates of valuations at a spectrum package level for each MNO. AM estimates possible ranges for those values, characterized by a lower bound and an upper bound, but without a specific base case. The upper end estimates of valuations in the AM models are used by Power Auctions to infer auction outcomes under different policy options.

A9.176 Analysys Mason provided Ofcom with a copy of two valuation models supporting results in Annex 16 of H3G's submission: a model about intrinsic value and another on strategic investment value. The total value of a spectrum package to a bidder is the intrinsic value plus the strategic value.

A9.177 Below we explain how the AM models estimate both intrinsic and strategic investment values.

Intrinsic Values

A9.178 In the intrinsic value model, the intrinsic value to an MNO is made up of commercial and technical value. Commercial value is extensively modelled by AM, while technical value is not directly modelled.

⁴⁹³ H3G main response, page 118.

A9.179 AM's intrinsic value ranges (i.e. the sum of commercial and technical value range estimates) are summarised for a subset of packages in Figure A9.12 below. The darker colour in each bar represents lower bound estimates, and the lighter colour represents potential additional value up to the upper end of the estimates.⁴⁹⁴ The labels on the horizontal axis represent package combinations (e.g. 10 + 20): the first number is the amount of 2.3 GHz spectrum and the second is for 3.4 GHz spectrum. Figure A9.12 shows that in the AM model [operator(s)] < [REDACTED] the highest intrinsic value for all spectrum packages, and this is also true for modelled packages not shown in the diagram. In addition, AM notes that *"there are significant overlaps in the ranges of values for [operator(s)] < [REDACTED], with [operator(s)] < [REDACTED] generally having slightly lower intrinsic values."*⁴⁹⁵ Consequently, AM finds that [operator(s)] < [REDACTED] intrinsic value may not be sufficiently high to allow it/them to outbid [operator(s)] < [REDACTED] for at least some spectrum.

Figure A9.12: AM model results for intrinsic valuations for specified spectrum packages

< [REDACTED]

Source: AM report, Annex 16 of H3G's response.

A9.180 Below we explain in turn AM's estimates for commercial and technical values.

Commercial values

A9.181 AM models commercial values by making assumptions on how additional spectrum would generate incremental costs and revenues to each MNO.

A9.182 The value for a particular package is obtained by comparing the enterprise value of each MNO with that package minus the enterprise value without any additional spectrum (i.e. with the null package). In AM's base case, it considers a 20 year NPV to estimate enterprise values.

A9.183 On the costs side, AM assumes a fixed cost of £11,500 per site to use each band of spectrum in the Auction. Such sites can be used for up to 40 MHz of a specific band. If more than 40 MHz are deployed in a band (only possible in the 3.4 GHz band), then deployment costs increase by a further 25% for each 40 MHz increment (costs increase at 45 MHz, 85 MHz and 125 MHz). There is an assumed annual operating cost of 5% of deployment costs.

A9.184 On the revenue side, AM assumes that downlink spectrum shares determine network performance as to average data speeds of each operator. Network performance is assumed to affect the commercial performance of each operator, as described below. The commercial performance, in turn, is assumed to affect the operator's customer churn and its share of gross market additions ("gross adds"), which is a source for incremental revenues.

A9.185 In determining downlink spectrum shares, AM assumes that:

⁴⁹⁴ The lower and upper ends of these ranges do not represent strict lower and upper limits on the value of the spectrum to each MNO, but rather separate low and high estimates for intrinsic values based on different combinations of input parameters.

⁴⁹⁵ H3G main response, page 119.

- All bands are immediately available and that there is no delay in useability of the 3.4 GHz or the 1400 MHz spectrum.
- Spectrum bands that may be available in the future are not considered (for example the 700 MHz and 3.6 GHz bands). Instead, the model assumes that commercial benefits are only present in the short to medium term before other spectrum is available or technology developments impact the market. Commercial benefits accrue over a five year period from 2018, with lower benefits in years 4 and 5 (despite the fact that the enterprise value is estimated over a 20 year period).
- The usefulness of bands is assumed to depend on their coverage properties. The network footprint of 3.4 GHz is assumed to be 30% [REDACTED]⁴⁹⁶, while all other bands are assumed to have a 100% network footprint. This 30% [REDACTED] is also used to down weight the 3.4 GHz spectrum when calculating overall spectrum shares. These assumptions decrease the value of 3.4 GHz spectrum relative to 2.3 GHz spectrum (and other bands).
- AM assumes that 70% of TDD spectrum can be used for downlink traffic.

A9.186 AM maps how downlink spectrum shares translate into a network's commercial performance through a so-called "commercial performance curve". At a high level, the larger the spectrum share, the higher the commercial performance. AM's intrinsic value model assumes that this curve is concave (i.e. the ability of additional spectrum to increase commercial performance decreases with spectrum holdings) as can be seen in Figure A9.13 below – the larger the downlink spectrum share, the flatter the curve. The upper end range for the commercial performance curve points are (from left to right): 30% [REDACTED]⁴⁹⁷, 30% [REDACTED]⁴⁹⁸, 30% [REDACTED]⁴⁹⁹, 30% [REDACTED]⁵⁰⁰, 30% [REDACTED]. The lower range points are: 30% [REDACTED].

A9.187 An important parameter in determining commercial performance is the "Acceptable Performance Threshold" (APT) which AM says 30% [REDACTED]. The APT represents the share of spectrum below which there is assumed to be a drop in commercial performance of operators. In the intrinsic value model, AM considers a range of 30% [REDACTED] for the APT.

Figure A9.13: AM mapping of downlink spectrum shares to commercial performance – the commercial performance curve

30% [REDACTED]

Source: Annex 16 of H3G's response

A9.188 In AM's model, the commercial performance of a network is a key determinant of revenues. Higher commercial performance (e.g. higher average speeds) causes lower churn rates and higher share of gross market additions for an MNO which

⁴⁹⁶ This estimate was provided by H3G to AM based on a simulation of H3G's network. The same value has been assumed for all other MNOs as well.

⁴⁹⁷ AM rationale from Annex 16: 30% [REDACTED]

⁴⁹⁸ AM rationale from Annex 16: 30% [REDACTED]

⁴⁹⁹ AM rationale from Annex 16: 30% [REDACTED]

⁵⁰⁰ AM rationale from Annex 16: 30% [REDACTED]

leads to higher revenues and reduced non-network costs. In essence, in AM's model a segment of consumers (8.7% in the models) can be influenced to switch away based on how their network is performing. Figure 3.16 of AM's report provides an example of such a relationship. In a scenario where H3G acquires no spectrum licences, its upper end commercial performance index amounts to £< [REDACTED] . If H3G wins an additional 10 MHz of 2.3 GHz and 40 MHz of 3.4 GHz spectrum, its commercial performance would increase £< [REDACTED] . The difference in commercial performance £< [REDACTED] is then multiplied by 8.7% (the relevant segment of consumers) to obtain by how much the share of gross adds and the churn would increase or decrease. In this particular example, H3G's share of gross additions would be £< [REDACTED] (in absolute terms) when it does not obtain new spectrum.

A9.189 The models use 2015 ARPUs based on AM research data for MNO retail only (it excludes MVNOs). These ARPUs are forecasted to remain flat in nominal terms. For contract handsets ARPUs, which drives commercial values the most, the MNOs' monthly values are: H3G £20.49, BT/EE £29.40, Vodafone £27.20 and O2 £28.90. If a customer churns away, for example, from H3G to BT/EE the model assumes that the customer will pay BT/EE's higher ARPU which is more 40% higher than the ARPU that H3G is assumed to lose.

Technical values

A9.190 Technical value, the other part of intrinsic value, is not directly modelled in AM's models. AM states that *"Calculating technical values is outside the scope of our assignment and, therefore, our estimates of technical value are not outputs of a model but are instead inferred [...]"*⁵⁰¹ The technical values are inferred by AM based on the following:

- Technical values are likely to be greater for MNOs that are more capacity constrained.
- AM considers £< [REDACTED] . In addition, 3.4 GHz spectrum has a smaller network footprint and is therefore unlikely to reduce the required number of sites as effectively as 2.3 GHz.
- £< [REDACTED] ⁵⁰² .

A9.191 The consequence of AM's approach to deriving estimates of technical value is that £< [REDACTED] . Figure A9.14 below shows AM's estimates of technical value for a larger set of packages.

Figure A9.14: AM estimated range of technical estimates for a subset of packages (£m)

£< [REDACTED]

Source: Figure 3.19 in Annex 16 of H3G's response.

⁵⁰¹ H3G Annex 16 submission, page 32.

⁵⁰² £< [REDACTED] .

Strategic investment value

A9.192 In the strategic investment model, strategic investment value arises for a strategic bidder (  [REDACTED]) when another (victim) operator is limited below the APT (  [REDACTED]). AM provides strategic investment estimates assuming the APT is at a spectrum share of   [REDACTED] . When [victim operator(s) fall(s)]   [REDACTED] below the APT, there are two effects:

- There is increased churn away from the MNOs that fall below the APT and these MNOs also attract fewer new customers. This creates a pool of lost/forgone subscribers, from which [strategic investor(s)]   [REDACTED] can benefit. This increases the number of subscribers that [strategic investor(s) gain(s)]   [REDACTED] , by assuming that the MNO that falls below the APT would not pick up any of the subscribers in that pool. Thus, depending on   [REDACTED] , the proportion of the subscribers captured by [strategic investor(s)]   [REDACTED] varies.   [REDACTED] These percentages are obtained by rebasing the share of market gross additions in a way that excludes [operator(s) which is/are]   [REDACTED] below the APT. As in the commercial value model, effects on churn and the share of gross additions only last 5 years.
- [Strategic investor(s) charge(s)]   [REDACTED] a higher amount to their existing and incremental post pay handset subscriber base due to the decrease in competitive constraint. The increase in ARPU is assumed to be   [REDACTED] .

A9.193 AM's report provides an upper bound and a lower bound for strategic investment value for [strategic investor(s)]   [REDACTED] . The upper bound is when a victim MNO is completely foreclosed from winning spectrum in the auction; while the lower bound is when a victim MNO is limited to a marginal amount less than the APT.   [REDACTED]⁵⁰³ However, AM derives no precise value of the strategic investment value to [strategic investor(s)]   [REDACTED] of limiting an MNO to an amount between their APT and no spectrum in the auction. To illustrate this point, AM does not provide figures for a strategic investment value to   [REDACTED] . The report only implies that the strategic value is between the upper and lower bound estimate.

A9.194 AM provides strategic investment value estimates associated with the whole spectrum in the auction and specifically with the 2.3 GHz spectrum. In particular:

- Overall spectrum: Under the same assumptions on band useability as in the commercial value model (described above), AM estimates the benefits of reduced competition would accumulate over a 20 year period.
- 2.3 GHz spectrum: AM assumes that the 3.4 GHz spectrum is not useful to improve network performance during the first three years before the end of 2019. This is implemented by attributing the increased profits due to reduced competition that accumulate during the first 3 years exclusively to the victim MNO(s) being denied 2.3 GHz spectrum, and by considering that 3.4 GHz spectrum does not contribute to spectrum shares in that period. It appears that

⁵⁰³ These results are for these specific packages and cannot be simply converted between 2.3 GHz and 3.4 GHz. This is due to 3.4 GHz having a network footprint of   [REDACTED] , while 2.3 GHz has a 100% network footprint. To illustrate this, if   [REDACTED] .

AM has implicitly modelled this by including 3.4 GHz in the denominator, but not adding 3.4 GHz to the numerator when calculating spectrum shares.

- A9.195 The results of AM's strategic model are shown in Figure A9.15 below. The higher bound estimates are when \propto [REDACTED] ; whilst the lower bound estimates are when \propto [REDACTED] .

Figure A9.15: AM model strategic values to [strategic investor(s)] \propto [REDACTED] if [victim operator(s) is/are] \propto [REDACTED] foreclosed from 2.3 GHz spectrum

\propto [REDACTED]

Source: Ofcom based on Annex 16 of H3G's response and AM's strategic investment model

Ofcom's response to AM's models

- A9.196 In this section, we discuss our view on AM's models. First, we explain that AM's assumptions are not fully consistent with Ofcom's views with regard to the context of the Auction. Second, we discuss the likely effects of AM's models failing to incorporate H3G's UK Broadband spectrum in the analysis. Third, we set out our concerns about AM's methodology for estimating technical values. Fourth, we analyse AM's methodology for estimating commercial values, including issues about the performance curve. Fifth, we conduct a similar analysis with respect to the methodology for estimating strategic investment values. Finally, we illustrate the sensitivity of results to variations in assumptions.

AM's models do not fully reflect Ofcom's view

- A9.197 H3G asked AM to reflect Ofcom's view of the market as far as possible, not H3G's. We have identified some examples where aspects of AM's models fail to reflect our view.
- A9.198 First, AM's intrinsic value model assumes that the 3.4 GHz is immediately useable, which was not our view in the November 2016 consultation or in this statement. As will be discussed later, this is likely to distort the substitutability of 2.3 GHz and 3.4 GHz spectrum.⁵⁰⁴
- A9.199 Second, and in contrast to NERA's model, AM does not consider 700 MHz and 3.6 GHz in the analysis, whereas we included both bands in our analysis in the November 2016 consultation and in this statement. This is likely to have a bearing on the estimation of both strategic investment and intrinsic values, especially regarding the 3.4 GHz band.
- A9.200 Third, although AM claims that its approach to the APT is based on Ofcom's approach, it departs from our approach in a number of respects, such as calculating weighted spectrum shares by multiplying 3.4 GHz spectrum by a \propto [REDACTED] network footprint. When we calculate spectrum shares we include all useable

⁵⁰⁴ AM's model has other assumptions aimed at mitigating the effects of the assumptions described above. For example, on page 121 of H3G's response, H3G explains "strategic investment would not deliver benefits beyond a certain date, when other spectrum is assumed to become available. The impact of strategic investment (...) extends only five years from 2018..." AM applies a similar logic in the determination of commercial values. Although this may address the absence of 700 MHz and 3.6-3.8 GHz in the analysis, it fails to do so when considered in conjunction with the assumption of immediate useability of 3.4 GHz. This is because future bands are likely to have different impacts on the value of 2.3 GHz and 3.4GHz.

spectrum equally (i.e. unweighted) in terms of MHz, including the 3.4 GHz band (after the first transitional period). Other departures from Ofcom's approach include AM making an adjustment to \propto [REDACTED] , and using shares of downlink spectrum instead of total spectrum.

A9.201 These examples illustrate that AM's approach does not fully reflect Ofcom's view (even though H3G asked AM to do so as far as possible). We also note that AM's model does not fully reflect H3G's view either.

No account taken of H3G acquiring UK Broadband

A9.202 AM's models do not take into account H3G's acquisition of UK Broadband. This is an important omission in the context of the analysis, which is likely to have a meaningful effect on the \propto [REDACTED] .

A9.203 In AM's model, \propto [REDACTED] .⁵⁰⁵

A9.204 In addition, H3G's values for additional spectrum are likely to be different than the estimates in AM's model, which reflect its spectrum holdings prior to the acquisition of UK Broadband.

Methodology for technical values

A9.205 Intrinsic values are the sum of technical and commercial values. In this sub-section we discuss AM's methodology for estimating technical values (and we comment on the methodology for commercial values in the next sub-section).

A9.206 We described above that, although AM extensively models commercial values, it does not estimate technical values using a similar level of detail. AM estimates such values in an indirect way, even though technical values form an important portion of the total intrinsic values in AM's model, \propto [REDACTED] .⁵⁰⁶

A9.207 **First**, we disagree with AM's estimates on the relative technical values for spectrum of different operators. \propto [REDACTED] .⁵⁰⁷

A9.208 **Second**, we do not agree that the analysis undertaken by Ofcom \propto [REDACTED] . Ofcom does not have a definitive view on the likely magnitude of such values, and this is one of the reasons why we \propto [REDACTED] .

A9.209 Ofcom's analysis that AM's refers to relates \propto [REDACTED] ⁵⁰⁸ :

- \propto [REDACTED] ;
- \propto [REDACTED] ;
- \propto [REDACTED] ; and

⁵⁰⁵ AM's model considers that \propto [REDACTED]

⁵⁰⁶ For example, according to AM's upper end estimates of intrinsic values, technical values account for \propto [REDACTED] of the intrinsic value for 20 MHz of 2.3 GHz spectrum \propto [REDACTED] . The role of technical values is \propto [REDACTED] . For instance, technical values explain \propto [REDACTED] for 40 MHz of 2.3 GHz spectrum. \propto [REDACTED] .

⁵⁰⁷ In this section, we focus on upper end estimates of both intrinsic and strategic value estimates. This is because Power Auction's analysis is based on these estimates.

⁵⁰⁸ H3G Annex 16 submission, page 33.

- 3< [REDACTED] .

A9.210 We consider that there is scope for significant error in each stage of this estimation approach, which involves – amongst other things – AM 3< [REDACTED] .

A9.211 3< [REDACTED] .

A9.212 3< [REDACTED] :

- 3< [REDACTED]
- 3< [REDACTED]

A9.213 3< [REDACTED] ⁵⁰⁹

A9.214 3< [REDACTED] .

A9.215 3< [REDACTED] .

A9.216 3< [REDACTED]

A9.217 **Third**, technical values are, in essence, the network cost savings for an operator from having additional spectrum (compared to not having that spectrum).⁵¹⁰ It is common for operators (and in some cases, regulators) to develop technical models that can model technical values. Instead of doing this, however, AM has adopted an approach which seems to us to be convoluted and prone to error. This raises serious concerns about the reliability of the resulting estimates of technical values.

A9.218 Overall, we consider that the very indirect method adopted by AM to infer estimates of technical values is prone to significant error, and that the estimates 3< [REDACTED] .

Methodology for commercial values

A9.219 As in the NERA model, commercial value estimates in AM's model are based on the premise that there is a mechanical or predictable relationship between spectrum shares and the ability to retain or gain subscribers. While this simplification of the complex reality may prove to be unavoidable for this kind of modelling exercise, such simplification needs to be realistic or at least sufficiently robust to provide reliable estimates. We have analysed AM's methodology and, in our view, it is not sufficiently robust to derive reliable estimates of the commercial values for each operator.

A9.220 First, we disagree with AM's assumption that the 3.4 GHz band is useable in a similar timeframe to 2.3 GHz. We consider this is likely to introduce distortions in the estimations of commercial values. This is because the assumption implies a degree of substitutability between bands that does not accurately reflect the context of the PSSR auction. Our view is that, while 2.3 GHz can serve to increase capacity both in the first transitional period and beyond, 3.4 GHz would only be useful to increase capacity beyond the first transitional period. Hence, operators needing to increase capacity in the first transitional period are less likely to be willing to give up 2.3 GHz spectrum in exchange for 3.4 GHz than the predictions in AM's model. This

⁵⁰⁹ 3< [REDACTED] .

⁵¹⁰ We discuss the definition of technical value in annex 11.

reasoning suggests that AM's estimation of relative intrinsic values between 2.3 GHz and 3.4 GHz spectrum can be distorted due to inappropriate assumptions on the useability of bands. We were not able to run sensitivities on this assumption, as our understanding is that the model is not built to incorporate the impact of varying spectrum shares across time.

- A9.221 Second, AM's estimates of commercial value depend on its assumptions on the performance curve, and how the performance curve translates into churn or share of gross additions.
- A9.222 The logic underlying the performance curve appears to be that spectrum shares determine the probability (or share) of the relevant set of subscribers that each operator is likely to obtain or retain. However, given that, in reality, operators with very different shares of spectrum can acquire a similar share of new subscribers (or have similar churn rates), no universal relation can be easily built. For example, annex 1 shows that the MNOs that have been increasing their market shares in recent years have been those with the smallest spectrum shares and this has been at the expense, in part, of market share loss by the operator with the largest share of spectrum (in addition, annex 4 shows that spectrum and market shares can also differ significantly in other countries).
- A9.223 In order to attempt to deal with this substantial complication, our understanding is that AM has normalised the performance curve to match the initial conditions of each operator. This is done by assuming that the share of market gross adds and churn would remain the same if the post-auction spectrum shares were to remain equal to the pre-auction shares. The performance curve would then identify how the operator's share of market gross adds and churn would change when spectrum shares change. Hence, even though BT/EE and O2 would gain a similar share of new subscribers if they were to maintain their pre-auction spectrum shares, increasing shares by a certain amount would be more useful for O2 than to BT/EE, given that O2 has lower initial spectrum shares and the performance curve is concave. However, we note the following issues:
- It appears that in AM's model the absolute change in the commercial performance percentage for an operator, which results from a change in its share of spectrum, is the change modelled by AM in the share of that operator of gross adds and churn (i.e. retaining existing or acquiring new subscribers in the segment of consumers that can be influenced to switch based on network performance). Taking into account this modelling implication, it is unclear to us how either the scale or the shape of AM's performance curve is properly justified and a range of alternative assumptions could be as or more reasonable.
 - The way AM modelled the commercial performance is likely to be sensitive to the scale of the curve. In AM's model, commercial performance can range from %< [REDACTED] to %< [REDACTED] . A wider or a narrower range can affect estimations and AM has not explained why the range it selected is the relevant one.
 - The shape of the performance curve is also likely to have a material impact on the results. This is because the degree of concavity determines the incremental commercial performance for each operator around its pre-auction spectrum holdings. We discuss below a sensitivity we have conducted on both the scale and the shape of the performance curve.

- Given the complexity of the relationship between spectrum shares and commercial performance, and the potential for substantial variation between operators reflecting their specific and different circumstances, we are doubtful that AM's normalisation is sufficient to capture the heterogeneity in MNOs' business plans and commercial strategies. Another approach would be to build completely independent performance curves for each operator (although that approach would still need adequately to address the complexity of the relationship between spectrum share and commercial performance).

A9.224 In the section on sensitivities below, we illustrate how changes in the performance curve affect the estimation of commercial values.

Conclusion on methodology for commercial values

A9.225 In summary, we conclude as follows on AM's methodology for commercial values:

- a) AM's intrinsic value model understates [operators'] \times [REDACTED] intrinsic value preference for 2.3 GHz spectrum over 3.4 GHz spectrum, because it assumes that the 3.4 GHz band is useable at the same time as the 2.3 GHz band.
- b) It is unclear that AM's performance curve, which links an operator's share of spectrum to its commercial performance and its ability to compete for subscribers, appropriately captures the complex and non-mechanical relationships that are, in reality, reflected in the mobile market.

Methodology for strategic investment values

A9.226 Turning to strategic investment values, as explained, such values arise in AM's model exclusively when an operator's share of downlink spectrum falls below \times [REDACTED]. This is judged by AM to be the "acceptable performance threshold" (APT). We have several points of disagreement with respect to this methodology.

A9.227 **First**, we disagree with the way AM estimates the strategic investment which arises exclusively with respect to 2.3 GHz. As explained, AM looks at the strategic investment value arising exclusively in the transitional period by considering the NPV of strategic investment profits generated only in the first 3 years (up to 2019), under the assumption that the 3.4 GHz band is not useable. However, in computing spectrum shares for each operator, AM takes into account 3.4 GHz spectrum in the denominator of the shares. This is inconsistent with the assumption that such spectrum is not useful to address capacity concerns up to 2019, and has the effect of artificially depressing the spectrum shares of all operators significantly. This causes the spectrum shares of the operators to add up to \times [REDACTED], as shown in Figure A9.16⁵¹¹, when (by definition) spectrum shares should add up to 100%.⁵¹²

⁵¹¹ Includes pre-existing spectrum and 2.3 GHz in the denominator and numerator. 3.4 GHz spectrum is only included in the denominator.

⁵¹² \times [REDACTED].

Figure A9.16: Shares of useable downlink spectrum by operator in AM's model in the transitional period

3% [REDACTED]

Source: Ofcom from AM model

A9.228 If 3.4 GHz spectrum was not included in the denominator in computing shares (as we consider appropriate for the assessment of strategic investment in 2.3 GHz), 3% [REDACTED] There are two important considerations:

a) 3% [REDACTED] ^{513 514} .

b) 3% [REDACTED] .

A9.229 **Second**, the assumptions on band availability are inconsistent in the strategic investment and the intrinsic value models. AM estimates strategic investment value arising exclusively in the transitional period under the assumption that the 3.4 GHz band is not useable. However, in estimating intrinsic values, AM assumes that 2.3 GHz and 3.4 GHz spectrum are available at the same time. Hence, we consider that intrinsic value estimates as presented by AM cannot be compared or added to the estimation of strategic investment values in the transitional period, as the two figures embody different assumptions on the useability of bands. Comparing figures from both AM models, as Power Auctions does, would overestimate the likelihood of strategic investment in 2.3 GHz. This is because, as explained above, the assumptions about band useability in the intrinsic value model are likely to overestimate MNO's willingness to give up 2.3 GHz in exchange for 3.4 GHz, therefore creating a bias.

A9.230 **Third**, strategic values, like commercial values, are affected by the particular choice of the APT and the performance curve. As previously discussed, AM models a higher and lower end range performance curve in the intrinsic value model. For the higher end range the APT 3% [REDACTED] , while for the lower end range is at 3% [REDACTED] . However, in the strategic value model only the higher end range performance curve is used. This causes the strategic value numbers to be at their highest estimates, rather than a base case or lower range. In addition, the considerations about the effect of the performance curve on churn and the share of gross adds apply to the strategic values as well. This is because a portion of the strategic value arises from the strategic bidder benefiting from the victim MNO's subscribers lost/not gained due to its inability to reach certain commercial performance. We discuss a scenario below that is affected by using a lower end range performance curve.

Conclusion on methodology for strategic investment values

A9.231 In summary, we conclude as follows on AM's methodology for strategic investment values:

a) AM's strategic investment model overstates strategic investment values given its methodology to compute spectrum shares of immediately useable spectrum, which sum to only 3% [REDACTED] instead of 100% and

⁵¹³ 3% [REDACTED] .

⁵¹⁴ 3% [REDACTED] .

artificially depress operators' spectrum shares relative to the APT (acceptable performance threshold).

- b) AM's strategic investment model considers that strategic investors would be willing to pay a premium to preclude [victim operator(s)] < [REDACTED] from obtaining 2.3 GHz in particular, by assuming that the 3.4 GHz band is not useful to address short term capacity issues. This assumption is inconsistent with the assumption in AM's intrinsic value model that 3.4 GHz is useable at the same time as 2.3 GHz (noted above), with the consequence that the risk of strategic investment in the 2.3 GHz band is likely to be overstated.
- c) Strategic values, like commercial values, are affected by the particular choice of the APT and the performance curve in AM's model.

Sensitivity to assumptions

- A9.232 Intrinsic value and strategic value estimates in AM's models also depend on a number of assumptions which have a large impact on the results. The sensitivity analysis conducted by AM has been to consider sensitivities on the intrinsic value model. The sensitivities discussed in their report are: higher and lower end estimates of technical value, higher and lower end ranges of their commercial performance curve, and shortening the time period the model looks at to 5 and 10 years.
- A9.233 Whilst we consider that a more thorough sensitivity analysis would be beneficial, we have not ourselves attempted to undertake a comprehensive sensitivity analysis, taking account of the complexity of AM's models and that the models are not set up to run all of the relevant sensitivities. However, in light of our comments above on the performance curve, which influences both commercial and strategic investment values, we have explored a variation to AM's performance curve assumptions.
- A9.234 AM's models assume that the shape of the commercial performance curve is concave (i.e. the ability of additional spectrum to increase commercial performance decreases with spectrum holdings). This general approach appears reasonable, but the precise shape (or degree of concavity) has a significant impact on value estimates. With respect to the particular assumptions made by AM on this, we do not find them convincing. For example, AM assumes that concavity does not change much when spectrum shares are between < [REDACTED] . In practice, this means that in AM's model getting an extra 1% of the share of spectrum would have similar effects in improving commercial performance for operators with very different spectrum positions, such as an operator with < [REDACTED] of the spectrum and another operator with < [REDACTED] of the spectrum.⁵¹⁵
- A9.235 We have tested the impact of adopting a variation of the performance curve, involving greater concavity, so that when spectrum shares are low, additional spectrum yields a larger increase in commercial performance (compared to AM

⁵¹⁵ More specifically, an extra 1% of spectrum share would increase commercial performance by < [REDACTED] (in absolute terms) if the operator has a share of spectrum in the range of < [REDACTED] , and < [REDACTED] (in absolute terms) if the operator has a share in the range < [REDACTED] . This is when considering the upper end of the performance curve, which is used to estimate upper end valuations. As explained, we concentrate on upper end estimates given that this is what Power Auction uses in its analysis.

assumptions) and when spectrum shares are high, additional spectrum yields a smaller increase in commercial performance. With this sensitivity, an extra 1% of spectrum share increases commercial performance in a similar way as AM assumed if spectrum shares are in the range of %< [REDACTED] AM's assumption when shares are in the range %< [REDACTED] of it if spectrum shares are in the range of %< [REDACTED] .⁵¹⁶ This sensitivity also implies a different scale for the performance curve, noting that commercial performance would be in the range %< [REDACTED] rather than %< [REDACTED] . For the avoidance of doubt, given the uncertainty about the nature, scale and shape of the performance curve (as discussed above), we are not suggesting this different performance curve is necessarily appropriate. However, in our view it is helpful to explore the sensitivity of the results of the AM models to alternative assumptions. Figure A9.17 below is a visualisation of our sensitivity on the commercial performance curve.

Figure A9.17: Ofcom sensitivity analysis on AM commercial performance curve

%< [REDACTED]

Source: Ofcom analysis using AM model

A9.236 A consequence of this sensitivity is that additional spectrum would give %< [REDACTED] greater gains in terms of gross adds and churn, while %< [REDACTED] would get smaller gains in terms of gross adds and churn, as compared with AM's original scenario.⁵¹⁷

Figure A9.18: Sensitivity of intrinsic value estimates in AM's model on parameters of the performance curve

%< [REDACTED]

Source: Ofcom from AM model

A9.237 The left-hand side of Figure A9.18 shows AM's original estimations of intrinsic values (upper end figures, as reported in Figure 3.20 of AM's report). On the right-hand side, Figure A9.18 shows how the value for those packages changes when adopting the different assumptions described above for in the performance curve. This change has the effect of increasing [operator's/operators'] %< [REDACTED] intrinsic value for spectrum, but decreasing [operator's/operators'] %< [REDACTED] intrinsic value. In particular, when this change is made, %< [REDACTED]⁵¹⁸ modelled by AM, %< [REDACTED] . As can be seen from the diagram above, %< [REDACTED] .

⁵¹⁶ For the purpose of the sensitivity, we changed the points to be %< [REDACTED] .

⁵¹⁷ For example, the original model with AM's assumptions produces the following changes for the increase in the share of gross adds when comparing a scenario without winning any spectrum with one where an operator wins 40 MHz of 2.3 GHz spectrum: [operator A] %< [REDACTED] gets an additional %< [REDACTED] of gross adds (all percentages in this footnote represent absolute increase in the share of gross adds) and [operator B] %< [REDACTED] gets an additional %< [REDACTED] . When taking into account our sensitivity on the performance curve, [operator A] %< [REDACTED] gets an additional %< [REDACTED] of gross adds, while [operator B] %< [REDACTED] gets extra %< [REDACTED] .

⁵¹⁸ %< [REDACTED]

A9.238 In addition, these changes in the performance curve also affect strategic investment values. Figure A9.19 summarises the effect of such changes on upper bound estimates:

Figure A9.19: Sensitivity of strategic value estimates in AM's model on parameters of the performance curve

⌘ [REDACTED]

Source: Ofcom from AM model

A9.239 As can be seen from the Figure A9.19 above, while changing the performance curve increases ⌘ [REDACTED] , would make strategic investment in that band less likely.

Conclusion on sensitivity to assumptions

A9.240 Overall, we do not find AM's assumptions on the performance curve to be convincing and we tested a sensitivity which has a significant effect on intrinsic and strategic relative and absolute values. These changes also illustrate a wider point that the AM model can be sensitive to changes in assumptions.

Conclusions on AM's models

A9.241 AM's models for each of intrinsic and strategic investment value provide another illustration of how strategic investment may arise in the Auction. However, as in the case of the other models analysed in this annex, we find it is not sufficiently robust to provide a reliable indication of the likelihood of strategic investment in the Auction. This is for the reasons set out in detail above, which we summarise below.

A9.242 First, while AM's models were built to reflect Ofcom's view of the market, we conclude that AM's approach does not fully reflect our view (nor H3G's view).

A9.243 Second, AM's models fail to take account of H3G's significant increase in spectrum through its acquisition of UK Broadband. The AM model assumptions seem to imply that [REDACTED] ⌘

A9.244 Third, in our view, the very indirect method adopted by AM to infer estimates of technical values is prone to significant error. In addition, ⌘ [REDACTED] .

A9.245 Fourth, with regard to AM's methodology for commercial values:

- a) AM's intrinsic value model understates [operators'] ⌘ [REDACTED] intrinsic value preference for 2.3 GHz spectrum over 3.4 GHz spectrum, because it assumes that the 3.4 GHz band is useable at the same time as the 2.3 GHz band.
- b) It is unclear that AM's performance curve, which links an operator's share of spectrum to its commercial performance and its ability to compete for subscribers, appropriately captures the complex and non-mechanical relationships that are, in reality, reflected in the mobile market.

A9.246 Fifth, in modelling strategic investment values:

- a) AM's strategic investment model overstates strategic investment values given its methodology to compute spectrum shares of immediately useable spectrum, which sum to only % [REDACTED] instead of 100% and artificially depress operators' spectrum shares relative to the APT (acceptable performance threshold).
- b) AM's strategic investment model considers that strategic investors would be willing to pay a premium to preclude [victim operator(s)] % [REDACTED] from obtaining 2.3 GHz in particular, by assuming that the 3.4 GHz band is not useful to address short term capacity issues. This assumption is inconsistent with the assumption in AM's intrinsic value model that 3.4 GHz is useable at the same time as 2.3 GHz (noted above), with the consequence that the risk of strategic investment in the 2.3 GHz band is likely to be overstated.
- c) Strategic values, like commercial values, are affected by the particular choice of the APT and the performance curve in AM's model.

A9.247 Finally, we tested a sensitivity on the scale and shape of AM's performance curve which has a significant effect on both intrinsic and strategic relative and absolute values. These changes also illustrate a wider point that the AM model can be sensitive to changes in assumptions.

Power Auctions' equilibrium bidding analysis

A9.248 In this section we describe the analysis set out in the report by Power Auctions. First, we summarise Power Auctions' preliminary and theoretical discussion of key features it considers relevant to the auction. Second, we outline the framework for analysis used by Power Auctions. Third, building on the preliminary discussion and reflecting the framework, we set out the theoretical economic models of equilibrium bidding which Power Auctions claims are directly applicable to the 2.3 GHz and 3.4 GHz bands and present the main results from these. Fourth, we summarise Power Auctions discussion of the likely outcomes of the auction under competition measure option C. Finally, we present Power Auctions' critique of Ofcom's view of strategic investment in the November 2016 consultation.

Power Auctions' preliminary and theoretical discussion

A9.249 H3G commissioned Power Auctions to comment on behalf of H3G, about our proposals in the November 2016 consultation to introduce competition measures in the auction.

A9.250 Power Auctions starts by distilling the main empirical features of the auction environment which it later utilises in making predictions about the outcome of the auction. Power Auctions discusses the following:

- Power Auctions takes the "upper end" intrinsic value estimates from Analysys Mason's report (discussed above) to reach the conclusion that there are strong value complementarities [for certain packages] % [REDACTED] .
- Due to these complementarities, each bidder has demand for the same minimum quantity of % [REDACTED] .

- Outcome for each band under intrinsic value bidding. With intrinsic value bidding this implies there can be at most $\frac{1}{2}$ [REDACTED] winners $\frac{1}{2}$ [REDACTED].⁵¹⁹

A9.251 Power Auctions then provides a theoretical discussion of three substantial motivations for deviating from intrinsic value bidding. These are i) demand reduction, ii) the exposure problem and iii) strategic investment.

- Demand reduction (also commonly known as ‘strategic demand reduction’) refers to a form of tacit collusion among bidders to split the available spectrum at low prices rather than engaging in competitive bidding for a higher share of spectrum.
- The exposure problem (also commonly known as ‘aggregation risk’) is an inherent problem with the standard SMRA where bids are placed for individual lots. In the standard SMRA it arises from the identification of ‘standing high bids’ at the end of each round which exposes bidders to the possibility that they can get stuck on an undesired package at a high price. To avoid this problem the bidder may have an incentive to drop out at a lower price than its maximum average value.
- Analysys Mason’s report (discussed above) finds that the current state of the UK mobile market creates incentives for large incumbents to engage in strategic investment (i.e. foreclosure of their smaller rivals). Strategic investment bidding skews auction outcomes towards outcomes with fewer winners than there would be with intrinsic value bidding.

A9.252 Power Auctions states that of these three incentives for deviating from intrinsic value bidding “the only incentive that potentially facilitates the winning of spectrum by weak bidders is demand reduction.”⁵²⁰

A9.253 Power Auctions notes that the academic literature devoted to the study of demand reduction is limited to environments with constant or decreasing marginal return and therefore claims it can be misleading to apply the general logic of demand reduction to environments with value complementarities (increasing marginal values). For this reason, Power Auctions sets out to “develop some new theoretical results demonstrating that value complementarities create a strong disincentive to demand reduction and may prevent demand reduction from occurring at all.”⁵²¹

Framework of Power Auction’s analysis

A9.254 Power Auctions makes inferences on outcomes of the auction under two different frameworks.

A9.255 In the section titled “Theoretical Discussion”, Power Auction undertakes equilibrium bidding analysis based on several stylized theoretical models. This is described in the next sub-section. These theoretical models differ in the number of bidders participating, and the number of lots available for sale. However, a common aspect across these models is that:

⁵¹⁹ Page 8, confidential version of Annex 19 of H3G’s response.

⁵²⁰ Page 3, non-confidential version of Annex 19 of H3G’s response.

⁵²¹ Page 4, non-confidential version of Annex 19 of H3G’s response.

- Bidders demand at most $\frac{1}{2} \times [\text{REDACTED}]$.
- The assumed information structure is that each bidder has private information about its own average value for $\frac{1}{2} \times [\text{REDACTED}]$ of the good. Such value is drawn from a commonly known distribution (i.e. all bidders expect other bidders' values to have the same pattern). The relationship between the [values for different units] $\frac{1}{2} \times [\text{REDACTED}]$ is commonly known (i.e. the average value for $\frac{1}{2} \times [\text{REDACTED}]$ is the only source of uncertainty in the model).
- In this context Power Auctions discusses outcomes that form an equilibrium, i.e. where each bidders' bids are optimal given the expectation of rivals' bids, which can depend on their private information, reflecting the assumed information structure described above.

A9.256 Next, Power Auctions analyses likely auction outcomes under different options for intervention. We describe this analysis in a later sub-section. In that analysis, we understand that Power Auctions assumes a different framework. Although Power Auctions does not define its framework as formally as in the theoretical analysis, it appears to characterise some of its predictions as “equilibrium outcomes”.⁵²² When checking the conditions for those equilibrium outcomes to arise, Power Auction sometimes refers back to the theoretical analysis, and sometimes uses a different framework which relies on AM's upper end valuations for spectrum. We understand that such analysis assumes that bidders' values are common knowledge (i.e. there is no uncertainty about own or rivals' values), although the level of formality of the analysis makes this less clear.⁵²³

Power Auctions' theoretical models and results

A9.257 Power Auctions performs an equilibrium analysis of a sealed-bid auction with a uniform price rule.

A9.258 Power Auctions states that the sealed-bid uniform-price auction provides a compact representation of the SMRA, and its equilibrium analysis is much more straightforward. Power Auctions provides two references to academic papers to justify its decision to use the sealed-bid uniform price approach in its analysis.⁵²⁴

⁵²² For example, on page 37, when discussing likely outcomes under Option A, Power Auctions observes that the proposed outcome is an equilibrium.

⁵²³ Our understanding is that Power Auctions' analysis of outcomes is in a context of complete information, for which a Nash equilibrium is a set of strategies (bids) such that each bidder chooses his bid optimally, given the equilibrium set of strategies. In other words, there is a consistency requirement for an equilibrium that bids should be optimal when bidders expect other bidders to bid their optimal strategies. Each bidder's choice is a best response to the strategies actually played by his rivals. A Nash equilibrium requires that players are correct in their conjectures about what rivals are doing.

On the other hand Power Auctions' theoretical analysis is in a context of uncertainty about other bidders' unknown type (their private information). An equilibrium is a set of type-dependent strategies (i.e. a bid for each valuation), such that it is chosen optimally given the bids expected from other bidders, based on equilibrium strategies. Hence, there is a consistency requirement as well, but it is less strong, as there is some uncertainty about what rivals will do, arising from the uncertainty on their type (i.e. valuation).

⁵²⁴ “The first reference is Vickrey's seminal 1961 article on auctions, which studies the dynamic English auction for a single item by examining the sealed-bid second-price auction. The second

- A9.259 Power Auctions starts by conducting an equilibrium analysis of a so called \propto [REDACTED] model. \propto [REDACTED]⁵²⁵
- A9.260 Power Auctions finds that when value complementarities are substantial \propto [REDACTED]⁵²⁶
- A9.261 Power Auctions claims that if all bidders conform to the value complementary assumptions set out above, \propto [REDACTED] .
- A9.262 After analysing the \propto [REDACTED] model, Power Auctions considers two models that it suggests are directly applicable to the 2.3 GHz and 3.4 GHz bands respectively:⁵²⁷
- A9.263 \propto [REDACTED] .
- A9.264 \propto [REDACTED] .
- A9.265 For the 2.3 GHz band, Power Auctions argues that \propto [REDACTED]⁵²⁸
- A9.266 For the 3.4 GHz band, Power Auctions \propto [REDACTED]⁵²⁹
- A9.267 While the results summarised above required all bidders to have symmetric value complementarities, Power Auctions also obtain similar results when bidders have different value complementarities. \propto [REDACTED]

Power Auctions' discussion of likely outcomes and analysis of options for intervention

- A9.268 Power Auctions proceeds to discuss the possible equilibrium outcomes under seven different options for intervention in the auction. The seven options considered by Power Auctions include five options, options A – E, which we consulted on in our November 2016 Consultation. In addition, option F is constructed by adding to option E a reservation in the 2.3 GHz band for an operator with a smaller market share (e.g. less than 20%) or a new entrant, and option G is constructed by adding a reservation in both bands to option E.
- A9.269 Given that we have decided to adopt competition measures as in option C (caps on both immediately useable and overall spectrum), we devote the rest of this summary to Power Auctions' outcome analysis under this option.⁵³⁰

Allocation of the 2.3 GHz band under option C

- A9.270 Power Auctions starts by listing all \propto [REDACTED] possible outcomes (also referred to as scenarios) in the 2.3 GHz band \propto [REDACTED]

reference is the "demand reduction" article by Ausubel, Cramton, Pycia, Rostek and Weretka (2014)"
Page 4 of the non-confidential version of Annex 19 of H3G's response.

⁵²⁵

Page 17, confidential version of Annex 19 of H3G's response.

⁵²⁶ Page 14, confidential version of Annex 19 of H3G's response.

⁵²⁷ \propto [REDACTED]

⁵²⁸ \propto [REDACTED]

⁵²⁹ \propto [REDACTED]

⁵³⁰ \propto [REDACTED]

A9.271 Power Auctions then considers the likelihood and rationale for each of these < [REDACTED] scenarios based on Analysys Mason's "upper end" estimates of the operator's intrinsic values and Analysys Mason's strategic investment [value(s) for strategic investor(s)] < [REDACTED] . Before providing the results of Power Auctions' analysis we note that the outcome that would maximise intrinsic value is < [REDACTED] .

A9.272 Power Auctions argues that < [REDACTED] ⁵³¹ .⁵³²

A9.273 Power Auctions considers that < [REDACTED] .⁵³³

A9.274 Overall, Power Auctions considers that < [REDACTED] .

Allocation of the 3.4 GHz band under option C

A9.275 Power Auctions then turn to the assessment of the 3.4 GHz band < [REDACTED] .⁵³⁴ Before providing the results of Power Auctions' analysis we note that based on Analysys Mason's model the outcome that would maximise intrinsic value is < [REDACTED] .

A9.276 Disregarding strategic investment values, Power Auctions acknowledges that < [REDACTED] .

A9.277 Taking strategic investment values into account < [REDACTED]

A9.278 < [REDACTED]

Allocation of the 2.3 and 3.4 GHz bands under option C

A9.279 Combining these results, Power Auctions concludes that there are < [REDACTED] plausible allocations for option C: < [REDACTED] From these, Power Auctions considers that the most likely outcome is < [REDACTED] . Power Auctions provides the following reasoning for considering that this is the most likely outcome:

A9.280 First, Power Auctions claims that this is an equilibrium outcome of the auction, based on the valuations provided by Analysys Mason. This is because: < [REDACTED]

i)

ii) .

A9.281 Second, Power Auctions claims that, while there may be as many as < [REDACTED] other possible equilibrium outcomes of the auctions, this outcome is a **focal point**. < [REDACTED]

• ⁵³⁵

⁵³¹ < [REDACTED]

⁵³² < [REDACTED]

⁵³³ < [REDACTED]

⁵³⁴ < [REDACTED]

⁵³⁵ < [REDACTED] .

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Power Auctions' critique of Ofcom's view on strategic investment

A9.282 Power Auction puts forward a critique of Ofcom's view of strategic investment:

- "Regardless of what happens in the 3.4 GHz band, [strategic investor(s) obtain(s)] < [REDACTED] strategic value by foreclosing [target(s)] < [REDACTED] from the 2.3 GHz band"⁵³⁸
- "The evidence suggests strong value complementarities for [certain packages] < [REDACTED]"⁵³⁹
- "Strategic value from the 2.3 GHz band alone, together with strong value complementarities [for certain packages] < [REDACTED] , make foreclosure likely"⁵⁴⁰
- Power Auctions' "analysis takes account of Ofcom's two other "mitigating" features"⁵⁴¹

A9.283 Each of these critiques are further explained below.

A9.284 In particular, Power Auctions argues that < [REDACTED]"⁵⁴²

A9.285 Power Auctions claims that the evidence from Analysys Mason's report suggests strong value complementarities for [certain packages] < [REDACTED] Furthermore, Power Auctions claims that Ofcom's own words in the November 2016 consultation document suggest strong indications of value complementarities in the range of 60-100 MHz in the 3.4 GHz band.⁵⁴³ Power Auctions concludes that *"[i]f Ofcom's speculation about large blocks of 3.4 GHz spectrum being needed for 5G services is correct, then < [REDACTED]"*⁵⁴⁴

A9.286 According to Power Auctions, the combination of strategic value in foreclosing the 2.3 GHz band alone and strong value complementarities [for certain packages] < [REDACTED] makes < [REDACTED] foreclosure likely to occur. This is because, based on Power Auctions' analysis, < [REDACTED] .

A9.287 Finally, Power Auctions claims that when we discussed mitigating effects of our auction design in our November 2016 consultation document we acknowledged that strong value complementarities may reduce or even neutralise the effect of the first feature of the auction design (the way prices are set), but that we considered that the other two features of the auction design still applied in the presence of strong value complementarities. Power Auctions states that its analysis takes into account our other two "mitigating features" features (use of single-item bidding rather than

⁵³⁶ < [REDACTED]

⁵³⁷ < [REDACTED]

⁵³⁸ Sub-section 5.1 of the confidential version of Power Auctions' report.

⁵³⁹ Sub-section 5.2 of the confidential version of Power Auctions' report.

⁵⁴⁰ Sub-section 5.3 of the confidential version of Power Auctions' report.

⁵⁴¹ Sub-section 5.4 of the confidential version of Power Auctions' report.

⁵⁴² < [REDACTED]

⁵⁴³ As examples of this, Power Auctions references paragraphs 5.80, 5.88, 5.74 and 4.233 of our November 2016 Consultation document. Page 51 confidential version of Power Auction's report.

⁵⁴⁴ Page 51 confidential version of Power Auction's report.

package bidding and information policy)⁵⁴⁵ and still concludes that strategic investment is likely to result in foreclosure of [target(s)] < [REDACTED] , unless competition measures stronger than options A or C are introduced.

A9.288 Power Auctions argues that there are three reasons why foreclosure occurs, notwithstanding the mitigating factors put forward by Ofcom.

- First, the value complementarity not only affects the bidding by the strategic investor, but also by the operator being foreclosed. < [REDACTED]
- Second, in what Power Auctions thinks is the most plausible equilibrium, < [REDACTED] it claims that the information policy has very little impact. < [REDACTED]
 -
 -
- Third, Power Auctions claims < [REDACTED] ⁵⁴⁶

Ofcom's view on Power Auctions' analysis

A9.289 In this section, we explain our assessment of the analysis carried out by Power Auctions in four parts: the first concerns the methodology used; the second relates to the role played by value complementarities in the analysis; the third discusses the underlying assumptions behind the derivation of auction outcomes by Power Auctions; and the fourth discusses the three reasons why Power Auctions believe that foreclosure occurs, notwithstanding the mitigating factors put forward by Ofcom.

Methodology

A9.290 Power Auctions conducted an equilibrium bidding analysis aimed at modelling the outcome of a spectrum auction. This approach can be informative and aid a discussion about the possible impact of different design features and competition measures. However, in our view, caution should be exercised when drawing conclusions from it.

A9.291 Equilibrium analysis is a commonly used technique in theoretical analysis of auctions. However, real bidding behaviour in auctions may differ to that suggested by the theory. In general, theoretical economic models are stylised, seeking to capture important aspects of reality. However, decision-making in the real world is complex and in practice operators may take account of a range of considerations that are difficult to capture in such models. For example, the way in which consumers or companies behave does not always accord with traditional economic theory (as recognised in the burgeoning literature on behavioural economics); competitive interactions can be complex and multi-dimensional, especially where operators sell a wide range of services to heterogeneous consumers as in the

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Power Auctions argues that it obtains insights into the SMRA format by performing an equilibrium analysis of a model that incorporates a sealed-bid, uniform-price auction, which utilises single-item bidding, not package bidding and that its equilibrium analysis necessarily takes the possibility of an exposure problem into account. Power Auctions also argues that a sealed-bid auction reflects a more severe information policy than is proposed by Ofcom for the Auction.

⁵⁴⁶ < [REDACTED]

mobile market; to estimate spectrum values, operators may take a long-term view with inherent uncertainty about future changes which can significantly affect values (such as the rate of growth of demand and the pace of technological change); bidding may be influenced by multiple objectives and constraints, including budget constraints; and operators may have wider strategic objectives.

- A9.292 In addition, equilibrium bidding analysis often relies on strong assumptions on the information structure of the auction participants. As discussed, Power Auctions' theoretical models assume a context where uncertainty is very limited. For example, even in the most uncertain context that Power Auctions considers, bidders have a common knowledge about the distribution of rivals' valuations, and (as we understand it) they have perfect knowledge about rivals' relative values for different amounts of spectrum. It is unclear whether Power Auctions results would hold in a context of greater uncertainty.
- A9.293 We have seen substantial differences in absolute and relative values in the models submitted by different parties. In addition, we have explained above that these values depend on many methodological issues and uncertain assumptions, and the results of the models are generally sensitive to changes in methodology and assumptions. This illustrates that, whilst assumptions of the kind made by Power Auctions are common in the theoretical literature, they may substantially understate the degree of uncertainty in the real world.
- A9.294 One important source of uncertainty not considered in Power Auctions' analysis is the extent to which different strategic investors may impose externalities on each other, such as the risk of free riding and the difficulties of coordination. For example, a bidder's strategic investment value for a given package may differ depending on the bids of others and how the overall spectrum is split in the auction outcome. An illustration of the potential magnitude of this phenomenon can be seen in our analysis of the NERA model (such as the discussion of criteria to choose from a multiplicity of enterprise values). With free riding, a bidder can avoid the costs of strategic investment, but still benefit from the strategic investment that is undertaken by another bidder. Or, with attempted coordination, the pay-off for bidder 1 from strategic investment may rely on bidder 2 also engaging in strategic investment to win a specific package of spectrum (so that between them bidders 1 and 2 foreclose the spectrum to the victim). But if bidder 2 does not win that package, bidder 1 could be left incurring the cost of strategic investment with no pay-off and so incur a loss. These externalities are not taken into account in Power Auction's model.
- A9.295 The effect of the externalities is that strategic investment values are not certain and, to a significant degree, are not under the control of the bidder, but rather also depend on the outcome of the auction. Indeed, in our view, even this significantly understates the uncertainty, because the valuation models of NERA and AM make particular assumptions about the competitive impact on the victim operator(s) of being denied spectrum and the extent to which any weakening of competition can be exploited by a strategic bidder through customer acquisition and price rises. There is additional uncertainty about each of these effects as well.
- A9.296 Against this backdrop of uncertainty, we note that in Power Auctions theoretical analysis, bidders are certain about their own values, and their valuation is assumed not to be linked to the outcome of the auction. While this may be realistic if all bidders' bids were based on intrinsic values, it may not be the realistic for the evaluation of bids of a strategic investor.

Conclusion on methodology

A9.297 Overall, in our view, this points to a limitation in Power Auctions' theoretical models in providing a complete or accurate view of real-world bidding decisions. Unless there is also specific empirical evidence to support the predictions of the model (which we do not consider has been presented in stakeholders' responses), in our view caution should be exercised before relying on these theoretical models adequately to capture all of the important real-world considerations in operators' bidding decisions.

Role played by value complementarities in the Auction

A9.298 As described above, Power Auctions assumes strong value complementarities [for certain packages] < [REDACTED] in the Auction based on the upper end value estimates from AM's report. These complementarities take account of both intrinsic value and strategic investment value, and both sources are treated in a similar way by Power Auctions.

A9.299 In our view, it would be both more transparent and very relevant to our analysis to distinguish more clearly between these two different sources of complementarities. One reason is that there can be different policy implications in terms of the potential trade-off between efficiency and competition, which we discuss in section 6. In particular, there may be such a trade-off where the source of value driving the Auction outcome is intrinsic value, which is not present if the relevant source is strategic investment value. Another reason is that, in general, the ability to realise intrinsic value depends on the actions of the bidder itself, whereas strategic investment can depend on things that are outside the bidder's control, such as bids made by other bidders and the Auction outcome. This is especially relevant to coordinated strategic investment (as discussed above in terms of externalities between bidders).

A9.300 The assumption of strong value complementarities – in total value, including both intrinsic and strategic investment value - seems to play an important role in Power Auctions' analysis and as a consequence on its assessment of the auction outcomes identified as being the most likely under each competition option considered.

A9.301 Below we first discuss the implications of value complementarities, and then the available evidence on the strong complementarities assumed by Power Auctions.

Implications of value complementarities

A9.302 Simply for the purpose of exploring the implications, the discussion in this sub-section proceeds on the basis that the assumptions made by Power Auctions about value complementarities, drawing on the AM model, are correct. In the next sub-section we consider the available evidence on the accuracy of these assumptions.

A9.303 In the November 2016 consultation document we noted three auction design features that might reduce the incentives to engage in strategic investment⁵⁴⁷.

- The first is the way prices are set in the auction (we are now referring to this as the "uniform price rule"). Under this rule, by bidding on a larger quantity of spectrum for strategic reasons, a strategic investor may be

⁵⁴⁷ Page 65 of the November 2016 consultation document

pushing up the price for all the spectrum it would wish to win, including spectrum it values for intrinsic value reasons.

- The second auction design feature is related to the risk of being stranded as a partial standing high bidder, which provides a further deterrent to bidders who wish to engage in strategic investment.
- The third auction design feature that could reduce the incentives to engage in strategic investment is the relatively strict information policy which we will adopt in the Auction. This makes unilateral and coordinated strategic investment more difficult because bidders do not receive information on who they are bidding against (such as whether it is the intended victim or another operator not vulnerable to being weakened as a competitor), or whether other bidders with whom they are attempting to coordinate are following the coordination bidding strategy or deviating from it.

A9.304 We discuss each of these in the context of strong value complementarities in turn below.

A9.305 Uniform price rule: One important consequence for the analysis of strong value complementarities is that they reduce, and could even fully eliminate, the incentives that would otherwise exist for bidders to engage in strategic demand reduction under the uniform price rule in the Auction.

A9.306 We considered the role of intrinsic value complementarities in the incentives to engage in strategic investment in our November 2016 consultation document⁵⁴⁸. We acknowledged that it could be argued that the presence of strong value complementarities based on intrinsic value could reduce or even neutralise the effect of the uniform price rule. Bidders might as a result be less tempted to reduce demand in order to win less spectrum, at a lower price, if they have strong values for large amounts of spectrum.

A9.307 However, in the Power Auctions analysis < [REDACTED] under the scenarios Power Auctions finds most likely, the value complementarities in AM's model depend on strategic investment value as well as intrinsic value.⁵⁴⁹

A9.308 Being stranded: A second important consequence is that due to the value complementarities assumed by Power Auctions, each bidder has a demand based on intrinsic value for the same minimum quantity < [REDACTED] This in turn reduces the effective number of relevant units of spectrum available in the Auction to < [REDACTED] All else constant, with larger units the scope for bidders to be stranded as partial standing high bidders at the end of each principal stage round is reduced.

A9.309 In the November 2016 consultation we said that the risk of being stranded still applied in the presence of strong value complementarities. However, we now recognise that in the presence of value complementarities for all bidders including victim operators, all else constant, the likelihood of a strategic investor to be "stranded" as a partial standing high bidder may be reduced. < [REDACTED]

⁵⁴⁸ Paragraphs 4.225 to 4.233 in the November 2016 consultation document

⁵⁴⁹

As noted by Power Auctions, "*strategic foreclosure values increases the effective degree of complementarity* < [REDACTED]

However, even under those assumptions, a strategic investor is still at risk. This is because it can still be made a partial standing high bidder on 30 [REDACTED] .

A9.310 Information policy: A third important consequence is that strategic investors that exhibit strong value complementarities can more easily divide up the spectrum amongst themselves, if they would wish to win large amounts of spectrum for intrinsic value reasons anyway. This would happen even in the presence of the information policy which we will adopt in the award.

A9.311 30 [REDACTED]

A9.312 30 [REDACTED]

A9.313 30 [REDACTED]

Conclusions on implications of value complementarities

A9.314 Based on the above discussion our main conclusions are as follows on the implications of auction design features and value complementarities:

- We recognise that strong value complementarities arising from intrinsic value could in some circumstances reduce the effect of the auction design features we have identified as making strategic investment more difficult, such as the uniform price rule or being stranded 30 [REDACTED] .
- However, in our view, this does not generally apply to complementarities arising from strategic investment value, which is at risk of failing to be realised by the strategic bidder. This is especially relevant in the case of coordinated strategic investment, where obtaining the desired strategic investment value depends on things outside of the bidder's control, such as the bids made by the other strategic bidder with whom it is seeking to coordinate.
- In addition, we note that in AM's model (on which Power Auctions relies) there are strong intrinsic value complementarities for blocks of 30 [REDACTED] . [However,] 30 [REDACTED] under the scenarios Power Auctions finds most likely, the value complementarities in AM's model depend on strategic investment value as well as intrinsic value.

Evidence on intrinsic value complementarities

A9.315 It is unclear whether it is reasonable to assume the same pattern of value complementarities arising from intrinsic values that Power Auctions assumes in its analysis. First, we present the evidence from AM's model on intrinsic value complementarities, on which Power Auctions relies for its assumptions on a clear pattern of value complementarities. Second, we describe the different evidence from NERA's model on intrinsic value complementarities. Third, we discuss other relevant evidence available to us. Finally, we comment on the implications of the available evidence.

A9.316 AM's model: AM's intrinsic value model shows strong value complementarities within particular ranges of MHz. 30 [REDACTED]

Figure A9.20: Average intrinsic values in AM's model per 10 MHz block in 2.3 GHz

⌘ [REDACTED]

Source: Ofcom analysis on the basis of AM's model

A9.317 With regards to 3.4 GHz, the marginal values for ⌘ [REDACTED]

Figure A9.21: Average intrinsic values in AM's model per 10 MHz block in 3.4 GHz

⌘ [REDACTED]

Source: Ofcom analysis on the basis of AM's model

A9.318 NERA's model: ⌘ [REDACTED]⁵⁵⁰

Figure A9.22: Average intrinsic values in NERA's model per 10 MHz block in 2.3 GHz⁵⁵¹

⌘ [REDACTED]

Source: Ofcom analysis on the basis of NERA's model

Figure A9.23: Average intrinsic values in NERA's model per 10 MHz block in 3.4 GHz

⌘ [REDACTED]

Source: Ofcom analysis on the basis of NERA's model

A9.319 Other evidence: In response to our November 2014 consultation⁵⁵², UK Broadband, EE and a confidential respondent agreed with our earlier proposals to make the spectrum in the Auction available in 5 MHz lots. The confidential respondent noted that outcomes where bidders target 15 or 25 MHz were plausible.

A9.320 In addition⁵⁵³, when responding specifically to our proposals to allow bidders to specify a minimum spectrum requirement up to 20 MHz in the Auction (our initial proposals applied to both 2.3 GHz and 3.4 GHz bands), BT argued that a figure greater than 20 MHz was not necessary and could be used strategically.

A9.321 We are cautious of drawing strong conclusions on the basis of these responses, as they were submitted some time ago (late 2014/early 2015). Views may have partially or completely changed since.

A9.322 One of the main changes since our November 2014 consultation is the fact that in 2016 the 3.4-3.8 GHz band was identified as a primary band suitable for the introduction of 5G use in Europe.

⁵⁵⁰ ⌘ [REDACTED] .

⁵⁵¹ NERA's graphs are without the UK Broadband acquisition to make a better comparison to AM's graphs.

⁵⁵² Paragraphs A4.7 to A4.14 at

https://www.ofcom.org.uk/data/assets/pdf_file/0027/68337/Public_Sector_Spectrum_Release_statement.pdf.

⁵⁵³ Paragraphs A4.107 to A4.113.

A9.323 As we describe in annex 11, having considered stakeholder responses and the latest industry developments, we believe an MNO will need at least 80 MHz to offer a 5G service. This in turn could translate into a strong value complementarity for 80 MHz for bidders that wished to acquire access to 3.4 GHz spectrum specifically for 5G.

A9.324 Bidders may however wish to use the 3.4 GHz spectrum to provide 4G services, at least initially, or may have different views regarding the transition from 4G to 5G. Different potential uses of the 3.4 GHz spectrum can in turn result in different amounts of spectrum required. As we note in annex 11, respondents to our November 2016 consultation had mixed views on the optimal channel size for 3.4 GHz – and may as a consequence have different views as to the amount of spectrum that is required.

A9.325 The most recent spectrum auction in Europe that included the 3.4 GHz band was in Ireland⁵⁵⁴. Different bidders won different amounts of spectrum. For instance, Airspan won 25 MHz in rural areas and 60 MHz in urban areas; the MNOs (Meteor, Three and Vodafone) won between 80 MHz and 105 MHz across the country. This suggests that different operators may have different patterns of value complementarities – although MNOs in Ireland seemed to have a preference for at least 80 MHz.

A9.326 The results of the Irish auction are presented in the table below.

Table A9.24 Results of the 3.4-3.8 GHz spectrum auction in Ireland

Region	Airspan Holdings Ltd	Spectrum Imagine Communications Ireland Ltd	Meteor Communications Ltd	Mobile Three (Hutchison) Ltd	Ireland Vodafone Ltd	Ireland
Borders Midlands and West	25 MHz	60 MHz	80 MHz	100 MHz	85 MHz	
South West	25 MHz	60 MHz	80 MHz	100 MHz	85 MHz	
East	25 MHz	60 MHz	80 MHz	100 MHz	85 MHz	
South East	25 MHz	60 MHz	80 MHz	100 MHz	85 MHz	
Dublin City and Suburbs	60 MHz	-	85 MHz	100 MHz	105 MHz	
Cork City and Suburbs	60 MHz	-	85 MHz	100 MHz	105 MHz	
Limerick City and Suburbs	60 MHz	-	85 MHz	100 MHz	105 MHz	
Galway City and Suburbs	60 MHz	-	85 MHz	100 MHz	105 MHz	
Waterford City and Suburbs	60 MHz	-	85 MHz	100 MHz	105 MHz	

Source: ComReg

A9.327 Implications of the available evidence: First, taking the AM and NERA models at face value, they provide conflicting evidence about value complementarities: > [REDACTED] .

A9.328 There are a number of possible explanations for this discrepancy in evidence. It could be that one or other of the models is inaccurate. Or it could be that they reflect alternative views which might both be reflected in the Auction, i.e. different bidders exhibiting very different patterns of intrinsic value complementarities. We also note that neither AM's nor NERA's models reflect values for 5G use, and this could have a significant influence on operators' intrinsic values, especially for the 3.4 GHz band. Different bidders having a different view about their path to 5G (as we noted earlier, this appears to be reflected in some stakeholder consultation

⁵⁵⁴ Results available at https://www.comreg.ie/media/dlm_uploads/2017/05/ComReg-1738.pdf.

responses) is a further significant reason why intrinsic value complementarities may be quite different for different bidders.

A9.329 As we will discuss later in this section, differences in value complementarities, and uncertainty as to whether all bidders exhibit similar value complementarity patterns, strengthen our views above that the auction design features have a role in reducing the scope of strategic investment.

A9.330 Second, we have set out in previous sections a number of significant concerns about both AM's and NERA's models. These included, for example, specific concerns about AM's modelling of intrinsic value, such as separate criticisms about both elements of intrinsic value: technical value and commercial value. In light of these concerns, we have reservations about the reliability of the evidence on intrinsic value complementarities in these models.

Conclusion on evidence of value complementarities

A9.331 Overall, given our reservations about both the reliability of the evidence and the fact that it is conflicting, we consider that there is significant uncertainty about the accuracy of Power Auctions' assumptions about strong value complementarities.

Outcomes derived by Power Auctions

A9.332 In addition to the presence of value complementarities discussed above, Power Auctions makes a number of other underlying assumptions in its analysis of likely outcomes that may not be correct. In particular, assumptions about valuations of individual bidders, and assumptions about the estimates that individual bidders will make about their competitors' valuations, may be wrong. In addition, assumptions about the relevant variables in bidder's decisions may be wrong as well.

A9.333 **First**, Power Auctions' analysis is based on the valuations in AM's model, which does not incorporate the effects of H3G's acquisition of UK Broadband including 40 MHz of spectrum in the 3.4 GHz band. This substantial omission on its own makes inferences unreliable on H3G's willingness to pay for spectrum, especially 3.4 GHz. The inclusion of the UK Broadband acquisition may or may not have changed the outcome analysis and we discuss both possibilities below.

A9.334 Power Auctions rationale for choosing particular outcomes as being the most likely might have changed if it incorporated the acquisition of UK Broadband by H3G. < [REDACTED] .

A9.335 If instead Power Auctions still identified the same outcome as being the most likely, < [REDACTED] .

A9.336 **Second**, even abstracting from the fact that it ignores UK Broadband acquisition by H3G, we have discussed in previous sections the results of the valuation models provided by AM and noted that they are sensitive to a number of assumptions.

A9.337 For instance, Power Auctions' analysis of likely outcomes in 2.3 GHz under option C is based on a relative ranking of valuations which is sensitive to assumptions. To illustrate, we consider just one source of sensitivity of results in AM's model - the effect on relative values of our sensitivity on AM's performance curve described above. Under that alternative set of parameters:

- \times [REDACTED] total value for \times [REDACTED] alone would reduce from \times [REDACTED] to \times [REDACTED] and further down to at most \times [REDACTED] when adjusting the calculation of shares of immediately useable spectrum.
- \times [REDACTED] intrinsic value for \times [REDACTED] becomes \times [REDACTED]

A9.338 \times [REDACTED] would not be able to buy \times [REDACTED] in such a scenario, as \times [REDACTED]. This would further imply that the outcome that Power Auctions claims is an equilibrium under option C, would not be an equilibrium under this alternative set of parameters. This illustrates how Power Auctions' conclusions are highly dependent on AM's specific set of assumptions.

A9.339 As another example, we noted that AM's intrinsic and strategic investment values for 2.3 GHz are based on different assumptions of useability of bands, and are therefore not comparable (see discussion above). Yet, Power Auctions' conclusions are based on comparing such values. In determining intrinsic values, AM assumes that 3.4 GHz and 2.3 GHz will be useable at the same time. This is likely to have a particularly relevant impact on the intrinsic value of packages combining both 2.3 GHz and 3.4 GHz spectrum, so that AM's model underestimates the incremental values of 2.3 GHz. This may also lead to wrong conclusions as to the willingness to substitute 2.3 GHz for 3.4 GHz spectrum based on intrinsic value. However, in estimating strategic investment values for 2.3 GHz spectrum, AM assumes 3.4 GHz is not available until the end of 2019. This inconsistency in assumptions is likely to mean that AM's model understates the cost of strategic investment in the 2.3 GHz band, compared to a context with more realistic and consistent assumptions.⁵⁵⁵

A9.340 **Third**, Power Auctions' conclusions are not only based on AM's valuations but also on the assumption that these valuations form the basis for MNOs' expectations about rivals' bids. For example, in Power Auctions' suggestion of the most likely outcome under option C \times [REDACTED].

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A9.341 In our view, Power Auctions' analysis significantly overstates the degree of certainty that bidders would have about their rivals' values. We have commented above on the valuation models submitted to us by stakeholders (the models of Frontier Economics, NERA and Analysys Mason), and the sensitivity of the results of these models to variations in methodology and assumptions. Even leaving this aside, such models, commissioned by different operators, display a substantial gap in estimated valuations for certain packages. For example, the differences in the estimation of values from AM's and NERA's model (discussed above) may be illustrative of the degree of uncertainty that operators face when estimating rivals' valuations.

⁵⁵⁵ We note that, taking the AM's model estimations at face value, \times [REDACTED] standalone intrinsic value for \times [REDACTED] exceeds \times [REDACTED] total value for the same package \times [REDACTED]. This shows that \times [REDACTED] the potential to outbid \times [REDACTED] in 2.3 GHz. Whether that is likely to happen or not depends on \times [REDACTED] willingness to substitute 2.3 GHz spectrum for 3.4 GHz, which in AM's model is overestimated due to useability assumptions. Hence, if \times [REDACTED] had a strong preference for 2.3 GHz over 3.4 GHz spectrum, \times [REDACTED] might not be able to outbid \times [REDACTED]

- A9.342 **Fourth**, the outcomes selected by Power Auctions as being the most likely under each option do not necessarily represent clear focal points which the bidders would identify in advance and around which they would coordinate their strategic bidding.
- A9.343 For instance, under the outcome that Power Auctions finds most likely under Option C, the % [REDACTED] .
- A9.344 Whilst Power Auctions claims that, under AM's estimates of the relative value of 2.3 GHz and 3.4 GHz, the % [REDACTED] . The bidders might, therefore, refuse to settle for the outcome Power Auctions finds most likely under Option C.
- A9.345 Our doubts that it is clear that bidders would agree the focal point suggested by Power Auctions, and stick to it during the Auction, are increased by the fact that a *different* focal point in 3.4 GHz was suggested by NERA. In NERA's suggested focal point, % [REDACTED] This focal point would therefore involve % [REDACTED] .
- A9.346 % [REDACTED] .
- A9.347 In addition, it is unclear whether % [REDACTED] .
- A9.348 Even if the outcomes selected by Power Auctions were clear focal points which individual strategic bidders would be able to identify in advance of the Auction, it is unclear the extent to which each of the strategic bidders could rely on the other strategic bidder or bidders bidding in a way consistent with the focal point identified.
- A9.349 In particular, during the Auction strategic investors will not know that the other or others is or are actually bidding on the basis of the same focal point. This is because of the relatively strict information policy. In Power Auction's likely outcome under option C, % [REDACTED] .
- A9.350 Power Auctions claims that it derives this equilibrium outcome on the basis of an auction design with an even stricter information policy than the one we will adopt in the Auction. That however seems to be because Power Auctions assumes that the valuations that they take as given form the basis for MNOs' expectations about rivals' bids. The information policy in the auction becomes less relevant in Power Auctions' analysis because bidders are *assumed* to be able to anticipate correctly how other bidders will bid without the need to observe their bidding. As we argued, the valuations which Power Auctions take as given may not only fail to reflect the real valuations from the different participants in the Auction, but even if they were accurate, they might not be known to all participants in advance of the auction.

Conclusion on outcomes derived by Power Auctions

- A9.351 In summary, in the analysis above of the outcomes derived by Power Auctions we reach the following conclusions:
- Power Auctions' analysis fails to take into account the fact of H3G's acquisition of UK Broadband. This substantial omission on its own makes inferences unreliable on H3G's willingness to pay for spectrum % [REDACTED] .
 - Power Auctions' analysis of likely outcomes in 2.3 GHz is based on a relative ranking of bidders' valuations from the AM model which is sensitive to assumptions.

- In our view, Power Auctions' analysis significantly overstates the degree of certainty that bidders would have about their rivals' values.
- We consider that the outcomes selected by Power Auctions as being the most likely under each option do not necessarily represent clear focal points.

Our response to Power Auctions' critique of Ofcom's view on strategic investment

A9.352 As we noted above, Power Auctions puts forward a critique of Ofcom's view on strategic investment, summarised in four points. In this sub-section we address these four points in turn. In some cases we refer to other points we make earlier in this section, or in other parts of the Statement.

A9.353 Point 1: "Regardless of what happens in the 3.4 GHz band, [strategic investor(s)] < [REDACTED] obtain strategic value by foreclosing [target(s)] < [REDACTED] from the 2.3 GHz band".

A9.354 We agree that [strategic investor(s)] < [REDACTED] may be able to obtain strategic value by foreclosing < [REDACTED] target(s)] from the 2.3 GHz band. We take that view now, as we did in the November 2016 consultation.⁵⁵⁶ The material risk of strategic investment in 2.3 GHz is a reason for our decision to impose the cap on immediately useable spectrum.

A9.355 Point 2: "The evidence suggests strong value complementarities for [certain packages] < [REDACTED]".

A9.356 Power Auctions claims that Ofcom's own words in the November 2016 consultation document suggested strong indications of value complementarities in the range of 60-100 MHz in the 3.4 GHz band. However, what we said was that an operator *might* wish to acquire access to a large block of spectrum in the 3.4 GHz band for 5G – perhaps within the range of 60 to 100 MHz,⁵⁵⁷ and we emphasised the lack of certainty about complementarities.⁵⁵⁸

A9.357 As we set out above, in our view, Power Auctions fails to distinguish properly between complementarities that arise from intrinsic value and from strategic investment value.

- For intrinsic value complementarities, we have explained our reservations that arise both from the reliability of the available evidence and the fact that it is conflicting. As a result, we consider that there is significant uncertainty about the

⁵⁵⁶ We consider that Power Auctions mischaracterised our position in the November 2016 consultation by suggesting that we did not recognise the potential pay-off from strategic investment in the 2.3 GHz band. For example, we said in paragraph 4.204 in the November 2016 consultation, in relation to the 2.3 GHz band, that some bidders "*may therefore see a discernible pay-off from engaging in strategic investment*", and in paragraph 4.206 that the "*possibility of strategic investment in the 2.3 GHz band is a significant concern*".

⁵⁵⁷ For example, paragraph 4.233 (second bullet point) said: "*We have also noted that an operator might wish for reasons of intrinsic value to acquire a large block for 5G in the 3.4 GHz band. In addition, there is uncertainty about exactly how large such a block might be, e.g. 60, 80 or 100 MHz...*".

⁵⁵⁸ For example, paragraph 4.233 (third bullet point) said: "*In general, a lack of certainty about the nature of complementarities, which could be different for different bidders, and the range of possibilities involving block sizes both larger and smaller than 40 MHz, make the focal point for any intended coordinated strategic investment less clear-cut*".

accuracy of Power Auctions' assumptions about strong intrinsic value complementarities.

- As to complementarities that are claimed to arise from strategic value, we have also identified concerns about the reliability of estimates of strategic value in AM's model on which Power Auctions relies (as well as other models from FE and NERA).

A9.358 Point 3: "Strategic value from the 2.3 GHz band alone, together with strong value complementarities [for certain packages] < [REDACTED] , make foreclosure likely".

A9.359 Point 3 from Power Auctions relies on its points 1 and 2. Whilst we largely agree with Power Auctions on point 1, we do not agree with point 2. This is part of the reason why we reach a different conclusion from Power Auctions on the likelihood of strategic investment in both bands together. We explain in annex 10 why in our view there is a risk of coordinated strategic investment leading to foreclosure when all the spectrum available in the award is considered, but our conclusion is that this is uncertain.

A9.360 Point 4: Power Auctions' "analysis takes account of Ofcom's two other "mitigating" features" (the information policy and the possibility of being stranded as a partial standing high bidder).

A9.361 On the possibility of being stranded as a standing high bidder, the analysis is affected by the assessment of complementarities, on which we summarised our view compared to Power Auctions under point 2. Even leaving aside this difference of view on complementarities, we do not entirely agree with Power Auctions' conclusions on the risk of being stranded. As explained above, we recognise that, in the presence of value complementarities for all bidders including victim operators, all else constant, the likelihood of a strategic investor to be stranded as a partial standing high bidder may be reduced. However, in our view, even with strong value complementarities, a strategic investor is still at risk, with the extent of that risk depending on the circumstances such as the amount of spectrum in the band (e.g. the risk seems higher in the 3.4 GHz band).

A9.362 On the information policy, we have a more fundamental disagreement with Power Auctions. Power Auctions claims that its analysis is based on an auction design with an even stricter information policy than the one we will adopt in the Auction. However, we have explained above our view that the information policy in the auction becomes less relevant in Power Auctions' analysis because bidders are *assumed* to be able to anticipate correctly how other bidders will bid without the need to observe their bidding. We consider this significantly overstates the degree of certainty that strategic bidders are likely to have.

A9.363 After setting out these four points, Power Auctions then argues that there are three reasons why foreclosure occurs, notwithstanding the mitigating auction design features put forward by Ofcom. Below we summarise the main reasons why we disagree with Power Auctions. Again, this summarises points which we make elsewhere.

A9.364 Reason 1: The value complementarity not only affects the bidding by the strategic investor, but also by the operator being foreclosed.

A9.365 We agree that if the victim(s) exhibit(s) particular patterns of intrinsic value complementarities, this may reduce the probability of a strategic investor being stranded as a partial standing high bidder or the multiplier effect of the uniform price rule. However, even if a strategic investor could rely on its assumptions of the shape of these value complementarity patterns, it would not fully eliminate the risk, particularly in 3.4 GHz. In addition, we have explained above our view of the unreliable and conflicting evidence about intrinsic value complementarities.

A9.366 Reason 2: In what Power Auctions considers the most plausible equilibrium, where \propto [REDACTED] it claims that the information policy has very little impact.

A9.367 We disagree with Power Auctions on the impact of the information policy. When identifying its most likely scenario, Power Auctions relies on AM's valuations and assumes that these valuations form the basis for MNO's expectations about rivals' bids.

- First, we have set out in detail above our assessment of AM's model and our conclusion that it is not sufficiently robust to provide a reliable indication of the likelihood of strategic investment in the Auction.
- Second, as explained under point 4 above, we consider that Power Auctions significantly overstates the degree of certainty that strategic bidders are likely to have.

A9.368 If, instead of Power Auctions' assumptions, strategic bidders cannot rely with certainty on the valuations of rival bidders' valuations being accurately derived in the AM model, they might need to observe information from the Auction in order to ascertain how other individual bidders are bidding and assess the risks involved in engaging in strategic investment. Our relatively strict information policy does not allow that. Therefore, we are of the view that the information policy has a more important role than suggested by Power Auctions.

A9.369 Reason 3: Power Auctions claims \propto [REDACTED] .

A9.370 \propto [REDACTED]

A9.371 \propto [REDACTED]

A9.372 \propto [REDACTED]

A9.373 \propto [REDACTED]

Conclusions on Power Auctions' analysis

A9.374 Power Auctions has set out theoretical models and an analysis of Auction outcomes with many interesting features, such as the role that could be played by strong value complementarities. However, we do not consider that the models or analysis of Power Auctions are sufficiently reliable to draw clear-cut conclusions on the likelihood of strategic investment in the Auction.

A9.375 We first summarise below our conclusions on detailed aspects of Power Auctions' analysis. Then we identify some higher-level themes.

A9.376 Methodology: An equilibrium bidding analysis, as used by Power Auctions, is a common technique in theoretical analysis of auctions. However, in our view there is

a limitation in Power Auctions' theoretical models in providing a complete or accurate view of real-world bidding decisions. Unless there is also specific empirical evidence to support the predictions of the model (which we do not consider has been presented in stakeholders' responses), caution should be exercised before relying on these theoretical models adequately to capture all of the important real-world considerations in operators' bidding decisions.

A9.377 Value complementarities: Whilst Power Auctions includes both intrinsic value and strategic value complementarities in its analysis, we consider that it would be both more transparent and very relevant to our analysis to distinguish more clearly between these two different sources of complementarities.

A9.378 On the implications of intrinsic value complementarities, we reach the following conclusions:

- We recognise that strong value complementarities arising from intrinsic value could in some circumstances reduce the effect of the auction design features we have identified as making strategic investment more difficult, such as the uniform price rule or being stranded > [REDACTED].
- However, in our view, this does not generally apply to complementarities arising from strategic investment value, which is at risk of failing to be realised by the strategic bidder. This is especially relevant in the case of coordinated strategic investment, where obtaining the desired strategic investment value depends on things outside of the bidder's control, such as the bids made by the other strategic bidder with whom it is seeking to coordinate.
- In addition, we note that in AM's model (on which Power Auctions relies) there are strong intrinsic value complementarities for [certain packages] > [REDACTED] under the scenarios Power Auctions finds most likely, the value complementarities in AM's model depend on strategic investment value as well as intrinsic value.

A9.379 On the evidence of intrinsic value complementarities, given our reservations about both the reliability of the evidence and the fact that it is conflicting, we consider that there is significant uncertainty about the accuracy of Power Auctions' assumptions about strong value complementarities.

A9.380 Auction outcomes: We reach the following conclusions from our assessment of Power Auctions' analysis of outcomes of the Auction:

- Power Auctions' analysis fails to take into account the fact of H3G's acquisition of UK Broadband. > [REDACTED] .
- Power Auctions' analysis of likely outcomes is based on a relative ranking of bidders' valuations from the AM model which is sensitive to assumptions.
- In our view, Power Auctions' analysis significantly overstates the degree of certainty that bidders would have about their rivals' values.
- We consider that the outcomes selected by Power Auctions as being the most likely under each option do not necessarily represent clear focal points.

A9.381 There are some higher-level themes which underlie the detailed disagreements with Power Auctions summarised above.

- A9.382 First, we consider that Power Auctions significantly overstates the information and degree of certainty that bidders will have about their own valuations (such as strategic investment value) and about the valuations of rival bidders (which are assumed to be based on the AM model and so also assumed to be known). A consequence is that, in our view, Power Auctions significantly understates the costs and risks faced by strategic bidders. This applies to unilateral strategic investment, but even more so to coordinated strategic investment, where each strategic bidder does not control the desired Auction outcome but is dependent on the other strategic bidder following through with the strategic investment. However, under our Auction rules, a strategic bidder will not know for sure whether the other strategic bidder, with whom it is attempting to coordinate, is doing its part, or how the intended victim(s) are bidding. This exposes the bidder to risks and costs which it will have to factor in when deciding whether to engage in strategic investment.
- A9.383 Second, Power Auctions relies on the intrinsic and strategic valuations in the AM model. We have identified concerns about the reliability of the value estimates in AM's model, which we set out above in the section of this annex discussing that model.
- A9.384 Third, there are facts that Power Auctions does not take into account. A simple, yet significant example is that AM's model – and hence also Power Auctions' analysis – fails to take account of H3G's significant increase in spectrum holdings as a consequence of its acquisition of UK Broadband. This means that H3G now already holds spectrum in each of the 3.4 GHz and 3.6-3.8 GHz bands – a fact which is ignored by both AM and Power Auctions.
- A9.385 On the one hand, Power Auctions' analysis of likely Auction outcomes might be different if it took account of H3G's acquisition of UK Broadband. If so, the analysis of Power Auctions in its report is less relevant for our analysis of competition concerns and measures.
- A9.386 On the other hand, if the same or a similar outcome is [REDACTED] .
- A9.387 The largest competition concern that would arise under this Auction outcome is [REDACTED] .

BT/EE's response on strategic investment

Summary of BT/EE's response

- A9.388 BT/EE argues that bidders do not have an incentive to bid on the basis of strategic values. It refers to our November 2014 consultation and our May 2015 statement⁵⁵⁹ and suggests that in those documents we said that strategic investment was unlikely in this auction, even without competition measures.
- A9.389 BT/EE argues that the key reasoning that supported this conclusion still holds, in particular there is no evidence that strategic investment would have an associated pay-off.
- A9.390 BT/EE argued that Ofcom had not carried out a proper analysis including the costs and risks faced by a would-be strategic bidder.

⁵⁵⁹ We did not say this in our May 2015 statement. But BT/EE may have intended to refer to our October 2015 statement.

A9.391 BT/EE also suggests that Ofcom's auction design features would make strategic investment unlikely.

Ofcom's views

A9.392 In the November 2014 consultation⁵⁶⁰ we said that strategic investment in spectrum is unlikely in awarding the 2.3 GHz and 3.4 GHz spectrum, for the following reasons:

- If all other factors were equal, we would expect operators with a low share of spectrum currently to have a higher intrinsic value for spectrum than rivals with a high share of spectrum currently. This is because those with a low spectrum share are likely to obtain the greatest network cost savings from obtaining more spectrum (because they will need to add to capacity more in order to meet forecast demand). This tends to increase the cost of strategic investment.
- There is a large amount (190 MHz) of spectrum in the award. A bidder trying to prevent others obtaining any spectrum would need to acquire access to all of this spectrum, which would tend to push up the price.
- It is unclear that such strategic investment would reduce competition, as this may depend on technical and market conditions that are difficult to predict.
- There is no obvious focal point for the division of spectrum in the auction between the operators with large spectrum shares currently.

A9.393 We still recognise that the above factors tend to reduce the risk of strategic investment. However, we have considered the risks of strategic investment afresh in our more recent November 2016 consultation and in this statement we set out our final view having considered responses.

A9.394 Unlike in the November 2014 consultation, we now consider there are competition concerns raised specifically by the allocation of the 2.3 GHz spectrum.

A9.395 We also note that in the November 2014 consultation we suggested there was a risk to competition and we proposed an overall spectrum cap (set on the basis of 37% of the spectrum we considered relevant at that time). Our conclusion in this statement is that there may be concerns related to overall spectrum holdings and we have decided to impose an overall spectrum cap (set on the basis of 37% of the spectrum we now consider relevant). We explain our competition concerns in section 6 and our competition measures in section 7.

A9.396 Our current assessment of the risk to competition also reflects developments since the November 2014 consultation. These include the merger of BT and EE, and also the recent merger of H3G and UK Broadband. At the time of the November 2014 consultation, we considered that BT and UK Broadband may have an impact on mobile competition in the future. For example, we said BT and UK Broadband could contract with one of the four MNOs for a national coverage service, which they can then combine with services provided with their own spectrum. We also said it was possible that BT and UK Broadband would sell the capacity they have in particular

⁵⁶⁰ See paragraph 7.102, https://www.ofcom.org.uk/data/assets/pdf_file/0025/78055/Public_Sector_Spectrum_Release_2-3_and_3-4_ghz_award.pdf.

locations to one or more of the four MNOs, which could mean that even if one or more of the existing four MNOs becomes capacity constrained in some high demand areas, retail competition could still be strong.⁵⁶¹ While H3G's purchase of UK Broadband has tended to reduce the asymmetry of spectrum holdings between MNOs, the merger of BT and EE has made it worse.

- A9.397 In the next annex, we set out our final assessment of the risk of strategic investment. On different facts and different competition concerns especially about 2.3 GHz, we have reached different conclusions compared to several years ago in the November 2014 consultation.
- A9.398 We do not agree with BT/EE that we have not carried out a proper analysis including the costs and risks faced by a would-be strategic bidder. While we have not carried out a quantitative modelling approach for the reasons given from paragraph A10.64, we have paid close attention to the costs and risks faced by would-be strategic bidders. We consider our analysis set out in this annex and annex 10 to be an appropriate assessment of the risk of strategic investment.
- A9.399 BT/EE also refers to the role of the auction design features and how these mitigate the risk of strategic investment. We have considered them as part of our assessment of the risk of strategic investment both in this annex and in annex 10. We consider that even though they make it more difficult, they do not eliminate the risk of strategic investment.

⁵⁶¹ See paragraphs 7.83 to 7.86 of the November 2014 consultation.

Annex 10

Likelihood of strategic investment in the Auction

- A10.1 In the previous annex we summarised what we said in the November 2016 consultation on the likelihood of strategic investment and assessed the responses we received. We described why we do not draw strong conclusions on the likelihood of strategic investment in the Auction from the modelling that has been carried out by Frontier Economics (FE), NERA, Analysys Mason (AM) and Power Auctions.
- A10.2 In this annex we provide our own assessment on the likelihood of strategic investment in the Auction. This is structured as follows:
- We set out our framework for assessing the likelihood of strategic investment;
 - We analyse developments since the November 2016 consultation; and
 - We set out our analysis on the likelihood of Auction outcomes based on strategic investment value. We first make this assessment without any competition measures in the auction. We then assess the likelihood with our competition measures.
- A10.3 We conclude in this annex that *in the absence of competition measures*:
- The possibility of strategic investment in relation to the 2.3 GHz spectrum specifically is a significant concern.
 - There is some risk of an incentive to engage in strategic investment for the 3.4 GHz spectrum specifically, but it is uncertain.
 - There is some risk of an incentive to engage in strategic investment for the spectrum overall, but it is uncertain.
- A10.4 We conclude that the measures we are taking reduce the risk that strategic investment will take place in the 2.3 GHz band and reduce the risk of unilateral strategic investment in the 3.4 GHz band.

Framework for assessing strategic investment

Drivers of allocation of spectrum in the auction

- A10.5 The allocation of spectrum in the auction, both the amount and the location within each band (frequency), will be determined by the relative bids that participants make. These in turn are likely to be determined by the expected difference in profits from supplying wholesale and retail services with and without the spectrum.

A10.6 We distinguish between two sources of value (i.e. profits) for operators in bidding for spectrum:⁵⁶²

- **Intrinsic value** – The present value of additional profits a bidder expects to earn when holding the spectrum compared to not holding it - in the absence of any strategic considerations to obtain spectrum that reduces competition in mobile services from the existing level.
- **Strategic investment value** – The present value of additional expected profits earned from bids that affect the future structure of competition in mobile services by depriving one or more competitors of spectrum.

A10.7 Even if operators do not necessarily make this distinction in an explicit way when formulating their own valuation of spectrum, it is relevant for our analysis because of the differential effect between these two sources of value.

A10.8 Strategic investment is where a bidder bids in excess of its own intrinsic value for an amount of spectrum, which denies use of that spectrum to its competitors - thereby weakening competition in the downstream market. Strategic investment can be attempted unilaterally by a single strategic investor, or with tacit coordination between two or more strategic investors.

A10.9 In considering strategic investment in this way, we are not supposing that bidders, individually or collectively, will act in a manner prohibited either in the Auction or more generally under competition law. Our concern is to consider whether strategic investment by one or more bidders, in pursuit of rational commercial goals, might result in an outcome that made the market less competitive.

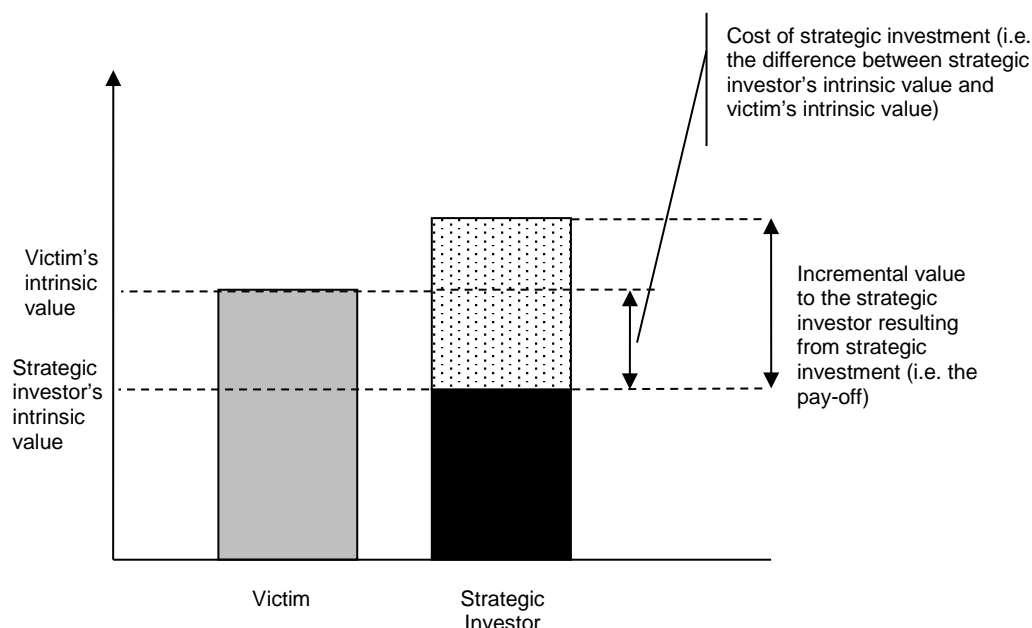
A10.10 The pay-off from engaging in strategic investment is the increase in profits arising from weakening competition in the market as a result of denying spectrum to one or more rivals. In Figure A10.1 below, the pay-off from strategic investment is illustrated by the dotted area above the black area.

A10.11 To succeed, the strategic bidder will need to outbid the potential 'victims' of strategic investment in the auction. The difference between the victim's intrinsic value (the grey area) and the strategic investor's intrinsic value (the black area) represents the cost of strategic investment. This is because the strategic investor would need to pay at least the intrinsic value of the victim⁵⁶³ in order to succeed in acquiring access to the spectrum.

A10.12 The higher the victims' intrinsic value for the spectrum, the higher the cost of strategic investment. Likewise, the higher the strategic investor's intrinsic value, the lower the cost of strategic investment.

⁵⁶² In the USA, the terms 'use value' and 'foreclosure value' have been used, which we understand to be similar in meaning to what we mean by intrinsic value and strategic investment value. See for example, page 10 and 11 of the US Department of Justice's submission to the Federal Communications Commission, *In the matter of policies regarding mobile spectrum holdings*, April 2013, <http://www.justice.gov/atr/public/comments/295780.pdf>

⁵⁶³ Given the nature of the auction design we chose for this award, the strategic investor might need to pay the victims' intrinsic value plus a price increment.

Figure A10.1: Illustration of cost of strategic investment and expected pay-off

A10.13 Our assessment of the risk of strategic investment is ultimately a judgement based on an analysis of: a) the ability and incentives for bidders to engage in it; and b) the likelihood of those incentives materialising in actual bidding behaviour. It is reasonable to assume that, all else constant, the stronger the incentives, the more *likely* it is that those incentives will materialise.

A10.14 The incentives of bidders to engage in strategic investment in turn depend on the expected pay-off for this strategy when compared to the expected cost involved. This will determine whether such investment would represent a profitable strategy overall - in which case the potential strategic investor may have an incentive to engage in such behaviour.

A10.15 Figure A10.1 is a simple illustration, where we assume there is a single lot of the relevant spectrum. The costs and pay-offs are more complicated if there are alternative lots to which the potential victim could acquire access or if the victim needs more than one lot of the relevant spectrum. We described this further in our discussion of the 'multiplier effect' from paragraph A9.76 above.

A10.16 For illustration, Figure A10.1 also presents the pay-off and cost of strategic investment as if they are certain to arise. However, in many circumstances there will be significant associated risk or uncertainty – we provide a few examples:

- a) The cost could be inflated above that shown in Figure A10.1 if the strategic investor was bidding for the spectrum against a different operator than the intended victim operator (and under the auction rules, a bidder will not receive information on the identity of other bidders in each round).
- b) There is likely to be uncertainty about the size of the pay-off, because it depends on the nature of the competitive effect of depriving the victim operator of specific spectrum. In turn, this depends on such considerations as: the network and commercial alternatives available to the victim operator, about which the strategic investor may not be fully informed; and the precise benefits to the strategic investor from weakening the victim

operator, such as the number of new subscribers gained from the victim and the scale and extent of any price increase the strategic investor can impose due to weaker competition.

- c) The precise nature of any weakening of competition may depend how the remaining spectrum (i.e. the spectrum not won by the strategic bidder) is split between the other bidders. For example, this is a feature of the NERA valuation model, which identifies a multiplicity of potential strategic investment values for a single package of spectrum won by a strategic bidder, for this reason.
- d) In coordinated strategic investment, the weakening of competition depends on the bidding of two strategic bidders. Each strategic bidder therefore faces the risk that it incurs the cost of strategic investment, by bidding above its intrinsic value for the spectrum, but obtains no pay-off and so incurs a loss, because the other bidder, on which it was depending, fails to do its part to achieve the weakening of competition.

A10.17 Both the pay-off and the cost are also dependent on some features which we take as given for the purposes of this analysis. These include the detail of the auction design adopted in the 2.3 GHz and 3.4 GHz award, the amount and type of spectrum available in each of the 2.3 GHz and 3.4 GHz bands, and the competition concerns identified in Section 6.

General factors affecting the pay-off from strategic investment bidding

A10.18 In Section 6, we identified two main competition concerns related to winning spectrum in the Auction. The **first** is related to the potential impact of an increasingly asymmetric distribution of overall spectrum, Competition Concern 1. The **second** concern is that one or more operators would cease to be credible MNOs if they failed to acquire access to spectrum in this Auction, Competition Concern 2.

A10.19 The potential pay-off from engaging in strategic investment for spectrum available in the Auction is the flipside of these two competition concerns. For a bidder to have an ability and incentive to engage in strategic bidding, at least two conditions should hold:

- a) Ability – the bidder is able to obtain spectrum and so deny it to rivals and weaken mobile competition; and
- b) Incentive - the bidder engaging in strategic investment bidding should benefit from a weaker competitive environment (i.e. obtain a pay-off) by being able to increase its profit, such as through its market share, margins or a combination of both.

A10.20 Denying new spectrum to other operators will only prove useful to weaken competition if such spectrum cannot be sufficiently substituted by other means. To some extent, operators have other options for expanding capacity apart from acquiring new spectrum access (as discussed further in annex 6). These include using their current spectrum holdings more efficiently or investing in additional sites. This tends to reduce the potential benefits of strategic investment. However, there are both technological and economic factors limiting the extent to which spectrum can be substituted in the provision of mobile services, meaning that there may sometimes be an incentive to engage in strategic investment.

- A10.21 Operators that already have large spectrum holdings are more likely to be able to expand capacity without relying on the spectrum auctioned. Hence, these operators are less likely to become a target for strategic investors.
- A10.22 Operators with small spectrum shares may also be able to rely on future spectrum awards to expand their capacity. Even if an operator expects to require new spectrum to expand capacity in the future, it may be able to acquire access to such spectrum in other spectrum releases. In this respect, the pay-offs attached to strategic investment are likely to depend on the specific characteristics and scarcity of each band. For example, only some of the spectrum in this auction (2.3 GHz) is likely to be capable of addressing immediate capacity issues in the first transitional period. Strategic investment in the 2.3 GHz band may therefore be associated with earlier effects on downstream competition.

General factors affecting the cost of strategic investment bidding

- A10.23 Strategic investment bidding, although potentially associated with positive pay-offs for bidders, would also involve a number of costs and risks.
- A10.24 Notably, in order to exclude rivals from winning spectrum, strategic investors would need to outbid their target rivals in the Auction. For the strategic investor, this involves bidding above its own intrinsic value for spectrum.
- A10.25 All else equal, the amount of spectrum available in the Auction will have a bearing on the cost of strategic bidding. This is because if there is a larger amount of spectrum, a bidder engaging in strategic investment usually needs to outbid rivals' demand for a greater number of lots. The smaller the amount of spectrum available in the Auction, the easier it is to exclude access to it.
- A10.26 The relevant way to assess the effective amount of spectrum available may depend on the extent to which there are complementarities for multiple lots of spectrum. If all operators are likely to pursue a minimum number of lots, this minimum (rather than a single lot) may become the relevant unit for the analysis. This issue plays an important role in the analysis of Power Auctions, on which we comment in detail in annex 9.
- A10.27 In addition, where more than one operator is likely to benefit from weakening a rival, the cost of strategic investment will depend on whether strategic investment bidding is done in a unilateral way or as a (tacitly) coordinated effort between two or more bidders. Unilateral strategic investment bidding generally creates costs which are substantially higher than coordinated strategic bidding. However, coordinated strategic investment may be difficult to achieve unless there is a clear focal point over which two or more strategic investors can coordinate their efforts.
- A10.28 There may also be a free riding problem as to how the cost of strategic investment is split. This is because an operator could benefit from a less competitive downstream market even if it were the actions of another operator which denied spectrum to competitors.⁵⁶⁴ Thus, it might have an incentive not to engage in strategic investment if there is a high chance that another operator will deny the spectrum to victim or target operators anyway.

⁵⁶⁴ This is a feature of NERA's valuation model which we consider in annex 9.

Auction design features

- A10.29 Our auction design for the 2.3 and 3.4 GHz award has three features that might increase the cost of strategic investment, and therefore reduce the risk of it occurring. However, we recognise that these features are on their own unlikely to fully prevent any risk of strategic investment in the Auction.
- A10.30 The **first feature** that could make strategic investment more costly is related to the way prices in each band are set in the auction. In our auction design the final price for lots within each band will be the same (or separated by at most one increment)⁵⁶⁵. We refer to this as the “uniform price rule”.
- A10.31 There are two consequences of the uniform price rule which are relevant to the discussion about the potential for strategic investment in the award.
- A10.32 The first is that the uniform price rule means that by bidding on a larger quantity of spectrum for strategic reasons, the strategic bidder will also be increasing the cost of any smaller amount of spectrum it would wish to win for intrinsic value reasons.
- A10.33 If the strategic bidder does not have any intrinsic value for any spectrum in the band, when the price in the band exceeds its strategic value, the bidder just stops bidding. If it is subsequently fully outbid by other bidders, the strategic bidder is not made worse-off by having decided to bid on the basis of strategic investment.
- A10.34 If however the bidder has an intrinsic value for some spectrum in the band, the decision to bid for a larger amount of spectrum than it would want to buy for its own use may make it worse off, if it fails in its strategic investment objective. It would also be worse off if, by having bid for a large amount of spectrum, it raised the price on the smaller amount of spectrum for which it has some intrinsic value. This applies even in the case where the bidder gets fully outbid: had it instead bid on a smaller amount of spectrum, it might have been able to win it at a price lower than its intrinsic value.
- A10.35 The second consequence of the uniform price rule is that, in the circumstances where the potential victim only needs to win a relatively small amount of spectrum compared to the spectrum available in the band(s), in order to succeed the strategic investor may need to win a larger quantity of spectrum than the victim at a high price. We describe this effect – the multiplier effect – in annex 9.
- A10.36 For example, in order for the strategic bidder to ensure that it succeeds in denying 20 MHz of the 2.3 GHz band (i.e. two lots of 10 MHz each) to the victim, it will need to win 30 MHz (three lots), because there is 40 MHz (four lots) of 2.3 GHz spectrum available in the Auction.⁵⁶⁶ Given the nature of the uniform price rule, the strategic bidder may need to win the entire quantity of spectrum it needs for strategic reasons at a multiple of the total intrinsic value of the victim. For instance, if the victim requires 20 MHz of 2.3 GHz, then the strategic investor will need to win 30

⁵⁶⁵ We are abstracting from the fact that any unallocated lots that are won by virtue of a withdrawal are offered to the bidder that withdrew at twice the price of its bids. The *lowest* price that the bidder would in any case be asked to pay – which would apply in the event it rejected the withdrawn lot licence – is the single price. Therefore, the discussion that follows broadly applies even when there are withdrawals.

⁵⁶⁶ More generally, to deny X MHz to the victim(s), the strategic investor(s) need to win more than $(T - X)$ MHz, where T is the total amount of relevant spectrum available in the Auction.

MHz at a total price that is 1.5 times higher than the intrinsic value of the victim for its 20 MHz.

- A10.37 The effect may be even greater at 3.4 GHz. For example, if the victim needs 40 MHz of 3.4 GHz, the strategic investor will need to win 115 MHz (given the 150 MHz of 3.4 GHz available in the Auction) at a total price that is 2.875 times higher than the victim's intrinsic value for 40 MHz.⁵⁶⁷
- A10.38 We explained in annex 9 that both FE's and NERA's analysis fail to take account of this multiplier effect.
- A10.39 Power Auctions argued in the report commissioned by H3G and which we discuss in annex 9 that the impact is < [REDACTED] .
- A10.40 In our view, if as a result of intrinsic value complementarities the strategic bidder wishes to win a large amount of spectrum for intrinsic value reasons, then the cost of winning an extra amount of spectrum to deny it to its competitors may be reduced. This tends to reduce the cost of strategic investment.
- A10.41 We also noted in annex 9 (when discussing the NERA model) that the victim's intrinsic value complementarities may also interact with the uniform price rule. With strong value complementarities, the victim will want to win a larger amount of spectrum. As a result, the multiplier effect is less powerful and the cost of strategic investment may be reduced.
- A10.42 We conclude in annex 9 that there is significant uncertainty about the accuracy of Power Auctions' assumptions about strong value complementarities.
- A10.43 The **second feature** in the auction that could make strategic investment more costly is related to the nature of bidding and the risk of being "stranded". Bidding in the 2.3 and 3.4 GHz auction will not be for packages of spectrum but for individual lots (with a lot sizes of 10 MHz and 5 MHz for the 2.3 GHz and 3.4 GHz bands respectively). This means that, although a bidder can place bids for multiple lots within each band, it is possible that it will win some of the lots it bids for but not all of them. This is a difference from the combinatorial clock auction which we used for the 2013 auction.
- A10.44 A strategic bidder may decide to bid up to its total value (which is the sum of intrinsic value and strategic investment value) in an attempt to deny spectrum to other bidder or bidders. However, there is a risk that the strategic bidder at some point is made partial standing high bidder⁵⁶⁸ at a given round price. Because it is a partial standing high bidder (as opposed to a full standing high bidder), it may have failed to deny a sufficient amount of spectrum to other bidders, so it would like to make more bids in the following round. However, if the price in the following round exceeds its total value *per lot*, it may not be optimal for it to make new bids. If no other bidder or bidders outbid the strategic bidder, the latter would only win a fraction of the spectrum it would need to succeed in its attempt to engage in strategic investment, possibly at a price that exceeds its intrinsic value for the spectrum.

⁵⁶⁷ For ease of exposition, in this discussion we take the simple case of a single (unilateral) strategic investor and a single victim operator that bids up to its intrinsic value.

⁵⁶⁸ That is, a standing high bidder on some but not all the lots it bid for.

- A10.45 In such a situation the strategic bidder would have paid more than its intrinsic value for the spectrum (so incurring a loss) without achieving the effect of foreclosing competition.
- A10.46 Power Auctions argued that if the bidder or bidders that the strategic investor is bidding against exhibit value complementarities, the risk of the latter being “stranded” as a partial standing high bidder may be smaller. For illustrative purposes, if we consider the 2.3 GHz band, where we have four 10 MHz lots and an example where the victims’ valuations are such that they only want to bid on multiples of 20 MHz. In that case, there will be no risk of any bidder being stranded as a partial standing high bidder on 1 or 3 lots.⁵⁶⁹
- A10.47 However, the strategic investor would only perceive a lower risk of being stranded in the way described if it could anticipate with a sufficient degree of confidence that its victim(s) exhibit these value complementarities. In addition, even if there are strong and predictable value complementarities within certain ranges of MHz, the risk of being stranded as a partial standing high bidder still exists when bidding for quantities that lie outside these ranges. For instance, in the example of 2.3 GHz described above, there is a risk that the strategic investor will be stranded as a partial standing high bidder on 20 MHz, when it needs to win either 30 or 40 MHz to foreclose the victim.
- A10.48 The **third feature** is related to the information we will make available to bidders during the Auction. The information policy we have decided to adopt is that, during the principal stage, bidders are provided with limited information about the bids made by other bidders. A bidder will not see information on any of the specific bids made by other bidders and instead it will only receive approximate aggregated information.
- A10.49 The limited information available to bidders makes some aspects of strategic investment much more difficult. In particular, it is difficult for a strategic bidder to target specific competitors, because it does not see any specific bids being made by other bidders. For example, it might be that the strategic bidder believes that only particular competitors are vulnerable to strategic investment (because other competitors’ alternative plans without the 2.3/3.4 GHz spectrum would be effective). However, the strategic bidder would not know for sure whether it was bidding against the competitor it wants to target or another bidder. The strategic bidder would face the risk that it would continue to bid when the competitor it wants to target had already dropped out. In this case, the cost to the potential strategic bidder of engaging in strategic investment would be higher (than if it could target particular competitors).
- A10.50 For ease of reference, henceforth we refer to the auction design features described above as the uniform price rule, the risk of being stranded, and the information policy.

⁵⁶⁹ As we explain in annex 12, at the end of each principal stage round, Ofcom will rank the bidders that made bids in a lot type (band). Our approach is then to satisfy the demand from each bidder in turn by assigning standing high bid status to their bids, until there are no more lots available in the band. This means that if every bidder bids on multiples of 20 MHz (2 lots), no bidder will be standing high bidder on one or three lots.

Developments since our consultation document

A10.51 There have been a number of developments since our November 2016 consultation that could affect our assessment of the likelihood of strategic investment:

- H3G's acquisition of UK Broadband;
- 1400 MHz spectrum will be useable earlier than previously expected; and
- we have less confidence that 3.6-3.8 GHz spectrum will be useable within a similar timeframe to 3.4 GHz spectrum across the UK

A10.52 We consider these in turn below.

H3G's acquisition of UK Broadband

A10.53 As described in section 5, H3G has recently purchased UK Broadband. This means it now holds 40 MHz of 3.4 GHz spectrum and 84 MHz of 3.6-3.8 GHz spectrum. This raises two questions:

- a) How does H3G's acquisition of UK Broadband affect the likelihood that it would either be the victim of strategic investment or become a strategic bidder?
- b) Does the fact that UK Broadband was acquired by H3G, and not another MNO, tell us anything about the likelihood of strategic investment in the Auction?

A10.54 On the first question, H3G's purchase of UK Broadband does not directly affect the incentive to invest strategically to prevent H3G from obtaining 2.3 GHz spectrum for the first transitional period, because it does not change the spectrum that H3G holds that is useable in the first transitional period.

A10.55 However, the purchase of UK Broadband reduces, though may not necessarily eliminate, the incentive to invest strategically to prevent H3G obtaining additional spectrum useable in the second transitional period (when it will now have at least 14% of useable spectrum). In addition, the purchase probably removes any incentive to deny H3G spectrum for the longer term (when H3G will have a spectrum share of at least 19% as its 3.6-3.8 GHz spectrum will be useable in the longer term).

A10.56 That H3G now has a high share of the wider band of 3.4-3.8 GHz spectrum potentially increases the incentive that it would itself strategically invest to prevent other MNOs from obtaining spectrum suitable for launching 5G services early. However, as we describe below, we consider it unlikely that H3G would have an incentive to strategically invest in the 3.4 GHz band.

A10.57 On the second question, if another MNO had a strategic incentive to prevent H3G from obtaining mobile spectrum, we might have expected that MNO to have obtained UK Broadband rather than let it be acquired by H3G. This might suggest that strategic investment in 3.4 GHz in the Auction is unlikely.⁵⁷⁰

⁵⁷⁰ Materially different considerations are likely to be relevant for the 2.3 GHz band, as it is useable in the first transitional period (unlike 3.4 GHz).

- A10.58 The purchase of UK Broadband did not only relate to the 3.4 and 3.6-3.8 GHz spectrum. The purchase also included other (lower value) spectrum and UK Broadband's sites and existing customer base (though this is modest at 15,000 customers). The situation is therefore not perfectly comparable with the circumstances of a spectrum auction, when only the spectrum is being sold. To the extent that the price H3G paid for UK Broadband reflected other assets (or uses of the spectrum other than mobile services)⁵⁷¹, it may weaken the weight that can be placed on the purchase of UK Broadband as evidence that strategic investment is unlikely.
- A10.59 A sale of at least the spectrum held by UK Broadband was foreseen by other operators. Before H3G's acquisition of UK Broadband was announced, BT/EE commented that UK Broadband was widely expected to be awaiting an opportunity to sell its 3.4 GHz and 3.6-3.8 GHz holdings given its very limited use of the spectrum.⁵⁷² < [REDACTED] .⁵⁷³
- A10.60 In summary, H3G's purchase of UK Broadband could suggest that strategic investment in 3.4 GHz in the forthcoming auction is unlikely. However, we are cautious of inferring too strong a conclusion from this piece of evidence alone.

1400 MHz spectrum useable earlier than expected

- A10.61 As discussed in section 5 we now consider that the 1400 MHz spectrum will be useable earlier than we thought at the time of the November 2016 consultation. This may have the effect of reducing strategic investment incentives for 2.3 GHz spectrum to try to weaken H3G. This is because H3G has 20 MHz of 1400 MHz (meaning its share of spectrum useable in the first transitional period is about 14%) and the potential benefits of preventing H3G from winning 2.3 GHz spectrum specifically are therefore reduced. However, whilst it may reduce the incentive, we do not regard this change as being sufficient on its own to remove any concern about strategic investment against H3G in 2.3 GHz spectrum.
- A10.62 The useability of 1400 MHz does not affect the position of O2, as its holdings of immediately useable spectrum remain unchanged.

Less confidence that 3.6-3.8 GHz spectrum will be useable at a similar time to 3.4 GHz spectrum

- A10.63 As discussed in section 5, our confidence that the 3.6-3.8 GHz band will become useable within similar timeframes to the 3.4 GHz band across the UK has diminished. This tends to increase the potential pay-offs from strategic investment in 3.4 GHz because of a second transitional period during which competition may be weaker.

⁵⁷¹ H3G may have placed some value on the spectrum not only for mobile use, but also for fixed-wireless substitution. It has been suggested in some press reports that H3G will expand the provision of fixed wireless services, for example, <http://www.telegraph.co.uk/business/2017/05/01/three-plans-blanket-cities-5g-network/>

⁵⁷² Paragraph 108, BT/EE response.

⁵⁷³ We recognise that members of the Li family have minority holdings in both CK Hutchison (the ultimate owner of H3G) and in PCCW (the ultimate owner of UK Broadband). However, H3G and CK Hutchison are third parties that are independent of PCCW - See pages 5 and 6 of PCCW's announcement of 6 February 2017 on the UK Broadband transaction, <http://www.hkexnews.hk/listedco/listconews/SEHK/2017/0206/LTN201702061696.pdf>.

The risk of strategic investment taking place without competition measures in the auction

Nature of our assessment

A10.64 We now turn to our assessment of the risk of strategic investment in the absence of competition measures. Our assessment is qualitative. We consider possible strategic investment scenarios and consider, in a qualitative way, the pay-offs and costs from strategic investment in the Auction.

A10.65 We have not built quantitative models to inform this assessment. Any such models would require making many assumptions on which it would be difficult to obtain reliable information, and the results would be likely to be sensitive to those assumptions. For example, we would need to take a quantified view on the intrinsic and strategic values different operators would have for different amounts of the 2.3 GHz and 3.4 GHz spectrum. Each MNO typically invests significant time and effort to develop its own valuations for significant spectrum auctions, and these valuations often depend on information specific to that MNO, such as its individual commercial strategy and detailed plans in the future. As noted in paragraph A10.16 above, the quantified strategic investment value is subject to a range of uncertainties.

A10.66 Therefore, we consider that the results of quantitative modelling of different operators' spectrum valuations and possible outcomes of this Auction are unlikely to be sufficiently robust. Indeed, if we were able to model companies' spectrum values in a highly accurate way, we would not need to rely on auctions to determine who values the spectrum most highly. Whilst these considerations are also present for our qualitative analysis set out below, in our view, detailed quantified modelling is unlikely to yield sufficient benefits for our competition assessment over and above that qualitative analysis.

A10.67 This view is consistent with our analysis of the quantitative models submitted to us in consultation responses. As part of their responses H3G and O2 have developed models to explore the likelihood of strategic investment. We have described and commented on these models in Annex 9. Our assessment is that the models provide a quantified illustration of how strategic investment can arise, but we do not regard them as sufficiently robust to draw reliable conclusions regarding the likelihood of strategic investment.

Structure of our assessment

A10.68 As explained in the framework set out above, we expect the specific characteristics of each band to have consequences for the pay-offs and costs of engaging in strategic investment bidding. Hence, we conduct our assessment of the risk of strategic investment, with respect to specific bands as well as for the auction spectrum as a whole.

A10.69 We structure our assessment as follows:

- We first consider strategic investment in 2.3 GHz specifically. This relates to our Competition Concern 1(a), about weaker competition in the first transitional period;
- Next we consider strategic investment in 3.4 GHz specifically. This relates to our Competition Concern 1(c), about weaker competition due to very

asymmetric shares of 3.4 GHz spectrum and the potential importance of this band for the early launch of 5G services; and

- We then consider strategic investment relating to both 2.3 GHz and 3.4 GHz together. We consider this last because the potential pay-offs from strategic investment in 2.3 GHz and 3.4 GHz individually feed into the pay-offs when both bands are considered together. As well as the potential pay-offs from Competition Concern 1(a) and Competition Concern 1(c), the potential pay-offs from strategic investment in all the spectrum together relate to undermining the credibility of an MNO - Competition Concern 2 - and weakening competition by causing very asymmetric holdings of spectrum overall in the second transitional period - Competition Concern 1(b).

The risk of strategic investment related specifically to 2.3 GHz spectrum - Competition Concern 1(a)

A10.70 As in the November 2016 consultation, we have identified three main hypothetical scenarios in which one or more bidders may deny 2.3 GHz spectrum to rivals through strategic bidding – noting that these scenarios do not exhaust all possible means by which bidders could bid strategically and deny this spectrum to their competitors:

- Scenario 1: A unilateral strategic investor winning 30 or all 40 MHz, which denies a 20 MHz block to any of its competitors;
- Scenario 2: A unilateral strategic investor winning 10 or 20 MHz which denies a 20 MHz block to more than one of its competitors;
- Scenario 3: Two tacitly coordinating strategic investors, each winning 20 MHz, which denies any 2.3 GHz spectrum to the other two MNOs (or new entrants).

Potential pay-off from engaging in strategic investment in 2.3 GHz spectrum

A10.71 Our Competition Concern 1(a) is that competition might be weaker in the first transitional period if the auction led to a very asymmetric distribution of immediately useable spectrum.⁵⁷⁴

A10.72 By denying 2.3 GHz spectrum to competitors, strategic investors may be depriving rivals of spectrum in the first transitional period, second transitional period, and in the longer term.

A10.73 We take the view that the pay-off a strategic investor might be able to extract by denying 2.3 GHz spectrum to its rivals in the second transitional period and longer term is likely to be limited, as more spectrum becomes useable after the first transitional period. However, the pay-off associated with denying 2.3 GHz spectrum during the first transitional period might be clearer because:

⁵⁷⁴ In the November 2016 consultation, we were also concerned that while the 3.4 GHz was likely to become sufficiently substitutable for the 2.3 GHz spectrum in the longer term, there was a risk this might not be the case. Based on the responses we received, we are now confident that 3.4 GHz will be a sufficient capacity substitute for other bands in the longer term.

- There is a relatively well-defined time frame within which victim operators may have limited ability to compensate for a lack of useable spectrum;
- The strategic investor may have an expectation that, if some operators are denied useable spectrum and have only limited mitigations available to them during the first transitional period, they may - at least for some customers - compete less aggressively and/or increase prices to reduce the rate of growth in demand they would otherwise face; and
- There may also be an expectation that this will benefit the operator that engages in strategic investment, either because it will capture some or all of the demand lost by the victim(s) of strategic investment, or because it will be less constrained by price competition, or a combination of the two.

A10.74 While it is plausible that some operators may benefit from engaging in strategic investment to exploit this concern, there is a risk to those operators that any of the assumptions presented above may be incorrect.

A10.75 The potential pay-off from weakening rivals would be temporary, as more spectrum will become useable after the first transitional period and more mitigation options are possible over a longer time period. On the other hand, there is a risk that a reduction in competition during the first transitional period could take some time to erode.

A10.76 As mentioned above, the earlier useability of the 1400 MHz spectrum than we previously thought may reduce the pay-off from denying spectrum to H3G, as H3G has more useable spectrum in the transitional period, given its 20 MHz of 1400 MHz spectrum. The useability of 1400 MHz does not affect the position of O2, as its holdings of immediately useable remain unchanged.

A10.77 We expect the risk of strategic investment causing harm to competition to be higher under our hypothetical scenarios 1 and 3 than under scenario 2, because more spectrum is denied to competitors. In fact, under scenario 2 the bidder who engages in the unilateral strategic investment is uncertain about who is being denied the spectrum.

A10.78 Operators are only able to engage in strategic investment if by preventing rivals from obtaining spectrum they weaken competition. If an operators' rivals have some spectrum that is lightly used, then that operator is less likely to have the ability and incentive to engage in strategic investment. In the first transitional period, BT/EE and Vodafone are more likely to have an incentive to engage in strategic investment, and O2 and H3G are more likely to be victims.

Vodafone has a significantly lower pay-off than BT/EE from strategic investment

A10.79 BT/EE is likely to have a greater benefit from weaker competition from O2 and H3G than Vodafone. This is because of both the main sources of pay-off from strategic investment: charging higher prices due to weaker competition; and gaining subscribers lost by capacity-constrained victim operators.⁵⁷⁵

A10.80 All else equal, operators with higher market shares would benefit more from a relaxation in price competition as they would be able to extract more surplus from

⁵⁷⁵ These two sources of strategic investment value are reflected in the valuation models discussed in annex 9.

their existing client base. BT/EE has substantially more subscribers than Vodafone. For example, in terms of network subscribers (including hosted MVNOs subscribers), BT/EE had \times [REDACTED] % of subscribers in 2016, and Vodafone had \times [REDACTED] %.

A10.81 BT/EE may also benefit more than Vodafone from any market share loss by O2 and/or H3G. This can be informed by “diversion ratios”. The diversion ratio from one company to a second company is the proportion of all customers switching away from the first company that go to the second company. Higher diversion ratios between two companies mean that they are closer competitors. Vodafone’s response provides diversion ratios for customers switching away from H3G and O2, \times [REDACTED] .⁵⁷⁶ Similarly, the Frontier Economics’ report submitted by H3G provides diversion ratios for \times [REDACTED] .⁵⁷⁷ Although there are differences in some of the diversion ratios from each of these sources, the range of post-paid retail level diversion ratios they report is:

- Vodafone might only gain around \times [REDACTED] % of subscribers lost by H3G and \times [REDACTED] % of customers lost by O2; and
- BT/EE could gain \times [REDACTED] % or more of the subscribers lost by H3G or O2.

A10.82 The diversion ratios above show a greater gap between the percentage of subscribers switching to BT/EE and the percentage switching to Vodafone than was the case in the diversion ratios used by the European Commission in its merger decision prohibiting the merger of H3G and O2. The European Commission found that for post paid subscribers, at the retail level:⁵⁷⁸

- Vodafone could gain 19% of subscribers lost by H3G and 31% of subscribers lost by O2; and
- EE could gain 24% of subscribers lost by H3G and 34% of subscribers lost by O2.⁵⁷⁹

A10.83 The European Commission’s diversion ratios were based on a survey which related to the period from July 2014 to June 2015, and may be less relevant than more recent surveys on diversion ratios.⁵⁸⁰ For example, the European Commission noted that its survey covered a period when the entry of BT Mobile and the merger between BT and EE were at their early stages, and that it appeared that during the period from its entry in the market to the merger with EE, BT Mobile acquired a non-negligible share of gross adds.⁵⁸¹ This is consistent with more recent diversion ratios after BT Mobile started to gain market share, and a higher diversion ratio from H3G to BT/EE and from O2 to BT/EE.

⁵⁷⁶ Vodafone reports diversion ratios at \times [REDACTED] .

⁵⁷⁷ Frontier Economics only reports diversion ratios from \times [REDACTED] to other operators at a retail level. The diversion ratios from \times [REDACTED] .

⁵⁷⁸ See Appendix A of Annex A of the European Commission’s merger decision of 5 May 2016, http://ec.europa.eu/competition/mergers/cases/decisions/m7612_6555_3.pdf

⁵⁷⁹ At the network level (so including hosted MVNOs), the European Commission’s survey found that Vodafone could gain 24% of subscribers lost by H3G and 36% of subscribers lost by O2, and EE could gain 29% of subscribers lost by H3G and 45% of subscribers lost by O2.

⁵⁸⁰ See from paragraph 447 of the European Commission’s decision for a description of the survey.

⁵⁸¹ See paragraph 278 of the European Commission’s decision.

A10.84 Both the market shares and diversion ratios suggest that Vodafone has a significantly lower pay-off from strategic investment than BT/EE.

Cost of engaging in strategic investment in 2.3 GHz spectrum

Cost of unilateral strategic investment

A10.85 Under hypothetical scenarios 1 and 2, a single bidder wins spectrum (ranging from 10 MHz to 40 MHz) which denies it to other bidders. The smaller the amount of spectrum won, the lower the underlying costs will tend to be. However, while the cost of strategic investment under scenario 2 is likely to be smaller compared to scenario 1, it is also less likely to be effective in weakening competition.

A10.86 First, the cost of strategic investment is smaller, the lower the intrinsic value of the potential victim(s). This is because, in scenario 1 for example, the acquisition of access to 40 MHz for strategic purposes would involve fully outbidding all the other bidders (or, in the case of 30 MHz, it would involve outbidding all the other bidders except on 10 MHz).

A10.87 While O2 (and perhaps H3G) are potential victims of strategic investment, we expect O2 in particular to have a high intrinsic value for the 2.3 GHz spectrum, given its high share of subscribers but low share of spectrum.

A10.88 However, while a high intrinsic value of other bidders raises the potential cost of strategic investment, it may also be indicative of its underlying pay-off.

A10.89 Second, the cost of strategic investment is smaller, the higher the intrinsic value of the strategic investor(s). If strategic investors have sufficient or close to sufficient capacity spectrum for their needs, their intrinsic valuation for 2.3 GHz spectrum will tend to be relatively small, which increases their cost of strategic investment. This may be a particular disincentive if the strategic bidder incurs the full cost of acquiring an indefinite licence⁵⁸² only to gain value during the first transitional period from weakening competition.

A10.90 However, it is possible that some of the operators which might have an interest in engaging in strategic investment would also have some intrinsic value for the spectrum themselves, thereby reducing the cost. Even if their intrinsic value based on using the spectrum in the first transitional period is relatively small, it may increase over time.

A10.91 Third, even if the cost of strategic investment *per lot* is high, the quantities of spectrum involved in scenario 1 are relatively small when compared to the overall 190 MHz available in the Auction. Therefore, the absolute cost of strategic investment may not be high.

A10.92 Fourth, although the auction design features discussed earlier may increase the cost or difficulties of strategic investment, the stand-alone mitigation provided by those features may be limited in 2.3 GHz.

- a) Uniform price rule: The difference between how much spectrum the bidder would wish to win for its own use – if any – and the total amount of

⁵⁸² The payments for the spectrum in the Auction are determined by the auction process itself. The licences are not subject to additional fees until after the end of the initial 20 year period. After the initial 20 year period, we will consider what fee level to apply.

spectrum available in the band is likely to be relatively small, especially compared to 3.4 GHz. Therefore, the impact on the final price of bidding for an additional small amount of spectrum, compared to bidding only for the spectrum the bidder wished to win for its own use, is likely to be limited. Also, the multiplier effect we explained earlier in this section may have limited impact on increasing the cost of strategic investment in 2.3 GHz, given the small amount of spectrum available. We gave the example earlier that, if the victim requires 20 MHz, then the strategic investor will need to win 30 MHz at a multiplier of 1.5 (which is significantly smaller than the multiplier could be in the 3.4 GHz band). It could actually have the inverse impact: if the victim requires 40 or 30 MHz of 2.3 GHz spectrum, then the strategic bidder will only need to bid for 10 or 20 MHz, respectively, to ensure it succeeds.

- b) Risk of being stranded: The extent to which the risk of being stranded as a partial standing high bidder offers a serious deterrent to engaging in strategic investment in 2.3 GHz is uncertain. On one hand, the amount of spectrum the strategic investor might end up winning at a loss, if it becomes stranded as partial standing high bidder on an insufficient amount of spectrum for its strategic purposes, is likely to be small. This is due to the fact that there is a small amount available in total (40 MHz). On the other hand, the cost of strategic investment could be high if the price the bidder has to pay for the spectrum it wins is high enough, and that outweighs the fact that the amount won is small. Finally, as we noted earlier, all else constant, if the victim(s) exhibit strong value complementarities for blocks of 20 MHz, then the risk the strategic investor faces of being stranded in 2.3 GHz is reduced.
- c) Information policy: While bidders do not know who they are bidding against, if some bidders are particularly capacity constrained in the first transitional period, they will tend to have high intrinsic valuations for 2.3 GHz spectrum. Therefore, a bidder engaging in strategic investment in 2.3 GHz may take the view that it is likely that it will be bidding against those bidders. The uncertainty could be greater in 3.4 GHz, with much more spectrum in the band.

Cost of co-ordinated strategic investment

- A10.93 We now consider coordinated strategic investment, and in particular scenario 3. This scenario denies the same, or close to the same, amount of spectrum to victim(s) as scenario 1, but does so while allowing the strategic investors to share the potential cost associated with strategic investment. This makes the potential costs lower to each strategic investor than with unilateral strategic investment.
- A10.94 In practice it may be difficult to tacitly coordinate strategic investment. One reason is that while the benefits from successful strategic investment will be captured by an operator irrespective of whether it participates or not, the costs will only be incurred if it does so. A bidder might as a consequence have an incentive to free ride, or in other words to let other bidders incur the costs of strategic investment while it enjoys the benefits, if the latter succeeds.
- A10.95 For example, in scenario 3 strategic investor A may choose to bid on 10 MHz under the expectation that strategic investor B will bid on 20 MHz, which would result in them jointly succeeding in denying a block of 20 MHz to another bidder. By bidding on 10 MHz, instead of 20 MHz, strategic investor A would partly free ride and let

strategic investor B incur a higher cost. However, if both strategic investors bid on the same expectation – i.e. each bidding on 10 MHz - they may both be unsuccessful in denying a 20 MHz block to another bidder.

A10.96 Additionally, the information policy we have adopted for the auction, as well as posing a challenge to bidders who wish to engage in unilateral strategic investment, also makes tacit coordination between bidders more difficult to achieve.

A10.97 For example, strategic bidder A would not know if strategic bidder B was bidding in a way that was consistent with its assumed strategic investment approach. Therefore, an attempt by bidder A to engage in strategic investment could result in it incurring the costs of bidding above its intrinsic valuation and yet failing to prevent the intended victim(s) from winning spectrum - and so there would be no pay-off as there would not be a reduction in downstream competition. In such a case, bidder A would incur a loss from its failed attempt at strategic investment. The prospect of such losses tends to increase the costs to potential strategic bidders of engaging in coordinated strategic investment.

A10.98 The extent to which both the scope for free riding and the lack of information available during the auction can be effective in deterring strategic investment specifically for the 2.3 GHz spectrum alone is uncertain. Tacit coordination may be facilitated by the existence of a clear focal point for the division of spectrum in the auction between the operators with high spectrum shares currently. The existence of a clear focal point may make free riding less appealing as a strategy. However, it will not necessarily be clear to strategic investor B that strategic investor A is pursuing a coordinated rather than a unilateral strategy, given that it cannot directly observe its bids. A lack of certainty about this could make free riding more attractive to strategic investor B. On the other hand, the clearer the division of spectrum, the less need strategic investors will have of information during the Auction.

A10.99 In summary, there are difficulties and uncertainties about coordinated strategic investment, but they are materially reduced if there is a focal point that is sufficiently clear. In the case of the 2.3 GHz band, a candidate for such a clear focal point is 20 MHz each for BT/EE and Vodafone.

Vodafone & [REDACTED]

A10.100 Vodafone argued that it has lower incentive to engage in strategic investment partly because & [REDACTED] .

A10.101 & [REDACTED] .⁵⁸³

A10.102 & [REDACTED] .

Conclusion on the risk of strategic investment in 2.3 GHz alone

A10.103 There is a possibility that denying 2.3 GHz spectrum to particular operators may result in Competition Concern 1(a) relating to the first transitional period. Some bidders may therefore see a discernible pay-off from engaging in strategic investment.

A10.104 The cost and the risk involved with engaging in strategic investment may be insufficient to deter it in this band. We consider therefore that there is a material risk

⁵⁸³ & [REDACTED] .

of unilateral strategic investment by one bidder (most likely BT/EE), or tacitly coordinated investment between two strategic bidders (which seems to be facilitated by the existence of a clear division of spectrum amongst the two operators with the highest spectrum shares).

A10.105 Our conclusion is that the possibility of strategic investment in the 2.3 GHz band is a significant concern. We also conclude that Vodafone has significantly less incentive to engage in strategic investment in 2.3 GHz spectrum than BT/EE.

The risk of strategic investment specifically for 3.4 GHz spectrum - Competition Concern 1(c)

A10.106 The 3.4 GHz band may be important for the early launch of 5G services. Some bidders might, as a result, specifically target the 3.4 GHz spectrum to deny competitors access to an early route to 5G. Vodafone suggested such a possibility in its response. Our concerns about this have increased since the November 2016 consultation as our confidence that the 3.6-3.8 GHz spectrum will be useable at a similar time to the 3.4 GHz spectrum across the UK has diminished. Our concerns about 3.4 GHz spectrum specifically relate to the second transitional period before the 3.6-3.8 GHz spectrum is useable.

A10.107 For the purposes of assessing strategic investment motivated by Competition Concern 1(c), we assume that an operator will need to have at least 80 MHz of 3.4 GHz spectrum to launch a 5G service. As there is only 150 MHz of 3.4 GHz in the auction, this means that only one MNO can obtain 80 MHz in the Auction. However, H3G already holds 40 MHz, and so two operators could obtain at least 80 MHz, if H3G was one of them.⁵⁸⁴ From paragraph A10.118, we consider another scenario, where consumers place materially higher value on 5G services during the second transitional period, but it is possible to provide services with 40 MHz of 3.4 GHz that are sufficient, in the second transitional period, to compete strongly with an operator providing a 5G service with 80 MHz.⁵⁸⁵

A10.108 We illustrate the possible pay-offs and costs with a hypothetical scenario in which one MNO (other than H3G) engages in unilateral strategic investment to win 120 MHz of 3.4 GHz spectrum. This means that even H3G (which already has 40 MHz of 3.4 GHz) is unable to win 80 MHz of 3.4 GHz spectrum.

A10.109 We focus on unilateral strategic investment because if 80 MHz of 3.4 GHz spectrum is required, then coordinated strategic investment in the 3.4 GHz spectrum makes little sense, as there can anyway only be at most two such operators.

A10.110 We consider it unlikely that H3G would have an incentive to invest strategically in 3.4 GHz spectrum.⁵⁸⁶ First, its intrinsic value for a large block of 3.4 GHz spectrum

⁵⁸⁴ H3G currently holds two non-contiguous blocks of 20 MHz spectrum each in the 3.4 GHz band. By choosing to apply for a replacement licence, it has the option of including this spectrum in the assignment stage of the Auction to make these two blocks contiguous, along with any 3.4 GHz spectrum it obtains in the principal stage of the Auction.

⁵⁸⁵ Our analysis assumes that there is no need for guard bands between spectrum held by different operators. We discuss the potential need for guard bands for 5G services in annex 11 and consider that guard bands are unlikely to be needed for all 5G deployment configurations. In the event that guard bands were required, the costs of strategic investment would tend to decrease somewhat as less spectrum would be needed for foreclosure.

⁵⁸⁶ O2 has also argued that H3G may have an incentive to invest strategically in 2.3 GHz spectrum. O2 said that, following H3G's acquisition of UK Broadband, there is "a strategic value for H3G, in

is likely to be lower than its rivals, which increases the cost of strategic investment. Its intrinsic value for 3.4 GHz may be lower partly because H3G is the smallest operator in terms of subscriber market share which may reduce its ability to gain additional revenue from selling 5G (such as if this derives in part from up-selling 5G services to its existing customers). Its intrinsic value for a large block of 3.4 GHz (such as 80 MHz) is also likely to be lower because it already holds 40 MHz at 3.4 GHz (so may only need to win a further 40 MHz to achieve obtain 80 MHz) as well as a further 84 MHz at 3.6 GHz. It would need to outbid rivals with potentially high intrinsic values for a large amount of spectrum.

A10.111 Second, the pay-off that H3G may gain from preventing rivals from being able to launch 5G services early may be lower than for its rivals, due to its lower market share and the lower diversion ratios of customers switching to it.^{587, 588}

Potential pay-off from engaging in strategic investment in 3.4 GHz spectrum

A10.112 The potential pay-off from this scenario would be that there was one rather than two operators that could launch 5G services in the second transitional period (before the 3.6-3.8 GHz spectrum becomes useable).

A10.113 However, in our view, as set out in more detail in paragraph 6.94, the potential pay-off from such a strategy is reduced by the following considerations.

A10.114 **Duration of pay-off:** When the 3.6-3.8 GHz spectrum is useable for 5G mobile services (i.e. after the second transitional period), any pay-off from strategic investment in 3.4 GHz specifically is likely to fall away. It is also possible that 3.6-3.8 GHz will be useable at a similar time as the 3.4 GHz spectrum (i.e. the second transitional period could be short or even not exist at all). In addition, other spectrum bands that are already useable for 4G mobile are likely to become suitable for 5G in due course.

A10.115 **Size of pay-off:** Although the ability to offer 5G services may provide a significant competitive advantage from the outset, some responses to the November 2016 consultation suggested that 5G may represent a more evolutionary step from 4G. An operator that took this more evolutionary view might consider that the pay-off from strategic investment in 3.4 GHz was likely to be less significant.

addition to Vodafone, to block O2 at 2.3 GHz, and leaves O2 as the sole focal point for strategic bidding by BT/EE and/or Vodafone at 3.4 GHz" (see O2's supplementary submission of 4 April 2017). However, the potential pay-off from H3G strategically investing in 2.3 GHz spectrum will be lower than for Vodafone, which is in turn lower than BT's potential pay-offs. This is for the same reasons as we set out from paragraph A10.79 above when we describe why Vodafone's pay-off is lower than BT's.

⁵⁸⁷ For example, in the GfK survey data provided by Vodafone, 3< [REDACTED] .

⁵⁸⁸ A further possible consideration for H3G is the potential linkage between bids and prices in the Auction for 3.4 GHz and annual licence fees for its existing spectrum in that band. In our statement on the Variation of UK Broadband's 3.4 GHz Licence, 9 October 2014

(https://www.ofcom.org.uk/data/assets/pdf_file/0018/74610/uk_broadband_statement.pdf), we said that this licence for existing spectrum will be subject to an annual fee after the expiry of the initial term in July 2018. We noted that we would consider the level of this fee nearer the time, but that the bids and prices indicated in the 3.4 GHz award were expected to provide a good indication of the opportunity cost of spectrum at the time of the auction (see paragraphs 15.9-15.10). As such, H3G may be reluctant to push the price of 3.4 GHz above intrinsic value because of the risk this could lead to higher annual licence fees for its existing spectrum in that band.

Cost of engaging in strategic investment in 3.4 GHz spectrum

A10.116 If the operator had a high intrinsic value for 100 MHz of 3.4 GHz (for example, because it wanted to launch 5G with the maximum speed possible), it would only need to obtain an extra 20 MHz to achieve its strategic objectives, and the cost of strategic investment may not be large (though obtaining the extra 20 MHz may push up the price for the other 100 MHz of 3.4 GHz).

Conclusion on the risk of strategic investment specifically for 3.4 GHz spectrum

A10.117 We conclude that there is some risk of there being an incentive to engage in strategic investment for the 3.4 GHz spectrum specifically, but that it is uncertain. The costs to an operator of engaging in strategic investment for 3.4 GHz specifically may not be large, for example, if a single operator had a high intrinsic value for a large amount of 3.4 GHz, such as 100 MHz. However, the incentive to engage in strategic investment for 3.4 GHz specifically is reduced because of the potential limitations on the duration and size of the pay-off.⁵⁸⁹

Strategic investment in 3.4 GHz if 40 MHz were sufficient to compete strongly with 5G

A10.118 We have set out from paragraph A11.153 that we believe that 80 MHz is sufficient to offer a 5G service. However, here we consider the implications if consumers place materially higher value on 5G services during the second transitional period, but it were possible to provide services with 40 MHz of 3.4 GHz spectrum that were sufficient to compete strongly in the second transitional period against a rival offering 5G services with 80 MHz of 3.4 GHz. This is because even though a 5G service could not be offered with only 40 MHz of 3.4 GHz spectrum, it would be possible to deploy the new 5G radio interface and latest antenna techniques to offer improved customer experience.

A10.119 H3G already has 40 MHz of 3.4 GHz spectrum, so in this scenario it would be able to offer services that could compete strongly with 5G services during the second transitional period even if it did not win spectrum in the Auction. This tends to reduce the potential gains from strategic investment by other operators in 3.4 GHz specifically, as there would always be at least two operators (assuming it was not H3G that was engaging in the strategic investment for the reasons set out from paragraph A10.110 above).

A10.120 There may nevertheless be some pay-off from strategic investment, if the investment reduced the number of operators who could provide services that could compete strongly with 5G during the second transitional period. For example, one scenario may be unilateral strategic investment to obtain 80 MHz of 3.4 GHz spectrum, leaving 70 MHz for others in the Auction. This would mean that there would be at most three operators in the second transitional period who could

⁵⁸⁹ Our conclusion is different from our view in the November 2016 consultation that strategic investment was unlikely for 3.4 GHz specifically. The reasons for the different conclusions are: (i) greater recognition that at least 80 MHz is likely to be needed to meet the 5G standard, meaning that some operators may have high intrinsic value for a large block of 3.4 GHz, tending to reduce the cost of strategic investment; and (ii) there is a greater risk of a payoff in the second transitional period, because we are less confident that the 3.6-3.8 GHz band will become useable at around the same time as the 3.4 GHz band.

provide services with at least 40 MHz of 3.4 GHz spectrum (one of which would be H3G).

A10.121 Even if 40 MHz were sufficient to provide a service that could compete strongly with 5G, there may be some benefits from winning 80 MHz and launching a real 5G service. This would raise the intrinsic value from obtaining 80 MHz, tending to reduce the cost of strategic investment.

A10.122 While the costs of strategic investment may be lower, the pay-offs of strategic investment may also be lower (as there are more operators able to compete strongly with 5G services in this scenario) and the pay-offs would anyway still have limitations for the reasons set out above.

A10.123 In this scenario, we also conclude that there is some risk of there being an incentive to engage in strategic investment for the 3.4 GHz spectrum specifically, but that it is uncertain.

Risk of strategic investment for 2.3 GHz and 3.4 GHz spectrum together - Competition Concerns 1(b) and 2

A10.124 We now discuss the potential for strategic investment related to the whole of the 2.3 GHz and 3.4 GHz spectrum available in the auction. This relates to Competition Concerns 1(b) and 2, as well as the motivations considered above for strategic investment in each band individually. In order to deny a relevant amount of spectrum to other bidders in the 2.3 and 3.4 GHz auction, strategic investment would potentially need to involve winning a large amount of spectrum.

A10.125 For illustration, as in the November 2016 consultation, we provide three possible scenarios of strategic investment when the whole 190 MHz in the auction is considered:

- Scenario 1: A unilateral strategic investor winning 40 MHz at 2.3 GHz and at least 135 MHz at 3.4 GHz, which denies any 2.3 GHz and a 20 MHz block of 3.4 GHz in the Auction to any of its competitors
- Scenario 2: A unilateral strategic investor winning 40 MHz at 2.3 GHz and at least 115 MHz at 3.4 GHz, which denies any 2.3 GHz to competitors and denies a 20 MHz block of 3.4 GHz in the Auction to more than one of its competitors⁵⁹⁰
- Scenario 3: Two tacitly coordinating strategic investors each jointly winning 20 MHz of 2.3 GHz and dividing the 3.4 GHz spectrum between them, denying any spectrum to the other MNOs (or new entrants).⁵⁹¹

A10.126 After discussing these three scenarios, we consider the implications if bidders' preferences exhibit strong value complementarities for blocks of 40 MHz or more in the 3.4 GHz band and 20 MHz blocks in the 2.3 GHz band – and, as a result, there is a perception that there are six blocks of spectrum available in the auction.⁵⁹²

⁵⁹⁰ If the intended victim(s) of the strategic investment needed 40 MHz to avoid being weakened as competitor(s), the amounts a unilateral strategic investor would need to win in scenarios 1 and 2 would be 155 MHz and 115 MHz respectively.

⁵⁹¹ < [REDACTED] .

⁵⁹² < [REDACTED] .

Potential pay-off from engaging in strategic investment for 2.3 GHz and 3.4 GHz spectrum

A10.127 We have described above the potential pay-offs in the first transitional period from excluding O2 and H3G from 2.3 GHz spectrum (relating to Competition Concern 1(a)), and the potential pay-off in the second transitional period from reducing competition in the early launch of 5G services from strategic investment in 3.4 GHz spectrum (relating to Competition Concern 1(c)). These potential pay-offs may also be relevant when considering the incentives for strategic investment for all the spectrum together.

A10.128 In addition, there may also be pay-offs resulting from our Competition Concerns 2 and 1(b).

A10.129 For Competition Concern 2 (the risk of there ceasing to be four credible MNOs), we set out in section 6 that H3G is likely to remain credible in the longer term even if it does not obtain spectrum in this award because of its acquisition of UK Broadband with its 3.4 GHz and 3.6-3.8 GHz spectrum. BT/EE and Vodafone already have strong spectrum holdings, sufficient for them to remain credible competitors even if they do not obtain any spectrum in this award.

A10.130 However, in our view there is a risk that O2 would cease to be a credible operator after the first transitional period if it did not obtain any spectrum (we do not consider that O2 needs spectrum to remain credible in the first transitional period). If O2 were to cease to be credible, the pay-off to other MNOs could be very considerable. But even if O2 needs additional spectrum to be credible, it is uncertain that excluding O2 from spectrum in this Auction would be sufficient to ensure it ceases to be credible. This is because O2 will have further opportunities to obtain spectrum in the 700 MHz and 3.6-3.8 GHz bands (useable in the second transitional period and the longer term respectively), as well as any other future spectrum releases.

A10.131 For Competition Concern 1(b) (the risk of weaker competition from very asymmetric shares of spectrum overall), if O2 does not obtain spectrum in this award, it may be vulnerable to being a weaker competitor in the second transitional period, if the 3.6-3.8 GHz spectrum is not useable within the same timeframe as the 3.4 GHz spectrum. While O2 may be able to obtain 700 MHz useable in the second transitional period, given the amount of 700 MHz spectrum, it may be a weaker competitor than if it obtained spectrum in the Auction. When the 3.6-3.8 GHz spectrum becomes useable, O2 may be able to obtain some of that spectrum.

A10.132 The threat of weaker competition due to O2 not being able to obtain spectrum is highest with scenario 3 in which O2 would obtain no spectrum. Next is scenario 1 in which O2 could obtain at most 15 MHz of 3.4 GHz. The risk of O2 being a weaker competitor is further reduced in scenario 2 in which O2 could obtain 20 MHz or more.

A10.133 H3G is less vulnerable to being a victim in the second transitional period and the longer term because of the spectrum it has from its purchase of UK Broadband. In the second transitional period, with its 40 MHz of 3.4 GHz spectrum, if it does not win any additional spectrum it will have 14% of useable spectrum. This compares to 10% based on its spectrum holdings at the time of the November 2016 consultation, before its purchase of UK Broadband. However, this spectrum share does not eliminate any vulnerability to being a weaker competitor in the second transitional period. In the longer term, when its 84 MHz of 3.6-3.8 GHz spectrum will be

useable, H3G will have 19% of useable spectrum (e.g. more than Vodafone's share based on its current holdings) and is not an obvious victim.

A10.134 On balance, we believe there are potential pay-offs from engaging in strategic investment for the 2.3 GHz and 3.4 GHz spectrum together that could be significant. There is a possibility of weakening competition in both the first transitional period (related to 2.3 GHz specifically) and the second transitional period (related to spectrum overall and in relation to early 5G services).

A10.135 However, the potential pay-offs from weakening rivals are still limited by there being other spectrum available in the future. For example, the future useability of 700 MHz mitigates the size of the potential pay-offs in the second transitional period as does the useability of the 3.6-3.8 GHz in the longer term. The certainty of the pay-offs is also reduced by the possibility that the 3.6-3.8 GHz spectrum may be useable at a similar time to the 3.4 GHz spectrum.

Cost of engaging in strategic investment for 2.3 GHz and 3.4 GHz spectrum

A10.136 The cost and the risk associated with winning all or almost all of the spectrum available in the 2.3 GHz and 3.4 GHz auction is likely to be high. The 2.3 GHz and 3.4 GHz auction will include 190 MHz of mobile spectrum (40 MHz at 2.3 GHz and 150 MHz at 3.4 GHz). This represents more than 20% of total mobile spectrum (of 836.9 MHz).

Unilateral strategic investment

A10.137 Given the amount of spectrum available, a unilateral strategic investor would need to pay not only above its own intrinsic valuation, but also above the intrinsic value of the potential victim, for a large amount of excess spectrum it would possibly not need. For example, under scenario 1, the strategic investor acting on its own would need to win at least 175 MHz, and, even under scenario 2, at least 155 MHz.

A10.138 First, the cost of strategic investment may be reduced if the strategic investor had a high intrinsic value for 80 to 100 MHz of 3.4 GHz spectrum because it wanted to launch 5G services. For example, in scenario 1 the strategic investor needs to win 135 MHz of 3.4 GHz and in scenario 2 it needs to win 115 MHz. If it anyway had a large intrinsic value for 80 MHz or 100 MHz, it would need to win an additional 35 MHz or 15 MHz in 3.4 GHz. However, although this might reduce the cost of strategic investment, obtaining the extra 3.4 GHz spectrum would tend to push up the price for the other 80 MHz or 100 MHz of 3.4 GHz.

A10.139 The cost of this is likely to be more substantial compared to when considering strategic investment in only the 3.4 GHz band specifically. This is because the victims would need to be excluded from both 2.3 GHz and 3.4 GHz.

A10.140 Second, as we noted when we looked at the cost of strategic investment specifically for the 2.3 GHz band, if one or more potential victim operators require capacity spectrum to remain strong competitors, their intrinsic value is likely to be high relative to other operators. If O2 considered there were a risk to its credibility if it did not obtain spectrum in this auction, its intrinsic value for spectrum would be very high and the cost of strategic investment would consequently be very high. Winning almost all the spectrum would also involve excluding rivals that may have high valuations for 80 MHz of 3.4 GHz spectrum for an early launch of 5G deployment.

A10.141 Therefore, the large volume of spectrum in the 2.3 GHz and 3.4 GHz award and the potentially high intrinsic value of other bidders both tend to increase the cost to any bidder engaging in strategic investment

A10.142 Third, we consider that the specific features of the auction format we have chosen for the 2.3 GHz and 3.4 GHz auction should increase both the cost and the risk associated with strategic investment when all the spectrum available in the auction is considered, as opposed to only the 2.3 GHz band. The three features of the auction design described above are particularly relevant when considering strategic investment in the 2.3 GHz and 3.4 GHz spectrum together. Those three features are as follows:

- a) Uniform price rule. The quantity of spectrum for which the strategic bidder may have a high intrinsic value is likely to be small compared to the overall spectrum available. By bidding for a large quantity of spectrum, like in scenario 1 or 2, the bidder is likely to be pushing up the price in both bands and, in the process, reducing the gains it would otherwise enjoy from a lower price. In addition, if the victim requires a small amount of spectrum relative to the total amount available, the unilateral strategic investor may potentially incur a significantly large sum due to the multiplier effect. On the other hand, these effects could be mitigated in the 3.4 GHz band if the strategic bidder and victim operator have a significant intrinsic value for a large block for 5G. In general, as we noted earlier in this annex, the existence of strong value complementarities by the strategic investor and victim operator can each reduce the effect of the uniform price rule.
- b) Risk of being stranded. The strategic bidder in scenarios 1 and 2 would need to bid in both bands simultaneously to achieve its goal. This means that the risk of being stuck as a partial standing high bidder at a price that exceeds its intrinsic valuation, when it would like to stop bidding, is higher than if it was bidding in a single band. The existence of predictable strong value complementarities from other bidders may reduce this risk. However, it is unclear how much a strategic investor could rely on other bidders' exhibiting predictable complementarities. This might be the case particularly for 3.4 GHz, as there are several different possible sources or types of value complementarities.
- c) Information policy. The limited amount of information will make it riskier to engage in strategic investment, especially if attempting to acquire access to less spectrum than in scenario 1 or 2 through targeting a victim operator. In particular, strategic investors will not know for sure in which band the intended victim(s) would be bidding and whether or not they were being successfully foreclosed.

A10.143 These features do not rule out the possibility of strategic investment, but they are relevant because they tend to reduce the likelihood of it occurring.

Co-ordinated strategic investment

A10.144 We now look at the possibility of coordinating strategic investment (such as in scenario 3). We believe coordination would be challenging to achieve when all the spectrum is considered.

A10.145 There are the general points for coordinated strategic investment discussed above, such as the inherent uncertainties about the costs and pay-offs, and the potential

for free riding or failing to coordinate successfully, leading to a risk of a strategic bidding making a loss by incurring the cost but obtaining no pay-off.

A10.146 There are also considerations that apply for strategic investment related to all the spectrum in the Auction:

- As noted in relation to 2.3 GHz spectrum in isolation, the information policy will make coordination difficult, and more so when all the spectrum is considered. Any assumption a particular strategic bidder might make about the way other bidders are bidding with whom it is seeking to coordinate, or alternatively whom it is trying to target, is subject to a significant degree of risk.
- When all the spectrum is considered, one possible focal point for the 3.4 GHz spectrum may be an even split of 75 MHz each for two strategic bidders. However, especially if there are strong value complementarities for large blocks there may not be a clear focal point, as we discuss below.
- Even if there were a clear focal point for the division of the spectrum, it might still involve a substantial cost to the bidders engaging in coordinated strategic investment. If for example BT/EE and Vodafone each acquired access to half of the spectrum in the Auction, 95 MHz of spectrum, BT/EE would increase its holdings by 37% and Vodafone by 54%.

Coordinated strategic investment in the presence of strong value complementarity for large blocks

A10.147 There are mixed views on whether there is strong value complementarity for large blocks of 3.4 GHz spectrum. While some of the more recent evidence submitted by stakeholders points towards value complementarities, other stakeholders are of the view that such complementarities are less relevant.⁵⁹³ We consider the implications of two scenarios below:

- a) High value for 80 MHz of 3.4 GHz spectrum; and
- b) High value for 40 MHz of 3.4 GHz spectrum.

A10.148 We focus on the costs, as value complementarities are likely to affect the costs and risks rather than the pay-offs of strategic investment. In particular, complementarities could make a difference in terms of the focal point for coordinated strategic investment.

A10.149 High value for 80 MHz: We describe in annex 11, having considered stakeholder responses and the latest industry developments, that we believe an MNO will need at least 80 MHz to offer a 5G service. This might mean the value of winning 80 MHz is significantly higher than the value of winning a smaller quantity. If this is the case, then an even split of the 150 MHz of 3.4 GHz in the Auction (with each obtaining 75 MHz) may not be attractive for bidders. This division of spectrum would mean that

⁵⁹³ For example, NERA argues that “Bidders can also be expected to have strictly declining marginal values for incremental spectrum, based on its role in alleviating capacity constraints (we view any premium for large contiguous blocks for 5G as small compared to capacity values)” (Page 115, NERA report). In contrast, H3G argues that “[REDACTED]” (Page 126, H3G’s response). We discuss the available evidence on value complementarities in more detail in annex 9.

neither of the strategic bidders attempting to coordinate would win the higher-value 80 MHz amount.

A10.150 Another possible focal point might be for one operator to win 80 MHz and the other 70 MHz. However, it may not be clear which operator would aim for 80 MHz and which would have to settle for the lower-value 70 MHz, especially if there is a significant difference in the value of having 80 MHz compared to 70 MHz. A further possible focal point is one strategic bidder win 100 MHz and the other 50 MHz, but again there is question of which obtains the much higher-value 100 MHz block and which the lower-value 50 MHz.

A10.151 High value for 40 MHz: If there are strong preferences for blocks of 40 MHz of 3.4 GHz spectrum, then there might effectively be four units or less of 3.4 GHz spectrum in the auction: three units of 40 MHz each and one smaller unit of 30 MHz. If we also consider that the 2.3 GHz spectrum might be won in two blocks of 20 MHz, this would mean there would effectively be six units of spectrum in the auction, two at 2.3 GHz and four at 3.4 GHz.

A10.152 In this scenario, if two operators were to coordinate with six units in the auction, there could be a focal point of three units each, and if three operators were to coordinate, there could be a focal point of two units each. However, having two different types of spectrum (i.e. 2.3 GHz spectrum and 3.4 GHz spectrum) combined with the limited information available during the auction, would complicate any arrangement. There could be uncertainty between those engaging in strategic investment in terms of who was bidding for 2.3 GHz and who was bidding for 3.4 GHz spectrum, and the cost and risk may not fall evenly on them (although each winning one unit in 2.3 GHz and two units in 3.4 GHz would be an equal split, subject to the discussion below).

A10.153 There is also a specific issue with the 3.4 GHz spectrum. If the complementarities in intrinsic value meant there was a strong preference for 40 MHz blocks of 3.4 GHz spectrum, the fact that the 3.4 GHz spectrum cannot be neatly divided up into four blocks would be significant. There can only be three blocks of 40 MHz and one smaller block of 30 MHz (given the 150 MHz of spectrum in the Auction). With strong preferences for blocks of 40 MHz, then the average value (per 5 MHz lot) of a 30 MHz block may be substantially lower than for a 30 MHz block. This difference in value may make a coordinated outcome where two operators are each assumed to obtain two blocks of 3.4 GHz harder, as the split could not be even. One operator may end up paying only a little less than the other operator (as paying for 14 lots, 70 MHz, rather than 16 lots, 80 MHz), but may have much lower value spectrum.

A10.154 In general, a lack of certainty about the existence or nature of complementarities, which could be different for different bidders, and the range of possibilities involving block sizes both larger and smaller than 40 MHz, make the focal point for any intended coordinated strategic investment less clear-cut.

Conclusion on the risk of strategic investment in 2.3 GHz and 3.4 GHz spectrum together

A10.155 The potential pay-offs from engaging in strategic investment in the 2.3 GHz and 3.4 GHz spectrum together could be significant. There is a possibility of weakening competition in both the first transitional period (related to 2.3 GHz specifically) and the second transitional period (related to spectrum overall and in relation to early 5G services).

A10.156 However, the costs and risks of engaging in strategic investment for all or almost all of the spectrum are also likely to be high. The cost of unilateral strategic investment would be likely to be high, given the large amount of spectrum that would need to be won. On the other hand, the high cost is reduced somewhat if the strategic bidder has significant intrinsic value for a large block of 3.4 GHz, such as 100 MHz. We conclude that unilateral strategic investment for the spectrum overall is relatively unlikely.

A10.157 While coordination may allow bidders to reduce the individual costs of strategic investment, coordination is made more difficult because there is not necessarily a clear focal point and because the individual costs associated with it are still likely to be high. We conclude that there is some risk that there may be an incentive to engage in coordinated strategic investment for the spectrum overall, but it is uncertain.⁵⁹⁴

The risk of strategic investment taking place under Ofcom's competition measures

A10.158 We now assess the scope for strategic investment under the competition measures we are imposing in the Auction: a cap of 255 MHz on immediately useable spectrum and a cap of 340 MHz on spectrum overall. We do so by comparison with the scenario where we do not impose any competition measures.

A10.159 With these competition measures, and on the basis of current holdings, BT/EE would be unable to bid for 2.3 GHz spectrum and would only be able to bid for at most 85 MHz of 3.4 GHz. Taking account of lot sizes, Vodafone would be restricted to 160 MHz in any combination of 2.3 GHz and 3.4 GHz. All other bidders would be unconstrained on both bands.

Scope for strategic investment in 2.3 GHz

A10.160 The 255 MHz cap on immediately useable spectrum addresses what we see as the greatest risk of strategic investment in the 2.3 GHz spectrum because BT/EE would not be able to win 2.3 GHz spectrum.

A10.161 It is possible that Vodafone might face lower risk if it unilaterally engaged in strategic investment for the whole of 2.3 GHz spectrum, compared to if there were no competition measures. This is because it would know for sure that it would not be bidding against BT/EE. It would know that, if successful, it would deny immediately useable spectrum to O2 and/or H3G.

A10.162 However, as we noted in the above (from paragraph A10.79), Vodafone is likely to have significantly less pay-off to gain from weakening its competitors than BT/EE.

A10.163 Absent BT/EE in the Auction for 2.3 GHz spectrum, a coordinated strategic investment outcome appears unlikely. This implies that all the costs of engaging in strategic investment would fall on Vodafone. Strategic investment by Vodafone would involve outbidding other operators with potentially much higher intrinsic value for some of the spectrum in the 2.3 GHz band.

⁵⁹⁴ This conclusion is different from our view in the November 2016 consultation for similar reasons as noted above in relation to strategic investment for 3.4 GHz specifically (see footnote 589).

A10.164 Overall, we conclude that, compared to no competition measures, with the 255 MHz cap on immediately useable spectrum:

- The risk of unilateral strategic investment by BT/EE is addressed;
- The risk of coordinated strategic investment is likely to be addressed; and
- While the risk of unilateral strategic investment by Vodafone is not removed, we consider that Vodafone's incentives are significantly lower than BT/EE's would have been.

Scope for strategic investment 3.4 GHz specifically

A10.165 When considering the 3.4 GHz spectrum specifically, we are primarily concerned about unilateral strategic investment. For example, when we consider operators obtaining 80 MHz of 3.4 GHz to launch 5G services, there can be at most two such operators, so coordinated strategic investment makes little sense.

A10.166 By capping BT/EE at 85 MHz of 3.4 GHz spectrum, our competition measures reduce the risk of BT/EE engaging in unilateral strategic investment in 3.4 GHz spectrum to prevent a rival obtaining 80 MHz. Whilst some unilateral strategic investment possibilities remain, BT/EE's ability to implement others is removed. For example, even if BT/EE obtained 85 MHz of 3.4 GHz spectrum, there would be 65 MHz remaining in the Auction. Combined with its existing 3.4 GHz spectrum, H3G would be able to obtain 80 MHz. Our competition measures do not affect the risk of unilateral strategic investment by other MNOs.

Scope for strategic investment in 2.3 GHz and 3.4 GHz together

A10.167 The combined effect of the cap on immediately useable spectrum and the overall cap is that BT/EE will no longer be able to engage in unilateral strategic investment for all the spectrum in the Auction, as it is restricted to at most 85 MHz of 3.4 GHz spectrum. Vodafone is prevented from winning more than 160 MHz, meaning there would still be 30 MHz of spectrum in the auction that it could not bid for. Given the likely high costs and Vodafone's significantly lower pay-off, in our view unilateral strategic investment for the 2.3 GHz and 3.4 GHz spectrum together is unlikely. In our view, therefore, the risk of unilateral strategic investment is likely to be addressed by our competition measures.

A10.168 The two caps might have effects in both directions on coordinated strategic investment by BT/EE and one or two other operators:

- On the one hand, they could make coordinated strategic investment easier in the sense of potentially reducing uncertainty over a focal point.
- On the other hand, the caps could change the division of the costs of strategic investment because BT/EE can acquire access to less spectrum. For example, if we consider coordinated strategic investment by Vodafone and BT/EE, then Vodafone would have to incur higher costs because of the caps, when it has less to gain than BT/EE.

A10.169 On the first of these, relating to the focal point, the caps may make the focal point for 2.3 GHz spectrum clear, given BT/EE is prevented from acquiring access to any. If there were one other strategic investor, it would know that to prevent rivals with

weaker spectrum holdings from obtaining any (or much) spectrum it would need to win all (or most) of the 2.3 GHz spectrum.

A10.170 The situation with 3.4 GHz is also simplified, in that the other strategic investor, such as Vodafone, could not rely on BT/EE obtaining more than 85 MHz of 3.4 GHz spectrum. This might mean that a potential focal point was for BT/EE to obtain 85 MHz of 3.4 GHz, with Vodafone obtaining all 40 MHz of 2.3 GHz spectrum (which BT/EE cannot bid for) and the remaining 65 MHz of 3.4 GHz (or a smaller amount if a rival would obtain little value from a small block of 3.4 GHz).

A10.171 However, this is not the only potential focal point. For example, if there were advantages in having 20 MHz units of 3.4 GHz spectrum, it may make more sense for BT/EE to seek to obtain 80 MHz and for Vodafone to obtain 70 MHz (or 60 MHz). Also, Vodafone may prefer a scenario where it had 80 MHz of 3.4 GHz and BT/EE had 70 MHz, if there is a large additional value from having 80 MHz of 3.4 GHz for providing 5G services. Therefore even though BT/EE is capped at 85 MHz, there may still be some uncertainty over the focal point for 3.4 GHz.⁵⁹⁵

A10.172 Even if the caps were to make a focal point clearer, the caps could also change the division of the costs between strategic investors. For example, we consider a scenario where Vodafone obtains all (or most) 2.3 GHz spectrum as well as a large block of 3.4 GHz spectrum. This would increase the costs to Vodafone of coordinated strategic investment compared to a more even split of spectrum between Vodafone and BT/EE. The risks for Vodafone of engaging in such coordinated strategic investment would be high, because it would be incurring high costs without certainty that BT/EE was also doing its part to achieve the strategic investment outcome. While the costs and risks to Vodafone would increase (and be higher than for BT/EE), Vodafone is likely to have a significantly lower pay-off than BT/EE from weakened competition, as described from paragraph A10.79.

A10.173 On balance, taking account of both effects, in our view, it is not clear that the incentive to engage in coordinated strategic investment either increases or reduces with our competition measures compared to without them.

A10.174 Overall, we conclude that, compared to no competition measures, with both the 255 MHz cap on immediately useable spectrum and the 340 MHz overall cap:

- The risk of unilateral strategic investment is likely to be addressed; and
- On balance, it is not clear that the risk of coordinated strategic investment either increases or reduces.

⁵⁹⁵ A focal point could involve coordination between three operators rather than two. < [REDACTED] . The caps we are proposing do not prevent this outcome. However, as we discuss in annex 9, we have concerns with the analysis suggesting this is a focal point, including that it does not take account of H3G's acquisition of UK Broadband.

Annex 11

Summary of other responses to our November 2016 competition assessment and Ofcom's comments

A11.1 This annex considers consultation responses under the following headings:

- Summary of MNOs' proposals for measures in the auction (from A11.3)
- Basis for intervention if four credible MNOs (from A11.4)
- Extreme asymmetry of spectrum holdings might harm competition (from A11.23)
- Consideration of spectrum shares by volume or value (from A11.51)
- Unused or underused spectrum by BT and Vodafone (from A11.64)
- Relevance of H3G's and Vodafone's purchase of 1400 MHz spectrum (from A11.77)
- Drivers of intrinsic value for additional spectrum (from A11.81)
- Enduring competitive advantages and experience of VHA in Australia (from A11.109)
- Use of a threshold price before competition measures apply (from A11.124)
- Strategic investment in other auctions (from A11.133)
- Use of 3.4 GHz spectrum for 5G (from A11.146)
- Use of 3.4 GHz for Fixed Wireless Access and regional licences (from A11.162)
- Coverage obligations (from A11.172)
- Ofcom letter to the European Commission in the context of the proposed H3G/O2 merger (from A11.182)

A11.2 Other responses are considered in separate annexes. For example, in annex 3 we discuss the timing of the availability of different bands and in annex 8 we discuss the future credibility of different MNOs.

Summary of MNOs' proposals for measures in the Auction

A11.3 Figure 11.1 below summarises the proposals for measures in the auction from the MNOs. We show separately the proposals from H3G UK and from Hutchison Europe. We set out views on these proposals in section 7 of the main document.

Figure A11.1 Summary of MNOs' proposals for measures in the Auction

MNO	2.3 GHz	3.4 GHz	Overall cap	Implications
BT/EE	No measure	No measure	No measure	No restrictions on any bidder
Vodafone	255 MHz cap on immediately useable spectrum, as proposed by Ofcom	80 MHz safeguard cap on all	No measure	<ul style="list-style-type: none"> 2.3 GHz: BT/EE excluded 3.4 GHz: every bidder limited to at most 80 MHz
O2	Tighter cap to exclude BT/EE and limit Vodafone to 20 MHz (and NERA report for O2 proposes different ways of achieving this)	No specific cap on 3.4 GHz (while NERA report for O2 proposes 100 MHz cap on 3.4 GHz)	35% of spectrum, where 700 MHz excluded from calculation, implying a cap of around 290 MHz	<ul style="list-style-type: none"> 2.3 GHz: BT/EE excluded and Vodafone limited to 20 MHz 3.4 GHz: BT/EE limited to 35 MHz, and Vodafone to 115 MHz⁵⁹⁶ Either band: BT/EE limited to 35 MHz, Vodafone to 115 MHz, H3G to 160 MHz and no restriction on O2
H3G UK	Spectrum reservation of 20 MHz for H3G or new entrants	Spectrum reservation of 40 MHz for H3G or new entrants	30% of spectrum, where 700 MHz excluded from calculation, representing cap of 255 MHz	<ul style="list-style-type: none"> 2.3 GHz: BT/EE excluded, O2 and Vodafone individually and between them limited to 20 MHz. Only H3G or new entrants could acquire access to all 40 MHz 3.4 GHz: BT/EE excluded, Vodafone limited to 75 MHz, H3G to 125 MHz⁵⁹⁷, and O2 not limited Either band: BT/EE excluded, Vodafone limited to at most 75 MHz, H3G to 125 MHz and O2 to 165 MHz
Hutchison Europe	Two lots of 10 MHz each reserved for H3G, O2 or new entrant, with requirement that reserved lots purchased by different buyers BT/EE excluded from 2.3 GHz	No measure	30% of spectrum as per H3G UK proposal	<ul style="list-style-type: none"> 2.3 GHz: BT/EE excluded, Vodafone limited to 20 MHz, O2 and H3G individually limited to 30 MHz 3.4 GHz: BT/EE excluded, Vodafone limited to 75 MHz, and H3G to 125 MHz⁵⁹⁸ Either band: BT/EE excluded, Vodafone limited to 75 MHz, H3G to 125 MHz and O2 to 165 MHz

⁵⁹⁶ This assumes that Vodafone does not win spectrum in the other band, 2.3 GHz. The limit across both bands is shown in the next bullet point. We adopt this approach for all MNOs in this table.

⁵⁹⁷ Or the limit would be 105 MHz if it won the reserved 20 MHz in 2.3 GHz.

⁵⁹⁸ Or the limit would be 115 MHz if it won a reserved lot of 10 MHz in 2.3 GHz.

Basis for intervention if four credible MNOs

Summary of our position in November 2016 consultation

- A11.4 In the November 2016 consultation, we said that the current UK market for mobile services included four MNOs, and was supplemented by MVNOs which have access to the networks operated by the four MNOs through commercial arrangements. We also said that we considered the existence of at least four credible MNOs to be important for the UK mobile market.⁵⁹⁹
- A11.5 We considered that even if there remain four credible MNOs, there was a risk that competition between them could be weaker with some outcomes of the auction. We identified that a very asymmetric spectrum distribution that weakens competition, even where there are four credible MNOs, can be characterised by one or more MNOs with a very high share of spectrum compared with other companies in the market; and/or one or more MNOs with a relatively low share of spectrum compared with other companies in the market (whilst still having sufficient spectrum to enable them to be credible).⁶⁰⁰
- A11.6 In particular, we were concerned that a further concentration of immediately useable spectrum would mean that competition would be weaker than it would otherwise be. We considered that increased asymmetry in holdings of immediately useable spectrum may lead operators with small spectrum shares to compete less strongly, especially for specific customer segments, such as those high value consumers who demand consistently high data speeds. This could result in increased prices for those customers to moderate the increase in data traffic of such operators.⁶⁰¹

Summary of responses

- A11.7 BT/EE said that, if we considered it unlikely that any of the four MNOs would cease to be credible, there could be no basis for intervening. BT/EE argued that the test of whether operators are credible is necessary and sufficient in assessing the need for competition measures. It did not consider a “capability-plus” analysis to be justified unless Ofcom had concrete evidence that some factors are particular drivers of competition.
- A11.8 BT/EE also argued that Ofcom could only justify competition measures in the Auction following a detailed competition assessment of relevant retail and wholesale markets for the supply of mobile services.⁶⁰²
- A11.9 BT/EE dismissed our assessment on the adverse effects we considered may arise from weakened competition resulting from a very asymmetric distribution of spectrum—i.e. that some operators might struggle to compete for some services or certain customer segments. BT/EE argued that we had provided insufficient detail on how consumer harm might arise, to the extent that it was difficult for it to respond

⁵⁹⁹ Paragraphs 2.24 and 3.4 of the November 2016 consultation.

⁶⁰⁰ Paragraphs 4.21 to 4.28 of the November 2016 consultation.

⁶⁰¹ Paragraphs 4.8, 4.78 and 4.79 of the November 2016 consultation.

⁶⁰² Paragraphs 6 and 63, BT/EE response. BT/EE identified that Ofcom's duties do not specifically include the promotion of competition in relation to spectrum, but to promote competition in the provision of electronic communications services.

to our concerns.⁶⁰³ It said that the assessment appeared to be merely a hypothesis, and that a hypothesis concerning a risk to competition in the future was not sufficient to justify a significant market intervention.⁶⁰⁴

A11.10 In particular,

- **BT/EE argued that we should have defined the relevant market(s).** BT/EE noted that the CMA and EC have identified national markets for the supply of retail mobile services to end consumers. It said that the CMA concluded that there was no evidence to support a finding that customers would not switch between high and lower data allowances or speeds in response to a price rise. It said that a customer segment of the sort implied by Ofcom, which was entirely divorced from competition in the rest of the retail mobile market was highly unlikely to exist. It said that Ofcom should have regard to the economic literature on competition in differentiated markets, which it said means it is not necessary for all competitors to fully replicate range, quality and segment coverage in order for there to be effective competition.⁶⁰⁵
- **BT/EE argued that we had not sufficiently evidenced possibility of harm.** BT/EE said that we should have described what services an operator with a high spectrum share may be able to provide that would be unmatchable, and if such services were found to exist, to weigh their benefits against harm to consumers from lost competition.⁶⁰⁶

A11.11 BT/EE also argued that we ought to have established whether any operator was dominant in the relevant market in order to rely on the possibility of a weakening of competition through aggressive price cutting by operators with high spectrum shares.⁶⁰⁷ BT also said that Ofcom had no duty to promote competition in relation to spectrum.

A11.12 ✂ [REDACTED] .⁶⁰⁸

Ofcom's response

A11.13 As we set out above, our aim in light of our duties is to design the Auction in a manner that promotes competition to the benefit of consumers. Our competition concern is not (as BT appears to suggest) about competition in spectrum per se; rather, it is about very asymmetric shares of spectrum which lead to a weakening of competition in electronic communications services markets. This is consistent with our duty under section 3(2)(d) of the WTA 2006.

A11.14 We consider that even if four operators are credible, there could be a weakening of competition that justifies an intervention. As described in more detail in paragraphs A8.45 to A8.50 above, we consider an MNO is credible if it is able to exert an effective constraint on its rivals and so contribute to the overall competitiveness of the market. But just because there are four credible MNOs does not mean that all four are equally strong or that competition is as strong as it could be. We therefore

⁶⁰³ Paragraphs 60 to 65 and 69 BT/EE response.

⁶⁰⁴ Paragraphs 2, 35, 60, 61, 63, and 69 BT/EE response.

⁶⁰⁵ Paragraphs 60 and 61, BT/EE response.

⁶⁰⁶ Paragraph 62, BT/EE response.

⁶⁰⁷ Paragraph 72, BT/EE response. BT/EE also suggests that Ofcom believes a price cutting strategy could be used to sustain a coordinated agreement (see paragraph 70, BT/EE response).

⁶⁰⁸ Paragraph 2.11, ✂ [REDACTED] response.

consider it is meaningful to talk about competition being weaker than it might be even if there are four credible MNOs.

- A11.15 We also consider that we provided a sufficient level of detail to allow parties properly to assess and respond to our provisional conclusions on competition concerns. To be satisfied that there is a risk to strong competition for consumers, such that the measures proposed were appropriate, we identified – by way of example – a competition risk to high value users.⁶⁰⁹ We explained: (a) how the spectrum being auctioned is well suited to adding capacity; (b) the importance of capacity to MNOs; and our consequent view that (c) a very asymmetric distribution of spectrum could adversely affect the services offered to data-oriented consumers. We made clear that this reasoning formed the basis for our provisional decision, and we consider that we provided a sufficient level of detail to allow parties properly to assess and respond to these conclusions.
- A11.16 Moreover, regulators must often take decisions based on their assessment of future risks to competition – doing so based on their assessment of the facts, as available at the time.
- A11.17 Further, contrary to the suggestion of BT/EE, our intervention is not based on a theory of anticompetitive conduct by an MNO – such that would, for example, require a finding of dominance – but on the harm to consumers from a weakening of competition in the provision of mobile services.⁶¹⁰
- A11.18 Indeed, when considering competition measures in an auction, we do not consider it necessary to formally define the market. Our assessment is different to a market review, where a market is formally defined and an assessment made about whether a company has significant market power. This is because, in our view, and taking account of the economic literature on competition in differentiated markets, there is scope for competition concerns to arise due to differences in spectrum holdings and for there to be a sound basis for taking measures to promote competition in spectrum auctions even in the absence of separate markets for specific customer segments or a company being dominant or having significant market power (e.g. in the context of a non-collusive oligopoly). We consider that our competition assessment is consistent with a range of possible market definitions. Not relying on defining specific markets or assessing dominance / significant market power is consistent with how we (and other National Regulatory Authorities) have approached competition measures for other auctions.⁶¹¹

⁶⁰⁹ Contrary to the suggestion of BT/EE, we were not seeking to define high value users as a sub-market, but were instead using them, in effect, as an analytical tool in our assessment about the risk of an adverse effect *across services and/or consumer segments*. That is, if we found a risk to at least one consumer segment, then we could not be satisfied that there would be strong competition for all consumers post Auction, even where there are four credible MNOs.

⁶¹⁰ Cf. paragraphs 67 – 72, BT/EE response. Our identification of the possibility of aggressive price cutting by operators with high spectrum shares was included as another example of the potential weakening of competition that could arise from very asymmetric mobile spectrum shares.

⁶¹¹ See for example paragraph A3.39 of the statement for the 2013 auction.

https://www.ofcom.org.uk/_data/assets/pdf_file/0031/46489/statement.pdf

See also a summary of ComReg's (Irish NRA) approach to spectrum caps for the 3.6 GHz spectrum in section 5.5 of *Response to Consultation and Decision on Proposed 3.6 GHz Band Spectrum Award*, 11 July 2016, ComReg, <https://www.comreg.ie/publication-download/response-to-consultation-decision-on-proposed-3-6-ghz-band-spectrum-award>

- A11.19 We also note that the CMA and EC findings of a single retail market were partly based on supply side substitution considerations and not solely on demand-side substitution by consumers (as appears to be suggested by BT/EE).
- A11.20 While the CMA said that there is a national market for the supply of retail mobile telecommunication services, it also said that it had not found it necessary to conclude that a separate market exists for customers with specific types of demands for data allowances, data speeds or that the market should be segmented by types of network technology. Rather it took these factors into account in its competitive assessment where appropriate.⁶¹²
- A11.21 In its assessment for the proposed H3G/O2 merger, the EC considered there was a single retail market for mobile services, but recognised that there were different market segments within that retail market. This finding of a single retail market was partly based on supply side substitution, as the EC found that some services may not be substitutable on the demand site.⁶¹³
- A11.22 We set out in the November 2016 consultation our duties and our auction objectives, and have set these out again in section 2 of this statement. We have taken account of our duties in making decisions relating to this auction. As in the consultation, in this statement we have considered possible competition concerns that might arise from the award, and considered whether it is proportionate to take measures to address them. In considering this, we have taken account of the nature of the competition concerns we have identified, the likely effectiveness of measures in addressing those concerns, the risks associated with possible measures, and the various uncertainties that are an inevitable part of the assessment.⁶¹⁴

Extreme asymmetry of spectrum holdings might harm competition

Summary of our position in November 2016 consultation

- A11.23 In the November 2016 consultation, we considered that even if there remain four credible MNOs, there was a risk that competition between them could be weaker with some outcomes of the auction. In particular, we were concerned that a further concentration of immediately useable spectrum would mean that competition would be weaker than it would otherwise be.
- A11.24 We considered that increased asymmetry in holdings of immediately useable spectrum may lead operators with small spectrum shares to compete less strongly, especially for specific customer segments, such as those high value consumers who demand consistently high data speeds. This could result in increased prices for those customers to moderate the increase in data traffic of such operators.⁶¹⁵

⁶¹² Paragraphs 10.41 and 10.49 of the *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016, https://assets.publishing.service.gov.uk/media/56992242ed915d4747000026/BT_EE_final_report.pdf

⁶¹³ Paragraphs 269, 279, and 293, EC Decision, http://ec.europa.eu/competition/elojade/isef/case_details.cfm?proc_code=2_M_7612

⁶¹⁴ For where this is set out in the November 2016 consultation, see especially paragraphs 2.18 to 2.23 and 5.3 to 5.9. In this statement, see especially sections 6 to 7 and associated annexes.

⁶¹⁵ Paragraphs 4.8, 4.78 and 4.79 of the November 2016 consultation.

Summary of responses

- A11.25 Vodafone agreed with Ofcom's assessment in regard to our view on extreme asymmetry of immediately useable spectrum. It highlighted the prospect of an operator holding a very high share of useable spectrum and being able to offer superior services that cannot be matched. Such an operator could have a significant influence on the market.⁶¹⁶
- A11.26 BT/EE said that Ofcom provided no explanation for why an MNO with a very high share of spectrum might be able to offer such superior services that rivals would be unable to replicate them. BT/EE said that Ofcom's view that concentration of spectrum may give rise to a competition concern was speculative, and contrary to the conclusions of the CMA when it cleared the BT/EE merger.⁶¹⁷
- A11.27 BT/EE stated that Ofcom failed to explain why current levels of asymmetry are unproblematic but higher, more extreme levels, which could occur because of the auction, would be problematic. BT/EE stated that Ofcom needed to establish the threshold at which this would happen.⁶¹⁸
- A11.28 BT/EE said that Ofcom's argument that marginal costs are higher for an operator with a small spectrum share is flawed because it ignores the fact that spectrum holdings have an associated cost, either lump sum when acquired or as an ongoing charge. It noted that there is a cost to purchasing spectrum in an auction, which will be determined by the avoided cost of the next best alternative.⁶¹⁹
- A11.29 BT/EE also argued that asymmetric spectrum holdings may encourage greater product differentiation and that product differentiation can help disrupt coordinated behaviour.⁶²⁰
- A11.30 H3G argued that to maintain a four-player market structure, each MNO's spectrum share needs to be kept between a 20% floor and a 30% ceiling.⁶²¹
- A11.31 NERA (on behalf of O2) stated that there is greater concern about spectrum asymmetry and its consequences today than before as "exceptional growth in consumer demand for 4G data is placing unprecedented pressure on mobile networks".⁶²²
- A11.32 City Fibre stated that network design and planning can offset smaller spectrum holdings, but that a company holding twice the volume of spectrum of its competitors "always has an unassailable advantage".⁶²³
- A11.33 One respondent X [REDACTED] and ITSPA both highlighted how extreme asymmetry could be bad for competition and consumers – noting that BT/EE, with an increased spectrum share, could cause smaller MNOs (who are also hosts for MVNOs) to favour their own (MNO) customers, due to capacity constraints on their own networks. ITSPA stated this could unfairly discriminate against the MNVOs

⁶¹⁶ Page 14, Vodafone response.

⁶¹⁷ Paragraphs 5 and 60, BT/EE response.

⁶¹⁸ BT/EE response, paragraph 51.

⁶¹⁹ Paragraph 53, BT/EE response.

⁶²⁰ BT/EE response, paragraph 71.

⁶²¹ Page 3, H3G response.

⁶²² Page 6, NERA report (non-confidential version).

⁶²³ City Fibre response, page 2.

which the capacity-constrained MNOs are hosting, and “in other words, MVNOs would be squeezed out of the market and/or the beneficiary of an asymmetric holding would be a natural monopoly host MNO”.⁶²⁴

A11.34 ✂ [REDACTED] .⁶²⁵

A11.35 The Welsh Government asked Ofcom to consider exploring mechanisms to address the historic imbalances in spectrum distribution. It agreed with Ofcom that competition was important and that the current level of competition should be preserved or increased.

A11.36 The Farmers Union of Wales expressed concern that no caps were proposed in the 3.4 GHz band. It identified the poor experience of 4G supplied by BT/EE in Wales (currently covering 52% by geography) and said this should not be repeated for 5G. It considered an overall cap of 30% represented the best prospect.

A11.37 The ‘Make The Air Fair’ campaign argued that there should be a cap of 30% on the total share of spectrum that any one network operator could hold of relevant spectrum.⁶²⁶ The Countryside Alliance also argued for a 30% cap.

Ability to add capacity other than with additional spectrum

A11.38 Vodafone said that there are other ways of adding capacity and that not all future demand will be met via licensed spectrum. It said that over half of mobile data was offloaded to Wi-Fi in 2016, and that this is expected to rise to 60% by 2019. It also cited the future role of LTE-LAA and other methods (such as refarming current/future bands, out building out more masts, MIMO). Vodafone concluded “availability of spectrum is important to mobile providers, but it is far from being the only enabler of network capacity”.⁶²⁷

A11.39 BT/EE agreed with Ofcom that there are alternative ways of adding capacity aside from deploying more spectrum.⁶²⁸

A11.40 NERA stated that the scope for utilising alternative solutions to resolve capacity constraints is limited, arguing that O2 is already ✂ [REDACTED] , carrier aggregation and MIMO have limited material gains and that small cells are not a substitute for macrocells.⁶²⁹ It concluded ✂ [REDACTED] .⁶³⁰

A11.41 One respondent ✂ [REDACTED] argued in its response that asymmetry cannot be countered by other investment in a network, and highlighted the EC’s assessment in the merger of Orange and T-Mobile, which concluded that spectrum is the main determinant for capacity and that other investment options “are generally more costly”.⁶³¹

A11.42 H3G said MNOs cannot address a spectrum shortage through network investment, because it was neither feasible nor economical to do so. It said that MNOs need to

⁶²⁴ ITSPA response, page 1; ✂ [REDACTED] response, page 9.

⁶²⁵ ✂ [REDACTED] response, page 2.

⁶²⁶ https://www.ofcom.org.uk/data/assets/pdf_file/0028/98128/Make-The-Air-Fair.pdf

⁶²⁷ Page 11-12.

⁶²⁸ Paragraph 55.

⁶²⁹ Page 48-49.

⁶³⁰ ✂ [REDACTED]

⁶³¹ ✂ [REDACTED] .

keep sites and spectrum in balance, and that expanding capacity solely through network investment (with a given spectrum portfolio) yields rapidly diminishing returns.⁶³²

Ofcom's response

- A11.43 In annex 1 we discuss why we consider that competition is generally working well currently, despite the current degree of asymmetry in spectrum holdings.
- A11.44 In section 6, we set out our views on how asymmetry may affect competition in the future, having considered the arguments in responses. Regarding 3< [REDACTED] and ITSPA's responses on wholesale access, we note that our discussion in section 6 does not explicitly address incentives to provide wholesale access to MVNOs. However, we consider the same broad arguments apply to providing wholesale access as apply to retail competition. We do not consider that MNOs need to have the same, or close to the same, shares of spectrum for there to be strong retail competition or wholesale competition to provide MVNO access. However, we are concerned that retail and wholesale competition could be weaker in the future if shares are very asymmetric.
- A11.45 We explain in annex 12 why we disagree with BT/EE's view that our conclusions are contrary to the conclusions of the CMA when it cleared the BT/EE merger. In response to BT/EE's complaint that our assessment is speculative, we have set out above why we consider our assessment appropriate given our duties.
- A11.46 In annex 6 we discuss how, to some extent, capacity can be added through network investment rather than using additional spectrum.
- A11.47 BT/EE argued that the marginal costs of adding capacity are not higher for an operator with a small spectrum share because spectrum holdings have an associated cost, either lump sum when acquired or as an ongoing charge. However, when we consider the *marginal* cost of adding capacity, we are not examining total or average costs, but how costs vary when network capacity is added. The costs that vary when capacity is added, such as adding another spectrum band to existing sites or adding more sites, are the network costs. The lump sum or ongoing costs of holding national spectrum licences do not vary depending on the extent to which the spectrum is used to add capacity, such as the number of base stations on which the spectrum band is deployed. These costs are generally better characterised as being fixed costs when considering adding capacity at particular locations.
- A11.48 An operator with large spectrum holdings has more opportunity to add network capacity by deploying an additional spectrum band to its existing sites, thereby avoiding the marginal cost of more sites (and incurring no increase in its spectrum costs). But an operator will need to add more sites for any given capacity increase if it has little spectrum, incurring the marginal cost of those additional sites. Therefore, we expect the marginal costs of adding capacity to be higher if an operator has less spectrum. It may also be the case that the cost of sites increases as more sites are added, as the most cost effective sites are likely to be the first ones used.

⁶³² Page 2, H3G response.

- A11.49 We continue to consider that the marginal cost for adding capacity through network investment tends to be higher for operators with a small share of total mobile spectrum than those with a greater share.
- A11.50 We agree with BT/EE that product differentiation tends to make coordinated behaviour more difficult. However, our potential competition concerns are not just about coordination, i.e. tacit collusion, but are also about non-collusive oligopoly. Also, it is not clear that such highly asymmetric spectrum shares are needed to facilitate product differentiation.

Consideration of spectrum shares by volume or value

Summary of our position in November 2016 consultation

- A11.51 In our November 2016 consultation, we acknowledged that different bands have different characteristics, but we considered that it was still useful to estimate overall spectrum shares by volume (MHz) to compare the ability of different MNOs to add capacity.
- A11.52 We said that the fact that different bands have different values does not negate the relevance of spectrum shares by volume. To the extent that differences in values of bands are due to different deployment costs (such as because more or less sites are needed to deliver similar network capacity), they may not be relevant to our consideration of spectrum shares for capacity.
- A11.53 For example, if two different bands are deployed to provide the same services, but one is more expensive to deploy than the other, we might expect this to be reflected in the cost of acquiring the spectrum, such as in auctions. In this case, it is reasonable to regard the bands as equivalent for the purpose of considering the shares of spectrum for adding capacity, even though one is more valuable than another.
- A11.54 However, we said that it could be that the cost of deployment with one band is so expensive that it would not be deployed to deliver network capacity to the same extent as another band. In that case, differences between bands might make spectrum shares by volume less meaningful for our competition assessment. Based on the available evidence, we took the view that the differences between bands were not so extreme as to undermine consideration of shares of spectrum by volume.

Summary of responses

- A11.55 BT/EE stated that Ofcom is incorrect to calculate overall volumes of spectrum holdings and base its intervention on this, as this method, whilst providing information on one aspect of quality (i.e. capacity) fails to provide any insight on the other aspects of quality (e.g. coverage).⁶³³
- A11.56 BT/EE argued that current spectrum holdings reflect differing strategies between the different MNOs during previous auctions, which would have been devised in light of each MNO's needs in order to compete in the retail market. BT/EE argued that, for example, Ofcom's spectrum share measurements omit O2's decision to

⁶³³ See paragraph 36 of BT/EE's response.

purchase low frequency spectrum in the 2013 auction, leaving it with a high share of low frequency spectrum.

A11.57 BT/EE calculated the MNOs' shares of spectrum by value using the relative values of different bands as per Ofcom's annual licence fees (ALF) statement, DCR statement and 4G auction data as well as Qualcomm's trade value for the 1400 MHz spectrum. It finds that on this value basis BT/EE has similar spectrum and subscriber shares whilst Vodafone and H3G have higher spectrum shares than subscriber shares.

A11.58 BT/EE also argued that Ofcom's approach is inconsistent, noting that it takes account of spectrum values in one scenario (i.e. annual licence fees) but not in another (i.e. this consultation). BT/EE considers that Ofcom is under a regulatory duty to be consistent "when exercising its regulatory duties".

Ofcom's response

A11.59 As in our November 2016 consultation, we recognise that different bands have different characteristics, for example, some bands are better for providing coverage than other bands. Also, some bands have different deployment costs to other bands for adding network capacity, which we would generally expect to be reflected in the price of the spectrum at auction.

A11.60 We expect MNOs to be interested in the 2.3 GHz and 3.4 GHz bands primarily for adding capacity, not for coverage, and that it will generally be cost effective to deploy these bands in areas where capacity is needed. Our relevant competition concerns arising from the acquisition of spectrum in the Auction relate to the ability of MNOs to add capacity where needed, and do not arise in relation to coverage.

A11.61 For assessing the specific competition concerns we have identified about adding capacity, we remain of the view that comparing the overall shares of spectrum by volume is more useful than estimating shares by spectrum value, for the reasons set out in our November 2016 consultation and summarised above.

A11.62 We consider spectrum for coverage when we assess the spectrum holdings of different MNOs for credibility in annex 8. In that annex, we consider whether each MNO has the minimum spectrum necessary to provide sufficient coverage to be a credible competitor. When considering coverage, we take into account that bands vary in how effective they are for providing this, and the distribution of low-frequency spectrum among MNOs. We consider that all MNOs have the minimum spectrum necessary for coverage to enable them to be credible competitors.

A11.63 We disagree with BT's suggestion that we are being inconsistent by considering spectrum value when setting ALF for 900 MHz and 1800 MHz spectrum, but not using shares of spectrum by value in our competition assessment for this Auction. The purpose of our analysis is different in these two situations. For ALF we were setting fees for spectrum licences to reflect the full market value of the relevant bands. Spectrum value was integral to our assessment of full market value. The role of spectrum shares in our competition assessment for this Auction is in considering competition concerns arising from this Auction and competition measures. For the reasons set out above, in our view spectrum shares by volume are more informative for this assessment than spectrum shares by value.

Unused or underused spectrum by BT/EE and Vodafone

Summary of our position in November 2016 consultation

A11.64 In our November 2016 consultation, we said that BT/EE is not currently deploying all of its existing spectrum widely. We said that it had deployed 2x20 MHz of 2.6 GHz spectrum, with an additional 2x15 MHz deployed on a number of sites in Central London, and at Wembley. We also mentioned that BT/EE had told us that it has recently begun small scale deployment of the 2.6 GHz spectrum held by BT prior to the acquisition of EE.⁶³⁴

A11.65 We also said that Vodafone was not currently deploying all of its 2.6 GHz spectrum widely. It has deployed its paired 2.6 GHz spectrum (of which it has 2x20 MHz) on only a small proportion of total sites < [REDACTED] , and is currently trialling the use of its unpaired 2.6 GHz spectrum. We recognised that currently Vodafone has a low share of data traffic and a lower ratio of data carried/MHz of spectrum than other operators.⁶³⁵

Summary of responses

A11.66 Four respondents – O2, H3G, < [REDACTED] and CityFibre - said that they believed underused or unused spectrum contributed to an asymmetric or inefficient assignment of spectrum in the UK. NERA's report, submitted as part of O2's response, refers to "the current grossly asymmetric assignment of spectrum".⁶³⁶ It says that two operators are "warehousing spectrum" while two others are "close to full capacity and their customers are starting to suffer as a result".⁶³⁷

A11.67 Similarly, H3G alleged that consumers in the UK are receiving "diminished benefits" due to "spectrum hoarding" by BT/EE and Vodafone.⁶³⁸ H3G argued that BT/EE and Vodafone are currently "sitting on 65 MHz of prime 2.6 GHz spectrum" while only "lightly using an additional 70 MHz of 2.6 GHz".⁶³⁹

A11.68 In support of its argument, H3G further presented results from its assessment of how intensively BT/EE and Vodafone are using their 2.6 GHz spectrum to show that, in tests conducted by P3 (a company that benchmarks mobile networks), in Q4 2016, "only a very small share of P3 measurements was on 2.6 GHz paired in a non-aggregated mode" (1.4% for Vodafone and 5% for BT/EE, i.e. of all the measurements that were taken for the test, when using a BT/EE connection the 2.6 GHz unpaired band was used 1.6% of the time and 5% with a Vodafone connection).⁶⁴⁰ It found that, for Vodafone, 7.1% of measurements were on 2.6 GHz FDD aggregated with 800 MHz while, for BT/EE, 30.1% of tests were on aggregated 2.6 GHz and 1800 MHz.⁶⁴¹ H3G did not find any P3 measurements for Vodafone's 2.6 GHz unpaired, EE's 2X15 MHz 2.6 GHz or BT's 2X15 MHz and 1X15 MHz 2.6 GHz.⁶⁴² H3G then carried out an estimate of the impact on average

⁶³⁴ See paragraph 5.37 of our November 2016 consultation.

⁶³⁵ See paragraphs 5.60 and 5.61 of our November 2016 consultation.

⁶³⁶ NERA Report, public version, p. 12.

⁶³⁷ NERA Report, public version, p. 80.

⁶³⁸ H3G's non-confidential response, p. 4.

⁶³⁹ H3G's non-confidential response, p. 71.

⁶⁴⁰ H3G's non-confidential response, p. 73.

⁶⁴¹ H3G's non-confidential response, p. 73.

⁶⁴² H3G's non-confidential response, p. 73.

download speeds if this allegedly unused or underused spectrum was reallocated.⁶⁴³

A11.69 < [REDACTED] ⁶⁴⁴

A11.70 CityFibre considered that only BT/EE and Vodafone are capable of launching 5G services without additional spectrum given the size of their existing holdings, much of which CityFibre alleged is unused or under-used at present.⁶⁴⁵

A11.71 On the other hand, Vodafone argued that it has shown efficient husbandry of spectrum stocks and stated that it does not “hoard” spectrum.⁶⁴⁶ It argued that it has paid a market price for this spectrum based on its intrinsic value to its business, and that it is investing in a network “fit for the future” which takes into account the dimensioning of the radio access network to cope with medium term growth.⁶⁴⁷ Vodafone said that at the end of FY17 it had < [REDACTED] .⁶⁴⁸

A11.72 The Scottish Government stated that Ofcom could take steps to prevent MNOs from banking spectrum in order to stop other MNOs using it.⁶⁴⁹

A11.73 Two other respondents discussed the potential benefits to consumers of using underused or unused spectrum. Famers Union of Wales argued that BT/EE's unused spectrum could be used to help rural Welsh connectivity.⁶⁵⁰ The Countryside Alliance argued that larger MNOs have excess spectrum lying idle while others are at full capacity and struggle to take on more consumers while serving current customers. It argued that rural consumers would benefit most if spectrum were more evenly distributed and considered that Ofcom has duty to promote efficient use of spectrum but never uses “use it or lose it” clauses.⁶⁵¹

Ofcom's response

A11.74 We do not believe that the fact that an MNO is not currently using all of its spectrum or that it has not deployed it at all of its sites necessarily implies spectrum hoarding or an inefficient spectrum allocation. We generally use auctions to allow the operator that has the highest intrinsic valuation for the spectrum to acquire access to it (with competition or other measures, where appropriate). It is up to individual MNOs to decide how they deploy the spectrum that they purchased at auction. For some MNOs, their valuation will be a function of immediate deployment while for others it will be based on long-term deployment plans. In general, the auction outcome should determine which is likely to yield larger benefits for consumers.

A11.75 If it is true that there are MNOs that have more spectrum than they need in the short to medium term then it is likely that their valuation for additional spectrum will be lower than for MNOs that have a more urgent need for additional spectrum, absent strategic investment (which we consider in detail in annexes 9 and 10).

⁶⁴³ H3G's non-confidential Annex 9, paragraphs 6-8.

⁶⁴⁴ See pages 2 and 3 of < [REDACTED] response

⁶⁴⁵ See page 4 of Cityfibre's response

⁶⁴⁶ See page 15 of Vodafone's confidential response.

⁶⁴⁷ See page 15 of Vodafone's confidential response.

⁶⁴⁸ See page 15 of Vodafone's confidential response.

⁶⁴⁹ See page 4 of the Scottish Government's response.

⁶⁵⁰ See page 2 of the Farmers' Union of Wales response.

⁶⁵¹ See page 2 of The Countryside Alliance's response.

A11.76 In our assessment, we have taken account of the current use of spectrum to the extent we consider it relevant to the subject of this statement – the Auction for new spectrum in the 2.3 GHz and 3.4 GHz bands.

Relevance of H3G's and Vodafone's purchase of 1400 MHz spectrum for consideration of strategic investment

Summary of our position in November 2016 consultation

A11.77 In the November 2016 consultation, we noted that in 2015 Qualcomm traded 20 MHz of 1400 MHz spectrum to each of Vodafone and H3G.⁶⁵² We said that it could be argued that the fact that H3G acquired access to 20 MHz of 1400 MHz spectrum is evidence against our view of the risk of strategic investment for 2.3 GHz spectrum. However, we said there were a number of differences in circumstances which may make such an argument unreliable.

A11.78 We said that the trade was concluded while the merger between BT and EE was being assessed by the CMA and the proposed merger between H3G and O2 was being assessed by the European Commission. This meant that there was significant uncertainty about the future industry structure for all potential bidders and also on the demand for spectrum for most of the parties involved. We also said that the sources of intrinsic value for 1400 MHz may be different than for 2.3 GHz, e.g. the 1400 MHz band may be used for coverage and, unlike 2.3 GHz spectrum, is not immediately useable for capacity.⁶⁵³

Summary of responses

A11.79 In its response, BT/EE said H3G has proved its ability to purchase spectrum it requires with the purchase of 1400 MHz spectrum, noting that H3G's winning bid for the spectrum was £ [REDACTED].⁶⁵⁴

Ofcom's response

A11.80 Our view and reasoning remains as set out in our November 2016 consultation. In its response BT/EE has not provided any new evidence or arguments that would lead us to change this view.

Drivers of intrinsic value for additional spectrum

Summary of our position in the November 2016 consultation

A11.81 In the November 2016 consultation, we did not discuss the potential composition of intrinsic value in terms of technical value and commercial value, and did not use those terms.

A11.82 However, we did say that we would generally expect the value each MNO places on additional spectrum to reduce as it obtains more frequencies. This means that those

⁶⁵² Footnote 83 on page 58 of the November 2016 consultation. For details on the trade, see https://www.ofcom.org.uk/_data/assets/pdf_file/0022/81670/trade-of-frequencies-statement.pdf.

⁶⁵³ Although we have since modified our view on the timing of the useability of 1400 MHz spectrum in light of evidence since the November 2016 consultation, the expectations at the time of the Qualcomm trades in 2015 are also relevant to this issue.

⁶⁵⁴ BT/EE response, para 41

operators with small spectrum holdings will tend to have higher values for additional spectrum than operators with high spectrum holdings. In turn, this may reduce the likelihood of this award resulting in a significantly more asymmetric distribution of spectrum because of differences in intrinsic value. We recognised, however, that there are many additional considerations that can affect the value of specific spectrum to different operators, such that this general tendency is not always the most important factor.⁶⁵⁵

A11.83 We also said that if O2 or H3G needed spectrum to be credible, they should be able to obtain a sufficient amount even without any competition measures, because would have a high intrinsic valuation for such spectrum and because of the high cost that other bidders would incur if they tried to compete for all or most of the spectrum available.⁶⁵⁶

Summary of responses

A11.84 NERA said that for this auction the intrinsic values will be dominated by commercial value rather than technical value (but did not explicitly define these terms).⁶⁵⁷ Its modelling of the likelihood of strategic investment therefore focusses on commercial value when estimating intrinsic value. We discuss this modelling in annex 10.

A11.85 H3G argued that an auction outcome where $\mathfrak{Z} < [\text{REDACTED}]$. It argued that a capacity-constrained MNO did not necessarily have a higher intrinsic value for spectrum. H3G cited a study conducted by Analysys Mason which supports its views.

A11.86 We discuss the Analysys Mason modelling and results in annex 9. In this section we focus on the way responses used the terms technical value and commercial value. In estimating intrinsic value, Analysys Mason included both technical value and commercial value. Analysys Mason defined these terms as follows:

- **Technical value** “corresponds to the present value (PV) of network cost savings achievable by an MNO in its most profitable network deployment with additional spectrum compared to its most profitable deployment without additional spectrum, noting that the network capacity may differ in the two deployments.”
- **Commercial value** “corresponds to the PV of additional revenues and non-network cost savings achievable by an MNO when holding additional spectrum, arising due to any differences in network capacity, which result in a difference in network performance, between the most profitable network deployment with the additional spectrum and the most profitable network deployment without it. Equalising network performance between these two scenarios drives the commercial value of the spectrum. In other words, better network performance (e.g. higher average user speeds) may lead to

⁶⁵⁵ Paragraph 4.166 of the November 2016 consultation.

⁶⁵⁶ Paragraph 4.241 of the November 2016 consultation.

⁶⁵⁷ NERA said that “operators with limited spectrum have few costs they can avoid from acquiring more spectrum because they lack the frequencies they need to take full advantage of network improvements; and operators with large spectrum holdings have no near-term costs that they need to avoid. As a result, commercial value associated with avoiding market share losses or making gains at expense of congested rivals become the dominant factor in valuation models.” NERA report for O2, page 83 (non confidential version).

*higher revenues or reduced non-network costs (e.g. lower churn or acquisition costs)."*⁶⁵⁸

A11.87 H3G's response also included a study by FTI Consulting (FTI) which assessed the key drivers of outcomes in auctions that include capacity spectrum, including whether intrinsic value is driven by commercial value, technical value or both. FTI defined technical and commercial value as follows:

- **Technical value** is the network cost saving of holding additional spectrum compared to not holding it; and
- **Commercial value** is the additional revenue from improved services, which would not be possible without the spectrum.⁶⁵⁹

A11.88 FTI's findings included:

- a) There is a positive correlation between the share of mobile connections an operator has and the spectrum it wins in an auction with high frequency spectrum. This correlation was relatively weak, with an R² of \times [REDACTED] when considering the full sample, and an R² of \times [REDACTED].⁶⁶⁰
- b) There is no relationship between \times [REDACTED].
- c) There is a *positive* correlation between \times [REDACTED], with an R² of 14%.

A11.89 While FTI acknowledged the limitations of its analysis, it concluded by suggesting that \times [REDACTED].

A11.90 H3G also argued that evidence from the UK's 4G auction showed that market share was important for determining auction outcomes. It assessed the data traffic per MHz prior to the 2013 auction and said that this implied that H3G was "*by far the most capacity-constrained MNO follows by O2*". Despite this, it found that EE bid the highest incremental values for 2.6 GHz spectrum. H3G said there were two possible explanation for this, either EE had a much higher intrinsic value, or EE bid strategically.⁶⁶¹ It considered that market share was a more important determinant of auction outcomes than capacity constraints.⁶⁶²

Ofcom's response

Meaning of technical value and commercial value

A11.91 In discussing the drivers of intrinsic value, FTI and Analysys Mason included specific definitions of technical value and commercial value. NERA uses the term commercial value but did not specifically define it.

⁶⁵⁸ Section 3.1.2, Annex 16, H3G's response.

⁶⁵⁹ Paragraph 4.3, FTI report, Annex 17, H3G's response.

⁶⁶⁰ Paragraph 5.32, FTI report, Annex 17, H3G's response.

⁶⁶¹ Annex 15, H3G's response.

⁶⁶² References in this sub-section to H3G's statements all relate to section 7 of its response and reference to statements by FTI relate to Annex 17 of H3G's response. References to Analysys Mason relate to Annex 16 of H3G's response.

- A11.92 Where the terms were not specifically defined, we understand technical value to derive from the ability with extra spectrum to avoid some network costs, and commercial value to derive from generating extra revenue from better network performance with the spectrum. However, we recognise that this broad understanding of the terms is not always sufficient to determine the precise boundary between them (and different definitions might imply different boundaries). This is especially the case if an operator would invest *more* on its network if it obtains some spectrum (because the spectrum allows it to do something that it would not otherwise be profitable to do).
- A11.93 We do not consider it necessary for us to select any more specific definitions of technical and commercial value for the purposes of this statement, as our decision is not affected by how exactly intrinsic value is broken down into commercial value and technical value.

Composition of intrinsic value into technical and commercial value

- A11.94 Our general view about the desirability of auctions, set out in section 6, applies regardless of the composition of intrinsic value between technical value and commercial value. We have therefore not assessed whether the intrinsic value is likely to be driven by technical value or commercial value.⁶⁶³
- A11.95 Some of H3G's arguments seem to be predicated on it necessarily being desirable for consumers for it to obtain spectrum in the Auction even if it did not have the highest intrinsic value for the spectrum. In the applicable circumstances, we do not consider this is necessarily the case. If H3G had a lower intrinsic value for additional spectrum than other operators it is not clear that it would be in consumers' interests, or even that competition would be stronger, if it obtained the spectrum. This is especially the case given H3G has rights to additional spectrum through its purchase of UK Broadband and our assessment set out in annex 8 that H3G is likely to remain credible even if does not obtain spectrum in this auction.

Ofcom's assessment of FTI report and argument that market share determines intrinsic value

H3G has obtained spectrum

- A11.96 We note first that while H3G is the MNO with the smallest subscriber share, it has obtained spectrum in recent years. This includes the 1400 MHz spectrum (as discussed from paragraph A11.77 above) and through its purchase of UK Broadband, which includes obtaining 40 MHz of 3.4 GHz and 84 MHz of 3.6-3.8 GHz spectrum. With H3G's purchase of UK Broadband, its intrinsic value for additional 3.4 GHz spectrum in the Auction is likely to have fallen.

H3G's arguments on the drivers of intrinsic value for additional spectrum

⁶⁶³ We note, however, that the balance between technical value and commercial value for an operator depends on its plans for use of the spectrum and its plans without the spectrum. For example, an operator's technical value would be reduced if it would not increase its capacity by as much as without the spectrum as with the spectrum. Also, commercial value might be increased if acquiring the spectrum (such as 3.4 GHz) would enable it to launch 5G earlier than without the spectrum.

- A11.97 H3G argued that an MNO's willingness to pay for additional spectrum decreases with the amount of spectrum the MNO has, all else being equal.⁶⁶⁴ We agree with this in general.
- A11.98 H3G also argued that other factors affect the valuation, including the incremental revenue per unit of capacity. We also agree with this.
- A11.99 H3G argued that intrinsic values increase with the number of sites an MNO has. This appears to be based largely on a report by Professor Peha. For the reasons set out from paragraph A8.65 above, we do not consider that strong, deterministic conclusions can be inferred from Professor Peha's analysis.
- A11.100 H3G also cited the Analysys Mason study that concluded [operator(s)] < [REDACTED] could find it difficult to win sufficient spectrum to remain competitive without stronger measures in the PSSR auction than we proposed in the November 2016 consultation. As discussed in annex 9, we do not find Analysys Mason's results provide reliable estimates of absolute or relative intrinsic values for spectrum.

FTI's findings on the key drivers of auction outcomes

- A11.101 We do not consider that it can be concluded that, for the spectrum in the Auction, the technical value component of intrinsic value may not be material, based on the analysis FTI has undertaken and the definitions of technical and commercial values FTI has assumed. While FTI says it acknowledges the limitations of its analysis, our view is that FTI has not sufficiently taken account of these limitations.
- A11.102 FTI relies on its statistical finding of correlation to draw conclusions on causation (i.e. that low market share causes low ability to win spectrum). However, the findings only show weak correlations between individual variables, and do not consider the effects of other factors affecting the variables. A reliable statistical analysis intending to make such conclusions on causation would need to consider (and reject, based on the evidence) alternative explanations for the observed correlation. In addition, a general analysis of the type conducted by FTI may not apply to the specific circumstances of this Auction.
- A11.103 There may be many factors influencing the valuations different operators put on spectrum and in our view FTI's study does not consider them in a robust way. In particular:
- a) There may be factors that affect both valuations and market shares simultaneously, as we discuss below;
 - o The FTI study does not include many factors that might influence the value an operator may obtain from spectrum, such as the cost and speed of deploying a specific spectrum band on that operator's network, how the spectrum fits with the operator's existing spectrum portfolio, the nature of the operator's customer base and the value the operator is likely to be able to obtain from services sold to those customers with the spectrum that it could not otherwise sell, which may be affected by many factors independent of spectrum, such as the attractiveness of its commercial offers to consumers.

⁶⁶⁴ Page 89 of H3G's non-confidential response.

- Some of the factors that are included in the FTI study may not be good proxies for what they are intended to represent. For example, while FTI says that, according to H3G, traffic per MHz should be a good estimator of how constrained an operator's network is, this may not necessarily be the case. How constrained an operator's network is may also be affected by, for example, the technology that an operator is using (as, for example, 2G is much less efficient than 4G technology for data traffic), how quickly that operator can refarm spectrum, the size of the operator's network and the relationship between the operator's peak traffic and its total traffic.

A11.104 While we do not consider it a reliable finding, FTI's suggestion that there is a weak positive correlation between share of pre-auction spectrum and share of spectrum won in auction ³< [REDACTED] does not necessarily imply that technical value is a small component of intrinsic value. There may be other explanations. For example, some MNOs may have a higher market share than rivals because they offer more attractive services to more consumers. This can be for reasons other than spectrum, such as good customer service or innovative retail offerings. Such operators may have a higher demand for capacity than rivals to serve their larger customer bases. This may have resulted in them winning more spectrum in the past and having a higher pre-auction share of spectrum than rivals. If they expect to continue to serve customers well and maintain high market share in the future, they may continue to have a higher demand for capacity and hence their intrinsic value for additional spectrum in an auction may be higher. This may enable them to win more spectrum than average and maintain their share of spectrum overall.

A11.105 While we do not consider it a reliable finding, one interpretation of there being a weak correlation between the share of mobile subscribers an operator has and the share of spectrum it wins is that operators with large subscriber shares tend to win more spectrum in auctions to serve their larger market share. This might be because they had higher technical value (from having more demand for capacity) or more commercial value (from having a larger customer base).

A11.106 But as operators' expectations about their future performance may vary, MNOs' relative values for spectrum may be expected to change to reflect that. For example, if an operator expects to grow its market share in the future, it may have a higher value for the spectrum than rivals with larger market shares. This might be one factor explaining why the correlation between share of subscribers and share of spectrum is weak, with the R^2 being ³< [REDACTED] .

A11.107 Finally, especially given the range of factors that can influence values, spectrum auctions are often affected by country-specific factors.⁶⁶⁵ It is therefore inherently difficult to draw reliable conclusions from a general analysis of auctions in many different countries about the specific circumstances of the Auction in the UK for 2.3 GHz and 3.4 GHz spectrum.

Evidence from UK's 2013 auction

A11.108 H3G argues that because EE had the lowest share of traffic per MHz before the 2013 auction, it follows that market share is important to auction outcomes, and is more important than the extent to which operators are capacity constrained. While we agree that market share may affect intrinsic values, we do not consider that any

⁶⁶⁵ See, for example, Annex 8 in our September 2015 ALF Statement, https://www.ofcom.org.uk/__data/assets/pdf_file/0033/79764/statement.pdf ALF statement.

strong, general conclusion can be drawn about the relative importance of commercial value (from market share) and technical value (from capacity constraints) from the result of the 2013 auction. As discussed above, traffic per MHz may not be a good measure of how constrained an operator's network is relative to other networks, for example as it ignores the technology that different operators are using. Moreover, there may be other factors affecting operators' bids that are not captured in this simple comparison, such as differences in operators' expectations about future demand growth and differences in their commercial strategies regarding the services they wish to offer.

Enduring competitive advantages and experience of VHA in Australia

Summary of our position in November 2016 consultation

A11.109 In the November 2016 consultation, we said that if there are operators who are competitively disadvantaged during a transitional period, they will have the opportunity to compete more strongly as that disadvantage diminishes. We therefore expected the effects of a reduction in competition in a transitional period to erode over time, though we recognised the risk that this process could take some time.⁶⁶⁶

Summary of responses

Enduring competitive advantage

A11.110 Vodafone was concerned that if an MNO obtained a first mover advantage in 5G services, that advantage could persist. < [REDACTED] . It considered that, as with 4G, if there were a 5G monopolist it would be able to sustain its coverage advantage for some time, as it was unclear when rivals would be able to launch 5G.

A11.111 Vodafone said that it would take a significant period for market shares to normalise as rivals caught up, because of customer inertia and because two year agreements are typical for mobile contracts. Vodafone thought this could be even more significant for 5G services, because for example Internet of Things (IoT), industrial applications and public sector (smart cities) agreements which will be the drivers of scale are likely to be long term strategic contracts rather than individual consumer relationships.

Experience of VHA in Australia

A11.112 O2 argued that the Australian mobile market provides an example of the enduring competition effect of a temporary loss of capacity.⁶⁶⁷ O2 references NERA's report which discusses the experience of Vodafone-Hutchison Australia (VHA).

A11.113 NERA said that there is no precedent available to observe how competition might be "impaired if two operators are chronically capacity constrained owing to a lack of spectrum, while two others have surplus spectrum."⁶⁶⁸ Nevertheless, NERA considered that the experience of VHA may provide a useful example in this

⁶⁶⁶ This is consistent with the analysis in our August 2012 decision to vary Everything Everywhere's 1800 MHz spectrum licences to allow use of LTE and WiMAX technologies – see pp32-33 in https://www.ofcom.org.uk/_data/assets/pdf_file/0021/74307/statement.pdf

⁶⁶⁷ Paragraph 43, O2's response.

⁶⁶⁸ Page 97, NERA Report.

respect. VHA was formed from a merger between Vodafone and Three in Australia in mid-2009, and operates under the Vodafone brand. NERA said that while VHA was primarily focussed on the merger, its competitors, Optus and Telstra, had already been preparing for a surge in data usage for several years. NERA said that when the data market soared in 2009, VHA's capacity was stretched and this led to network and customer service issues in 2010 and 2011. NERA said that VHA started investing heavily in its network from 2012, but it continued losing customers until 2014 owing to "enduring poor brand perception".⁶⁶⁹ NERA also claimed that to this day Telstra – which has a 53.3% market share – does not have to compete with VHA's data plans. NERA compared the price (\$60) charged by VHA for an 11 GB monthly data plan, with the price (\$70) charged by Telstra for 10 GB in 2016. NERA claimed that this suggests VHA "*is not able to exert an effective constraint on its rivals*".⁶⁷⁰

Ofcom's response

Enduring competitive advantage

A11.114 We do not agree with Vodafone that if there were a first mover in 5G the monopolist would necessarily be able to enjoy a significant commercial advantage over rivals from launching 5G services before rivals. < [REDACTED] BT/EE has lost wholesale market share since 2012 (despite launching 4G ahead of rivals on 30 October 2012), as shown in Annex 1. However, we recognise that the experience with 5G might be different to that with 4G.

A11.115 As we said in the November 2016 consultation, it seems likely that it will take some time for customers to be regained even when rivals are able to catch up in terms of the services they offer. We identified two possible reasons for this:

- a) If the MNO obtains a reputation for being a weak competitor during a transitional period for some customer segments, it may take time for this to be reversed; and
- b) The pace of consumers switching providers may be constrained if they face contractual and non-contractual costs associated with switching, such as being in a contract of two years' or potentially longer, if there are longer contractual arrangements for certain Internet of Things applications. In addition, there may be some inertia that limits how quickly consumers churn to other operators as retail prices change.

A11.116 At least with the second factor, it might be that the first mover advantage is delayed, rather than necessarily of longer duration. This is because these factors may delay the start of any first mover advantage, as well as delaying when it unwinds. This would not be the case if the move to 5G is characterised by contracts with longer duration, as that could extend the period of the first mover advantage. However, we note that it is currently not possible to offer contracts of greater duration than two-years to most consumers.

A11.117 While the effects may not disappear immediately, the mobile market is highly dynamic, with rapid changes of technology and consumer preferences. We have

⁶⁶⁹ Page 97, NERA Report.

⁶⁷⁰ Page 97, NERA Report.

also made proposals to improve the switching process for mobile consumers.⁶⁷¹ This makes it less likely that effects such as the ones described would be long lasting.

A11.118 In conclusion, as in the November 2016 consultation, we would expect the effects of a reduction in competition in a transitional period to reduce over time when rivals catch up, but we recognise the risk that this process could take some time.⁶⁷²

Experience of VHA in Australia

A11.119 We do not consider that we should draw strong conclusions from the experience of VHA in Australia for assessing how future competition in the UK might be affected if some operators were to become “capacity constrained owing to a lack of spectrum”. One reason is that VHA’s network issues in 2010-2011 appear to have arisen from short-term network performance issues rather than being related to spectrum. Furthermore, as explained below, there may have been other contributing factors to the reduction in VHA’s market share, such as customer service issues and the finding that VHA had breached its obligations under the Privacy Act following an alleged security breach in early 2011.

A11.120 NERA said the fall in VHA’s market share was due to an enduring poor brand perception resulting from “network and customer service issues”, rather than being directly related to spectrum. Indeed, the news report referenced by NERA⁶⁷³ provides a quote from VHA’s CEO Mr Berroeta claiming that in 2013 the company chose not to bid for digital dividend spectrum because it had much more spectrum than it needed.⁶⁷⁴

A11.121 The Australian Competition & Consumer Commission (ACCC) noted that VHA’s network issues were predominately related to VHA’s attempts to consolidate the networks post-merger.⁶⁷⁵ There were also reports of “unstable software” affecting network performance for some consumers and therefore the requirement to replace existing software to stabilise the network.⁶⁷⁶ Similarly, Mr Nigel Dews, the CEO of VHA referred to “*short-term performance issues with the network*” in a speech given in August 2011, which he claimed had been “resolved”.⁶⁷⁷

A11.122 In any case network issues appear to have brought customer service issues to light, which may have contributed to VHA’s market share losses. In a report in 2011 the

⁶⁷¹ In May 2017, we set out our proposals to improve the process for switching mobile provider, <https://www.ofcom.org.uk/consultations-and-statements/category-2/consumer-switching-proposals-to-reform-switching-of-mobile-communications-services>

⁶⁷² This is consistent with the analysis in our August 2012 decision to vary Everything Everywhere’s 1800 MHz spectrum licences to allow use of LTE and WiMAX technologies – see pp32-33 in https://www.ofcom.org.uk/_data/assets/pdf_file/0021/74307/statement.pdf

⁶⁷³ Page 106, NERA Report.

⁶⁷⁴ “Two years ago, we had much more 3G spectrum than we needed. You need to invest in spectrum when you need it,” <http://www.news.com.au/technology/gadgets/mobile-phones/how-vodafone-came-back-from-vodafail/news-story/65eb96d2487efc3b5d3ca251e4d259be>, accessed on 23 April 2017.

⁶⁷⁵ “These network issues were primarily related to VHA’s attempts to consolidate networks. VHA reports that it has stemmed the loss of customers by focusing on building a robust 3G network.” pages 7-8, Australian Competition & Consumer Commission, May 2015, *Competition limits advice for 1800 MHz spectrum in regional areas*

<https://www.communications.gov.au/file/5591/download?token=A81buKbY>

⁶⁷⁶ <https://www.itnews.com.au/news/wa-outage-the-latest-in-vodafones-horror-run-241577> and <http://eftm.com.au/2011/02/vodafail-to-vodacare-the-long-road-to-recovery-11866>

⁶⁷⁷ <http://clients3.weblink.com.au/pdf/HTA/01203686.pdf>

Telecommunications Industry Ombudsman (TIO) said the following with respect to complaints it received in 2010 about VHA (which operates under the Vodafone brand): *“Complaints [about Vodafone] have not only included mobile telephone coverage issues, but also a failure in customer service, with increased concerns about long wait times, failing to act on promises and consumers not being able to contact Vodafone at all.”*⁶⁷⁸

A11.123 In addition to the network and customer service issues, VHA’s brand reputation and market share may have also suffered from a security breach in January 2011, which allegedly revealed the personal details of millions of VHA customers.⁶⁷⁹ The Australian privacy commissioner launched an investigation concluding in February 2011, which found that Vodafone had breached its obligations under the Privacy Act.⁶⁸⁰

Use of a threshold price before competition measures apply

Summary of our position in November 2016 consultation

A11.124 In our November 2016 consultation, when considering our five options for competition measures, we said that it would be possible for the competition measures to apply only once the round price in the principal stage of the auction had risen to a ‘threshold price’, set above the reserve price. Until the threshold price was reached, there would be no restrictions on any operator.

A11.125 We explained that the rationale for using a threshold price would be to try to strike a balance between reducing the risk of adverse effects from a competition measure and reducing the effectiveness of the measure. We noted that the aim would be to set the threshold price at the intrinsic value of those operators who would be excluded from being able to obtain spectrum because of the competition measures. If this could be done, it would mean that those operators would be prevented from engaging in strategic investment while being able to obtain the spectrum at their intrinsic value, if this was higher than the value placed on the spectrum by other bidders. In paragraphs 5.118 – 5.122 of our November 2016 consultation we considered in more detail how a threshold price would apply in relation to the different competition measures.

A11.126 We acknowledged that, in principle, a threshold price has some attractions. However, we noted that it would not prevent asymmetric spectrum holdings resulting from differences in intrinsic value and we explained that this may still cause consumer detriment. Furthermore, we explained that the approach would rely on being able to set the threshold price at an appropriate level and we considered that in practice we did not have reliable evidence to do this.⁶⁸¹ Therefore, on balance, we considered that the potential benefits of introducing a threshold price would not be sufficient to outweigh the additional concerns that might arise through its practical implementation.

⁶⁷⁸ Page 1, Telecommunications Industry Ombudsman, TIO talks, No. 1 2011, http://www.tio.com.au/_data/assets/pdf_file/0003/8814/TIOTalks_No1_2011.pdf

⁶⁷⁹ <http://www.abc.net.au/news/2011-01-09/vodafone-says-security-breach-a-one-off/1899268> accessed on 23 April 2017.

⁶⁸⁰ <http://www.zdnet.com/article/vodafone-breached-privacy-act/>, accessed on 23 April 2017.

⁶⁸¹ See paragraphs A8.5 – A8.24 in Annex 8 to our November 2016 Consultation for a full discussion of our concerns with the methodology and lack of relevant evidence to set the threshold price.

Summary of responses

A11.127 Vodafone agreed with our conclusion on threshold pricing. It said that whilst there is theoretical merit in adopting a threshold price based on BT/EE's intrinsic value (in the context of Option A), in practice it is flawed by the "impossibility of ascertaining the correct intrinsic value".⁶⁸² Furthermore, Vodafone raised the concern that even if Ofcom could accurately estimate BT/EE's intrinsic value it would risk releasing this most confidential information to other bidders.⁶⁸³

A11.128 H3G said that there are several options as regards the price payable in respect of spectrum reservation proposed by Three. It also said that < [REDACTED] .⁶⁸⁴

A11.129 H3G suggested that an alternative option to setting the threshold price equal to the intrinsic value of the bidder(s) excluded from bidding would be to set a threshold price in accordance with Ofcom's estimate of the intrinsic value of the bidder(s) for which the spectrum is reserved. More specifically, H3G proposed the option of setting the threshold price as a percentage (e.g. 80-90%) of Ofcom's estimate of the intrinsic value of the bidder(s) for which the spectrum is reserved.⁶⁸⁵ It stated that this would ensure that "the price would be low enough to ensure that the bidder would purchase the reserved spectrum at that price."⁶⁸⁶

Ofcom's response

A11.130 After considering the responses summarised above, we remain of the view expressed in our November 2016 consultation that the potential benefits of introducing a threshold price would not be sufficient to outweigh the additional concerns that might arise through its practical implementation (discussed in detail in Annex 8 to our November 2016 consultation).⁶⁸⁷

A11.131 Furthermore, even if we could accurately estimate the excluded bidders' intrinsic value this would lead to the following risks:

- risk revealing this highly sensitive information to other bidders (as pointed out by Vodafone); and
- if the operators with smaller current spectrum holdings did have lower intrinsic value for spectrum than the excluded bidders, setting a threshold price at a higher level would risk making our competition measure ineffective.

A11.132 H3G's suggestion that we could set the threshold price at 80-90% of our estimate of the intrinsic value of spectrum for the bidders for which the spectrum is reserved does not resolve our concerns about the lack of reliable evidence to set accurate intrinsic values, as discussed in our November 2016 consultation.⁶⁸⁸ Nor does it resolve concerns associated with revealing this confidential information to other bidders.

⁶⁸² Vodafone's response, page 28.

⁶⁸³ Vodafone's response, page 29.

⁶⁸⁴ H3G's confidential response, page 142.

⁶⁸⁵ H3G's response, page 104.

⁶⁸⁶ H3G's response, page 104.

⁶⁸⁷ See paragraphs A8.5-A8.24 in Annex 8 to our November 2016 consultation.

⁶⁸⁸ See paragraphs A8.21-A8.24 in Annex 8 to our November 2016 consultation.

Strategic investment in other auctions

Summary of responses

A11.133 A few stakeholders provided examples where strategic investment may have taken place in other spectrum auctions.

A11.134 Analysys Mason, in a report for H3G, identified three potential examples of strategic investment in spectrum auctions. These are the Austrian multiband auction in 2013, Denmark's 800 MHz auction in 2012 and the UK DECT guard band auction in 2006. Analysys Mason said that these show that strategic investment is not just a theoretical construct but something that can and does happen in practice.

A11.135 H3G noted that in the 2013 UK auction EE bid by far the highest incremental values for 2.6 GHz spectrum. According to H3G, this suggested that either EE had the highest intrinsic value for 2.6 GHz spectrum despite being less capacity constrained than other operators or that EE bid strategically to deny spectrum to smaller rivals.

A11.136 In the context of arguing that the current spectrum distribution in the UK is inefficient, NERA claimed the 2013 auction outcome came about because the bids submitted were not reflective of the true valuations of the participants. It further argued that the outcome of the auction can be attributed to three factors:

- a) O2 was subject to a hard budget constraint that prevented it from expressing its full value for incremental spectrum in the 2.6 GHz band;
- b) In the clock and supplementary rounds, EE and H3G engaged in bidding behaviour that appears strategic, in particular having adopted a tactic of bidding up the price of 800 MHz and then dropping out of bidding when this would result in the clock rounds ending with provisionally unsold lots. This created uncertainty for other bidders which in turn precipitated O2's budget problem in the supplementary bids round and led EE to win 'too much' spectrum; and
- c) BT acquired access to spectrum based on a business case that it ultimately did not pursue.

Ofcom's response

A11.137 As a general point, we agree that strategic investment is a possibility in spectrum auctions. We also recognise that the incentives to engage in it are influenced by the perceived pay-offs and costs involved, and also by the competition measures implemented and the auction design adopted. The analyses which we carried out in the November 2016 consultation and in this statement reflect this understanding.

A11.138 However, we do not necessarily agree with that the examples Analysys Mason cites to suggest that strategic investment has occurred.

A11.139 We assessed allegations of strategic bidding in the Austrian auction when we set ALF for 900 MHz and 1800 MHz spectrum. We concluded that the available evidence was consistent with either strategic or intrinsic value bidding.

A11.140 In Denmark's auction, we considered that the 800 MHz price might be an understatement of market value, which is not usually consistent with strategic investment.⁶⁸⁹

A11.141 The 2006 award of DECT guard band in the UK was for spectrum that would be concurrently shared between the licensees (i.e. the technical restrictions limited the power at which transmissions could be made, meaning that multiple licensees could share the spectrum, with suitable technical coordination mechanisms in place). Analysys Mason's basis for claiming there was strategic investment in this auction was that BT and Cable & Wireless chose to bid more for an outcome with fewer licensees (as the number of shared licensees was determined in the auction). However, in the particular circumstances of the DECT guard band spectrum, we designed the auction rules for that award specifically to allow bidders to express their different valuations for a licence depending on the number of other licensees with whom they would be sharing the spectrum. This was because we had reasons to expect that the intrinsic value to each bidder them could have fallen with more operators obtaining licences to use the spectrum on a shared basis. Our auction rules then determined the number of licences to be awarded based on these bids. Given the potential intrinsic value reason, we do not consider that the evidence cited by Analysys Mason of two bidders making higher bids for an outcome with fewer licensees provides a reliable basis to infer strategic investment in the DECT guard band award.

A11.142 Regarding H3G's and NERA's comments about strategic investment by EE in the 2013 UK auction, in the context of ALF for 900 MHz and 1800 MHz spectrum we assessed evidence put forward by stakeholders on some aspects of strategic investment, and in particular on the possibility that EE might have placed bids in the supplementary bids round that contained strategic investment value. Our conclusion was that we should not ignore or adjust EE's bids because of the suggestions about strategic bidding made by stakeholders.⁶⁹⁰

A11.143 NERA suggested that, as well as the supplementary bids round, there was strategic bidding in the clock rounds in the 2013 auction. To the extent this is different from the suggestions which we considered for ALF, the argument appears to be that strategic bidding by EE and H3G in the clock rounds made it more difficult for O2 to bid in the supplementary bids round. We understand NERA's suggestion to be that such strategic bidding made it harder for O2 to predict final auction prices, which affected O2's supplementary bids because it was budget-constrained.

A11.144 Regardless of the merits on this argument (on which we do not express a view), the situation described above reflected specific features of the auction format used in 2013, the combinational clock auction (CCA), which will not be present in the Auction. In particular, in the CCA the auction prices are determined by bids in the supplementary bids round on the basis of a second-price rule (highest losing bid). In contrast, the format for the Auction will be different from the CCA and will use a different pricing rule of pay-as-bid.

⁶⁸⁹ On Austria see from paragraph A8.216 and for Denmark see A8.262, A8.286(a) and A8.287 in Annual licence fees for 900 MHz and 1800 MHz spectrum statement, 24 September 2015, https://www.ofcom.org.uk/_data/assets/pdf_file/0032/78629/annex_8.pdf

⁶⁹⁰ For more information, see paragraphs 2.151-2.159 in the September 2015 ALF Statement, https://www.ofcom.org.uk/_data/assets/pdf_file/0033/79764/statement.pdf

A11.145 In any case, whatever the claims of strategic investment in other auctions, we have assessed the likelihood of strategic investment in this Auction, given the particular circumstances of this award.

Use of 3.4 GHz spectrum for 5G

Summary of our position in November 2016 consultation

A11.146 In our November 2016 consultation, we said that the possibility of 3.4 GHz spectrum being used for new 5G mobile services had increased since the publication of our earlier consultations. For example, the RSPG, the high-level advisory group that assists the EC in the development of radio spectrum policy,⁶⁹¹ recently identified the wider 3.4-3.8 GHz band as the “*primary band suitable for the introduction of 5G use in Europe even before 2020*”.⁶⁹² We also noted that this band could be refarmed from early 4G use to subsequent 5G use if necessary.

A11.147 We said it was not yet clear what the optimum channel size for 5G would be, but there were views that large contiguous blocks of spectrum – perhaps with channels of 40-100 MHz wide – could be desirable. It was therefore possible that there might be interest from some operators in acquiring a large block of the 3.4 GHz spectrum with a view to using it for 5G services in the future.

Summary of responses

A11.148 BT/EE, O2 and UK Broadband responded that the 3.4 GHz band would initially be used for 4G and could be used to add capacity to congested networks. The respondents agreed that the 3.4 GHz band would subsequently transition to be used for 5G. The Farmers Union of Wales also emphasised the likely use of 3.4 GHz for 5G rollout, while CityFibre considered its use for 5G almost certain. Vodafone considered < [REDACTED] .

A11.149 NERA said, in its report for O2, that many of the benefits associated with 5G will initially be realised through deployment of advanced 4G. It said that other spectrum bands would become available for 5G in the future. Because of this, it did not consider that 3.4 GHz spectrum offered unique benefits that cannot be replicated with other spectrum. O2 considered that the commercial case for deployments involving large carriers at 3.4 GHz for 5G will be weak or non-existent for the next 4 years.⁶⁹³

A11.150 Respondents had mixed views on what the optimal channel size for 3.4 GHz would be, given its likely use for 5G. O2 did not consider broad channels to be required for data consumption. It claimed that a similar effect can be achieved by having five 20 MHz channels as with one 100 MHz channel. Consequently, O2 currently believed broader channels than 20 MHz are not required. On the other hand, GSA and Qualcomm argued that large contiguous bands were required for the optimal performance of 5G. They indicated that blocks of spectrum of at least 80 MHz, ideally 100 MHz, will be required to reap the full benefits. Vodafone responded that

⁶⁹¹ <http://rspg-spectrum.eu/>

⁶⁹² Public consultation on the Draft RSPG Opinion on spectrum related aspects for next-generation wireless systems (5G), June 2016, https://circabc.europa.eu/d/a/workspace/SpacesStore/1a40dd19-c8a8-4ed0-bc9c-6cc5a7755f7d/RSPG16-031Final_Opinion_5G_for_public_consultation.pdf

⁶⁹³ O2's supplemental response of 4 April 2017, https://www.ofcom.org.uk/_data/assets/pdf_file/0016/103066/telefonica-supplement.pdf

3< [REDACTED] . BT/EE agreed with Ofcom's view that there is no consensus as to the optimal channel size for 5G, with estimates ranging widely.

A11.151 In its response, Vodafone stated that for 3.4 GHz spectrum, there is the potential need for guard bands within an MNO's spectrum. Vodafone stated 3< [REDACTED]

A11.152 Vodafone noted that 3< [REDACTED] .

Ofcom's response

A11.153 Our view that the 3.4 GHz band is likely to be used for 5G, and possibly used for 4G initially, remains unchanged, consistent with most responses. It is still unclear when the transition from 4G to 5G will occur and respondents had differing views on this matter.

A11.154 Our understanding is that industry expects a gradual migration to 5G. The standard is expected to be backward compatible with existing 4G technologies and allow a migration to the new technology, including where possible a migration of the spectrum currently used for 4G to 5G.⁶⁹⁴

A11.155 We acknowledge that there is still uncertainty around the bandwidth requirements for 5G.⁶⁹⁵ Having considered stakeholder responses and latest industry developments, we are of the view that 80 MHz will be sufficient to meet the 5G performance requirements by deploying a combination of new 5G radio interfaces and other techniques mainly based on multiple active antenna technologies.

A11.156 In this respect, Qualcomm's response shares the latest results of new simulations to highlight the benefits of using these new active antennas solutions together with wideband channels and the 5G new radio interface. According to Qualcomm, massive MIMO over 80 MHz of 3.6 GHz allows re-use of existing macro sites at same transmit power to obtain a significant throughput gain at cell edge.⁶⁹⁶

A11.157 For 5G deployment in blocks of 100 MHz or more, there is a clear prospect for aggregating spectrum across multiple bands. 3.4 GHz spectrum could for instance be aggregated with existing spectrum or with other spectrum becoming available in the future. It is however less clear what other existing spectrum bands will be available for 5G use in the early stages.

A11.158 As noted above, some respondents argued that the migration from 4G to 5G will be evolutionary with 3.4 GHz spectrum likely to be used for 4G first and 5G later.⁶⁹⁷ One respondent, Vodafone argued that "*an absolute minimum of* 3< [REDACTED]

⁶⁹⁴ See for example Ericsson's and Qualcomm's views on the path to 5G, <https://www.qualcomm.com/news/onq/2017/02/25/how-we-will-get-5g> and <https://www.ericsson.com/assets/local/publications/white-papers/wp-5g.pdf>

⁶⁹⁵ We note the ITU has not reached a final position in relation to minimum bandwidth requirements for IMT 2020 (5G standard). The latest relevant document is available in draft and will be considered for final adoption later this year: <https://www.itu.int/md/R15-SG05-C-0040/en>

⁶⁹⁶ "Throughput gains are 3.9x to 4.1x for cell edge and median users, respectively, compared to 2 x 4 MIMO using the same 80 MHz bandwidth at 4 GHz and delivers an average cell throughput of 808 Mbps.", Qualcomm response,

https://www.ofcom.org.uk/_data/assets/pdf_file/0022/98131/Qualcomm.pdf

⁶⁹⁷ O2 stated that "MNOs will initially deploy 4G solutions in the 3.4-3.6 GHz band, possibly upgrading them to 4G/5G operation at some point.", https://www.ofcom.org.uk/_data/assets/pdf_file/0025/98134/Telefonica.pdf.

of spectrum would be required to be a credible 5G competitor and, allowing for the potential need for guard bands on either side, this translates to 3< [REDACTED] of spectrum being required'. We are of the view that 3< [REDACTED] is unlikely to be sufficient to support a full 5G service able to meet the high data speed requirements of the IMT 2020 vision (5G standard). This view is supported by several responses to our consultation.

A11.159 Early implementations of 5G technology are likely to use available spectrum, including smaller bandwidths (e.g. 40 MHz), to deploy the new 5G radio interface and latest antenna techniques to offer improved customer experience. Qualcomm shows in its response for example, that the 5G new radio interface deployed over a 40 MHz channel can theoretically deliver peak speeds of 1.2 Gbit/s and average ones of 300 Mbit/s. Although these early deployments may use smaller bandwidths (40 MHz and/or 60 MHz) initially, they are unlikely to deliver the high speeds required by the 5G standard.⁶⁹⁸

A11.160 In relation to spectrum block sizes for 5G, the industry is still to decide on minimum block sizes allowed for 5G use. Discussions at international levels are currently considering blocks of 20 MHz or 10 MHz, as well as 5 MHz. No final decision has been made in this regard. Since one of the improvements brought about by 5G technologies will be the ability to transmit over very wide channel bandwidths, we consider that wider channel sizes are likely to be more valuable for MNOs. However, as 5G will allow aggregation of different bands of different width, MNOs are still likely to find smaller bandwidths beneficial for their deployments.

A11.161 It is not yet clear how compatibility between adjacent licensees will be managed in this band and guard bands are one way this may be achieved. Frame synchronisation – as we have implemented in this award – is another option. If 5G frame structures are used that are not compatible with the 4G ones implemented in the licences then this will require the use of guard bands within a licensee's spectrum in order to meet the transmission emission mask requirements specified in the licences. However, we expect that 5G transmissions will have at least some frame structure options that are compatible with existing 4G services thus reducing or avoiding altogether the need for guard bands. We are therefore of the view that Vodafone's assumption on the need for 3< [REDACTED] or 3< [REDACTED] MHz guard bands is pessimistic and guard bands are unlikely to be needed for all 5G deployment configurations.

Use of 3.4 GHz for Fixed Wireless Access and regional licences

Summary of responses

A11.162 Several responses⁶⁹⁹ said the 3.4 to 3.8 GHz band could be used by Fixed Wireless Access (FWA) operators. They said FWA will be increasingly needed for the most difficult to reach premises for standard and superfast broadband - and that the current bands allocated for FWA, at 5.0 GHz and 5.8 GHz, are insufficient. With respect to the 5.8 GHz band in particular, respondents noted: limitations on power levels; channel bandwidths; reduced spectrum use (due to meeting DFS⁷⁰⁰ and

⁶⁹⁸ Peak data rate of 20 Gbit/s and user experienced data rate of 100 Mbit/s, available at http://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-!!!PDF-E.pdf.

⁶⁹⁹ Moorsweb, ASA Group, Viridian Communications, Cambium Networks, TxRx Communications

⁷⁰⁰ Dynamic Frequency Selection: a technology that makes equipment change frequency when a primary user on the same frequency is operating nearby.

RTTT⁷⁰¹ requirements); and poor penetration characteristics (relative to 3.4 GHz). One respondent stated that usage of the 3.4 to 3.8 GHz band would increase the efficiency of Wireless Internet Service Providers (WISPs) by a factor of between two and 10 and allow speeds up to 100 Mbps.

A11.163 Respondents varied in whether they thought mobile usage of the band was justified, but all argued that mobile operators would not use the 3.4 GHz band effectively nor efficiently in rural areas. Therefore, respondents suggested the 3.4 GHz band should be licensed on a regional basis – high density (i.e. urban) areas to be for mobile usage, and low density (i.e. rural) areas for FWA.

A11.164 One respondent included a specific method for how to auction the 3.4 GHz band on a regional basis, suggesting we should divide the UK into 242,000 one km squares. Bidders would then bid for each square and the amount of spectrum required in each square. The respondent suggested a reserve price per 10 MHz per each square of approximately £1000.

A11.165 The Scottish Government/Scottish Futures Trust suggested implementing a ‘use it or share it’ or ‘use it or lose it’ approach on a geographical basis to avoid the same problem of unused spectrum in certain areas of the country, noting this *“could allow future use of unused spectrum by alternative users who may wish to offer localised services in specific geographic areas”*.

A11.166 The Scottish Government/Scottish Futures Trust also raised the question of whether Ofcom had considered the role of the 2.3 and 3.4 GHz spectrum as part of the fixed broadband USO, including how it affects its design and cost effectiveness.

Ofcom’s response

A11.167 We have noted and considered the points expressed by the FWA operators. The manner in which we intended to auction the 2.3 and 3.4 GHz spectrum was discussed in a number of earlier documents. In our November 2014 consultation⁷⁰² we proposed awarding the spectrum under national licences as follows:

- The 2.3 GHz licences to cover Great Britain (i.e. England, Scotland and Wales, but not Northern Ireland);
- The 3.4 GHz licences to cover the whole of the UK.

A11.168 We also proposed that ‘use it or lose it’ should not be applied to this award.

A11.169 We did not receive any responses proposing a different approach to awarding the spectrum, such as through regional licences or sharing, or any comments about our proposal in relation to ‘use it or lose it’. Accordingly, in our May 2015 statement and consultation⁷⁰³ we confirmed we would award the spectrum as we had proposed. However, we were clear that licences would be issued on a non-exclusive basis, and stated:

⁷⁰¹ Road Transport and Traffic Telematics

⁷⁰² <https://www.ofcom.org.uk/consultations-and-statements/category-1/2.3-3.4-ghz-auction-design>

⁷⁰³

https://www.ofcom.org.uk/data/assets/pdf_file/0027/68337/Public_Sector_Spectrum_Release_statement.pdf

“We note that our thinking on spectrum sharing remains an issue for the long term, as identified in the November 2014 consultation... However, we think it is important to note that no licences issued by Ofcom are exclusive, and we have discretion to authorise use of any spectrum frequencies, for any purpose, in line with our statutory duties. The November 2014 consultation merely noted this point and assured potential licensees that no changes would be made to facilitate sharing without further consultation”.

A11.170 This remains our position, as clarified in the Information Memorandum published alongside this statement and which states:

“For the avoidance of doubt the licences will not guarantee exclusive use of the spectrum awarded. In the future, we may grant additional authorisations to allow the use of all, or part, of the spectrum, including the spectrum that is the subject of this Award Process. Such authorisation may occur, for example, by way of the grant of new licences, decisions as to the variation of existing licences, or decisions as to exemptions from licensing. We would develop and consult on the conditions of use under any such additional authorisations in order to manage the risk of harmful interference”.

A11.171 We are continuing to work with Government on delivering the broadband Universal Service Obligation of 10 Mbps to every UK premise by 2020, through a variety of methods.

Coverage obligations

Summary of our position in November 2016 consultation

A11.172 In our consultation, we outlined that we had already considered whether we should include and consider a third policy objective in the auction, improving the availability of mobile services in the UK – namely, in rural areas and ‘not spots’.

A11.173 We stated that, because of the technical characteristics of the 2.3 and 3.4 MHz spectrum, the spectrum in the auction was more suited to adding capacity, and is not an effective means of extending mobile coverage. Therefore, we concluded it was not suitable for this purpose, and that coverage obligations attached to either or both bands were not suitable.

A11.174 We said we would revisit the issue of mobile coverage obligations in future awards – in particular, in regard to the 700 MHz spectrum award.

Summary of responses

A11.175 The Scottish Government and Scottish Futures Trust, whilst acknowledging our decision not to implement a coverage obligation on the bands because they were more likely to benefit capacity, suggested several possible options, including:

- Rural tariffs – for instance, MNOs being required to provide rural area tariffs, allowing mobile broadband to become an alternative to fixed services; and
- Geographic obligations to infrastructure investment – for instance, outside-in coverage approaches, deployment on key transport routes, different obligations on different UK nations.

A11.176 The response said: (whilst 2.3 GHz) *“may not deliver wider coverage, it will complement MNOs current spectrum holdings”* and the consultation stated it will be immediately used for 4G. Ofcom should assess MNOs’ spectrum overall and explore additional 4G coverage obligations.

A11.177 The Countryside Alliance responded on the issue of coverage, stating *“Ofcom must use this auction to address some of these issues, and fix the provision of mobile coverage in rural areas”*.

A11.178 The Welsh Government recognised the spectrum in this auction was best suited at improving capacity rather than extending coverage.

Ofcom’s response

A11.179 As stated in the consultation, we consider that the bands in the auction (2.3 and 3.4 GHz) are not suitable for extending geographic coverage due to their characteristics. Therefore, we are continuing with the award of both bands with no coverage obligations on either band.

A11.180 However, we note the concerns expressed by the variety of stakeholders who responded on this issue, and highlight the following:

- The Government signed an agreement in December 2014 with the four MNOs, who each agreed to deliver voice coverage to 90% of the UK landmass by the end of 2017.⁷⁰⁴ We subsequently varied the relevant MNO licences to implement this agreement. In addition, O2, as part of its winning bid for a package of spectrum in the 2013 4G auction, has a separate coverage obligation to provide 98% indoor coverage for mobile broadband, capable of supporting a minimum speed of 2 Mbps, by the end of 2017.
- We are continuing to work on improving coverage, under our Mobile Coverage Programme, and are exploring various approaches to improving and extending mobile coverage. For example, we are currently considering responses to a recent consultation on an approach that would allow consumers to operate mobile repeaters.⁷⁰⁵

A11.181 As previously set out in our Digital Communications Review, we will seek to include a coverage obligation as one of the conditions of using the 700 MHz spectrum. The 700 MHz band is more suited to coverage and could help to improve mobile coverage in difficult to reach areas. We plan to seek views on the inclusion and form of a coverage obligation when we consult on the conditions for that award.

Ofcom letter to the European Commission in the context of the proposed H3G/O2 merger

Summary of responses

A11.182 H3G said that during the course of the proposed merger between H3G and O2, Ofcom had *“promised to the European Commission that it would regulate to avoid*

⁷⁰⁴ <https://www.gov.uk/government/news/government-secures-landmark-deal-for-uk-mobile-phone-users>

⁷⁰⁵ <https://www.ofcom.org.uk/consultations-and-statements/category-2/mobile-phone-repeaters>

an auction outcome that would weaken [H3G]'s ability to compete". H3G quoted extracts from a letter from Ofcom to the European Commission, including:

"... Ofcom would like to see the UK continue to have four mobile network operators (MNOs). We believe four MNOs, rather than three, competing for customers is the only way to ensure that competition is effective, in terms of pricing, quality and innovation"

"Ofcom previously secured this outcome by reserving spectrum for a fourth MNO (or national wholesaler, as we referred to them) in the 2013 4G auction to ensure that it had at least the minimum spectrum requirements to allow it to be an effective competitor so that UK consumers continued to benefit from a competitive market. Ofcom anticipates that it will continue regulating to secure this policy objective in the future."

*"An outcome which results in a weakening of an MNO's ability to compete effectively, if it were to prevail, would be inconsistent with this policy objective. The assumption that Ofcom will not impose competition measures in the PSSR award, on which Three's submissions appear to be based, is not correct. To reiterate, our position is that there should be four MNOs in the UK and we will continue to regulate to achieve that."*⁷⁰⁶

A11.183 H3G said that the European Commission relied on these commitments in its decision to prohibit the H3G/O2 merger. H3G said that it expected Ofcom to honour the commitments provided to the European Commission.

Ofcom's response

A11.184 In the letter to the European Commission we went on to explain that:

"When we revisit the question of how the auction should be structured following the conclusion of the Commission's merger process, we would propose including competition measures in the PSSR award where we considered it to be necessary and proportionate to promote effective and sustainable competition. A proposal to include competition measures would be subject to consultation."

A11.185 We duly considered the case for competition measures in the Auction and consulted on this in November 2016. Having considered responses to that consultation, we are now imposing the competition measures we judge to be necessary and proportionate to meet our duties. This is in line with what we said we would do in our letter to the European Commission in March 2016.

A11.186 It is clear from the quotations above that we did not promise to the European Commission to impose competition measures that would necessarily ensure that H3G obtained spectrum in the auction. It would have been inappropriate for us to have done so.

⁷⁰⁶ Pages 12 and 13 of H3G's non-confidential response, quoting from the letter from Philip Marnick of Ofcom to Michele Piergiovanni of the European Commission of 10 March 2016.

Annex 12

Additional analysis

Introduction

A12.1 This annex presents supporting analysis for a few specific issues that we draw on in the main text. It sets out:

- shares of spectrum when only considering downlink spectrum;
- a history of spectrum distribution; and
- the CMA's assessment of the merger between BT and EE.

Downlink spectrum

A12.2 There is an argument that downlink spectrum shares are more relevant than spectrum overall for assessing capacity, given the asymmetric nature of traffic (with downlink traffic being many times greater than uplink traffic). For example, this is the approach in the AM models of intrinsic and strategic value of spectrum (see annex 9). However, uplink constraints in a network can also be important given the relative performance of the uplink with lower power devices compared to the downlink, and so we have retained our focus on total overall spectrum in our assessment.

A12.3 In any case, we do not consider that our analysis or decision would be fundamentally changed by considering only downlink spectrum.

A12.4 For completeness, below we set out how spectrum shares would change if we considered downlink only spectrum. To do this, we have assumed that the ratio of downlink/uplink for TDD spectrum was 3:1⁷⁰⁷, which means that we have counted 75% of TDD spectrum as being for downlink.⁷⁰⁸ We include 50% of paired (FDD) spectrum and 100% of SDL spectrum.

A12.5 In Figure A12.1 below, we show the current holdings and future availability of downlink spectrum. The shares of spectrum for the different MNOs in terms of downlink spectrum are broadly similar to those shown in section 6 when we consider total spectrum (including downlink and uplink), though there are some differences. For example: the shares of H3G are a little higher based on downlink than total spectrum (because of its holdings of SDL spectrum at 1400 MHz and TDD spectrum at 3.4 GHz); and the shares of the other MNOs are lower (with the exception of Vodafone in the first transitional period). The 2.3 GHz and 3.4 GHz spectrum represent a larger share of the total available downlink spectrum compared to the share of total spectrum they represent when both uplink and downlink are included.

⁷⁰⁷ This is consistent with the "preferred" LTE frame structure specified in technical licence conditions, although under certain circumstances other frame configurations with different downlink/uplink ratios are possible for the 3.4 GHz band.

⁷⁰⁸ Analysys Mason assumed a similar figure of 70% in its assessment of how much downlink capacity is provided by TTD spectrum, see footnote 19, page 16 of annex 16 of H3G's response.

Figure A12.1: Current holdings of downlink spectrum and future availability

Spectrum Band	Type	BT/EE	Vodafone	O2	H3G	To be auctioned	Total
<i>Useable in first transitional period (all in MHz)</i>							
800 MHz	FDD	5	10	10	5		30
900MHz	FDD		17.4	17.4			34.8
1800 MHz	FDD	45	5.8	5.8	15		71.6
2100 MHz	FDD	20	14.8	10	14.6		59.4
2.6 GHz (paired)	FDD	50	20				70
2.6 GHz (unpaired)	TDD	11.25	15				26.25
1452-1492 MHz	SDL		20		20		40
Sub-total of above bands		131.25	103	43.2	54.6	0	332.05
Downlink share with above bands		40%	31%	13%	16%	0%	
Overall share (uplink & downlink)		42%	29%	14%	15%	0%	
2.3 GHz	TDD					30	30
Sub-total with 2.3 GHz		131.25	103	43.2	54.6	30	362.05
Downlink share with 2.3 GHz		36%	28%	12%	15%	8%	
Overall share (uplink & downlink)		39%	27%	13%	14%	6%	
<i>Useable in the future (all in MHz)</i>							
3.4 GHz	TDD				30	112.5	142.5
Sub-total with 3.4 GHz		131.25	103	43.2	84.6	142.5	504.55
Downlink Share with 3.4 GHz		26%	20%	9%	17%	28%	
Overall share (uplink & downlink)		30%	21%	10%	15%	23%	
700 MHz	FDD & SDL					50	50
Sub-total with 700 MHz		131.25	103	43.2	84.6	192.5	554.55
Downlink share with 700 MHz		24%	19%	8%	15%	35%	
Overall share (uplink & downlink)		28%	19%	9%	14%	21%	
3.6-3.8 GHz	TDD				63	87	150
Sub-total with 3.6-3.8 GHz		131.25	103	43.2	147.6	279.5	704.55
Downlink share with 3.6-3.8 GHz		19%	15%	6%	21%	40%	
Overall share (uplink & downlink)		23%	16%	8%	19%	17%	

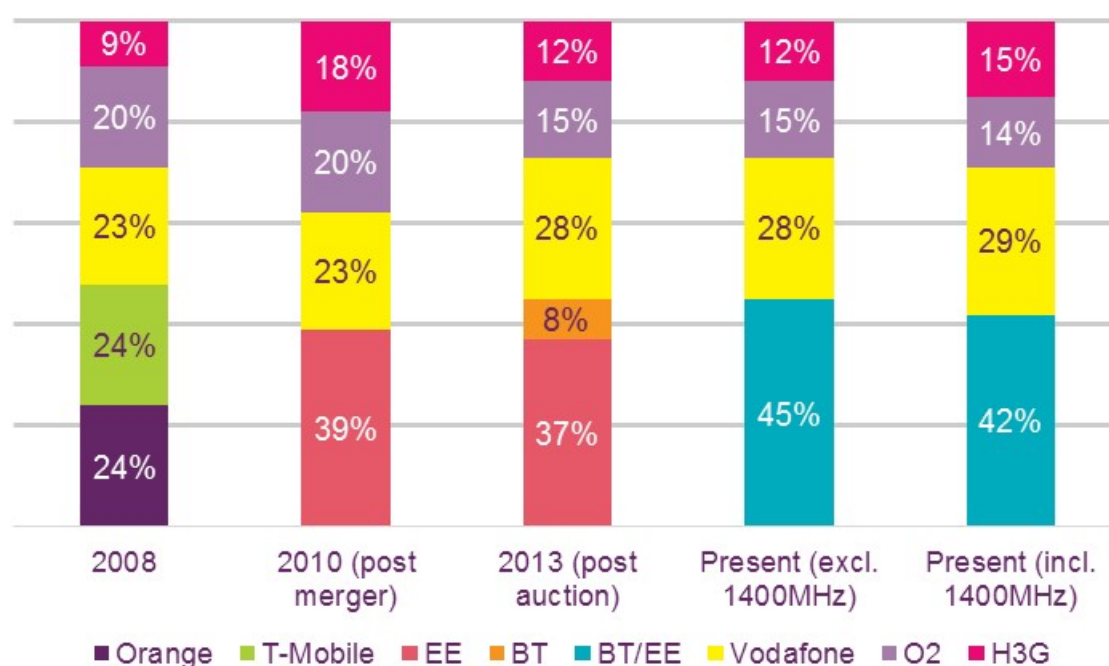
History of current spectrum distributions

- A12.6 The current asymmetric distribution of spectrum has arisen for historic reasons – its evolution is illustrated at Figure A12.2.
- A12.7 Before 2010 there were four larger operators all with shares of spectrum between 20% and 25% (O2, Orange, T-Mobile and Vodafone) plus a fifth operator (H3G) with a further 9%. The 2010 merger of Orange and T-Mobile to form EE meant that the spectrum distribution became more asymmetric. However, the competition authorities determined that the combined entity should divest some spectrum frequencies in the 1800 MHz band; access to these frequencies was eventually acquired by H3G, which raised its share of mobile spectrum to 18%. EE retained 39%; Vodafone 23% and O2 20%.
- A12.8 The 2013 auction of frequencies in the 800 MHz and 2.6 GHz bands (widely known as the 4G auction) substantially increased the amount of available mobile spectrum by about 70%. Even so, there was still an asymmetric distribution of spectrum after the 2013 auction. Ofcom applied competition measures in the auction to ensure the maintenance of an effective market of at least four credible network operators and

to limit the degree of asymmetry in both overall spectrum and sub-1 GHz spectrum. The measures included a reservation of some spectrum that could only be won by H3G or a new entrant, and a cap on the total amount of spectrum a single operator could hold which was set at a level representing 37% of mobile spectrum. Given these competition measures, bidding in the auction left EE with 37% (the maximum allowed); Vodafone with 28%; O2 with 15% and H3G with 12%. The remaining spectrum was won by BT in the 2013 auction.

- A12.9 More mobile spectrum became available in 2015 when Qualcomm traded licences for the 40 MHz of frequencies it held in the 1400 MHz band. Through this process, Vodafone and H3G each acquired access to 20 MHz.
- A12.10 The current distribution of spectrum among the four MNOs arose after the acquisition of EE by BT, which was approved by the Competition and Markets Authority (CMA) in January 2016.⁷⁰⁹ Although BT was not acting as an MNO, it had obtained frequencies in the 2.6 GHz band in the 2013 auction. The combined BT/EE holding therefore rose to 45% of the spectrum considered by the caps in the 2013 auction (which excluded the 1400 MHz band from the pool of relevant spectrum). We expect Vodafone and H3G's holdings of 20 MHz each in the 1400 MHz band to be useable during the first transitional period - this reduces BT/EE's share to 42%.

Figure A12.2: Evolution of useable spectrum shares



- A12.11 The proposed acquisition of O2 by H3G's parent company CK Hutchison would have reduced the number of UK MNOs from four to three, and allowed the combined H3G/O2 entity to also consolidate its spectrum holdings. It would have left the three remaining operators with a more even distribution of spectrum than at present.

⁷⁰⁹ <https://www.gov.uk/cma-cases/bt-ee-merger-inquiry>

A12.12 However, in May 2016, the merger was blocked by the EC on competition grounds.⁷¹⁰ Ofcom supported that conclusion, which is also consistent with the policy we set out ahead of our 2013 4G auction that competition in the UK market is best served by there being at least four credible MNOs.

CMA's assessment of the merger between BT and EE

A12.13 In submissions to the CMA in late 2015 in the context of the BT/EE merger, various operators raised concerns about capacity constraints in the future.⁷¹¹ For example, H3G said that it will face capacity constraints in the coming years.⁷¹²

A12.14 The CMA considered in detail whether the merger of BT and EE would lead to a substantial lessening of competition in the retail mobile market because other operators faced capacity constraints:

The CMA “considered whether the competitiveness of the retail mobile market was likely to decline absent the merger, due to possible capacity constraints of some operators, and whether BT would therefore have become a more important competitor. We considered capacity constraints in detail and our view is that, although some MNOs face challenges, it is unlikely that they would individually or in combination be sufficiently and enduringly weakened by any potential capacity constraints to the extent that the loss of BT from the retail mobile market is expected to lead to a SLC [substantial lessening of competition].”⁷¹³

A12.15 The CMA's conclusion was partly based on evidence that, without the merger, BT would have provided limited additional competition to MNOs, that BT was not then a strong competitor in retail mobile and that its market share forecasts were modest.⁷¹⁴ Because the CMA did not consider that BT was at that time a strong competitor in retail mobile, it focussed its assessment of the merger on mobile competition in the medium to long term, after operators could obtain new spectrum, as it considered that any potential harm would not arise for several years.⁷¹⁵

⁷¹⁰ We note that the EC decision to block the acquisition is now the subject of an appeal. See Case T-399/16 CK Telecoms UK Investments v Commission, action brought 25 July 2016.

⁷¹¹ See section 14 of the *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016, https://assets.publishing.service.gov.uk/media/56992242ed915d4747000026/BT_EE_final_report.pdf. See also paragraphs 28 to 32, Appendix G, *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016, https://assets.publishing.service.gov.uk/media/56991ae4ed915d468c00002b/FR-Appendices_and_Glossary.pdf.

⁷¹² Paragraph 14.70, *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016.

⁷¹³ Paragraph 18, *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016.

⁷¹⁴ Paragraph 11.81, *BT Group plc and EE Limited: A report on the anticipated acquisition by BT Group plc of EE Limited*, CMA, 15 January 2016.

⁷¹⁵ The CMA said “The theories of harm we are assessing involve potential effects on competition from the merger that would not arise for several years – that is, over time as BT potentially grew as a mobile retailer; and in future when the MVNO contracts of Sky, TalkTalk and Virgin become subject to new negotiations. For that reason, we consider it appropriate to consider MNOs' capacity in the medium to long term, including how it may be affected by the deployment of new spectrum.” Paragraph 71, Appendix G, *BT Group plc and EE Limited: A report on the anticipated acquisition by*

A12.16 In this decision, we are not considering whether, without the BT/EE merger, BT would have been a strong competitor in mobile in the first transitional period. Rather we are considering whether a further concentration of useable spectrum may weaken mobile competition, at least for some temporary period of time. There is therefore no tension between the CMA's finding that BT would have added little to retail mobile competition for several years and our concern that a further concentration of immediately useable spectrum may harm mobile competition.⁷¹⁶

BT Group plc of EE Limited, CMA, 15 January 2016, <https://www.gov.uk/cma-cases/bt-ee-merger-inquiry>

⁷¹⁶ In our submission of 31 July 2015 to the CMA on the BT/EE merger, we did not consider that other MNOs would be capacity constrained in the longer term, as all MNOs would have a reasonable opportunity to increase capacity, including through the acquisition of spectrum in auctions. It was therefore only in the shorter term that there could be a question over whether other MNOs may be unable to increase capacity sufficiently to keep pace with increasing demand and result in a sustained capacity shortage (as transitional capacity shortages that would soon be addressed were unlikely to pose a significant threat to competition). See paragraphs 1.14 and 3.28 to 3.45, https://assets.digital.cabinet-office.gov.uk/media/55cc79abe5274a547300002f/Ofcom_Phase_2_submission.pdf. In our competition assessment for the Auction we consider that there is sufficient risk of the first and second transitional periods being long enough for us to be concerned about significant threats to competition.

Annex 13

Illustrative auction procedures

- A13.1 This annex seeks to provide a practical illustration for applicants and bidders in the 2.3 GHz and 3.4 GHz spectrum auction of the processes and procedures that we will adopt for that auction.
- A13.2 The rules of the auction will be as set out in Ofcom's proposed statutory instrument. A statutory Notice which constraints Ofcom's proposed draft of the statutory instrument, the proposed Wireless Telegraphy (Licence Award) Regulations 2017, is also published today and is available at Ofcom's website at <https://www.ofcom.org.uk/consultations-and-statements/category-3/notice-of-proposal-to-make-regulations-in-connection-with-the-award-of-2.3-ghz-and-3.4-ghz-spectrum>. This draft is referred to in this annex as "the Regulations".
- A13.3 The illustrative procedures set out in this Annex are intended to provide a description for how the spectrum award auction process will work. In the event of any discrepancy or inconsistency between this description and the rules set out in the draft Regulations, it is intended that the proposed rules in the draft Regulations take precedence. Once the draft Regulations have been finally enacted by Ofcom and entered into legal force, following this consultation, they will constitute enacted UK legislation and as such will also, in the event of any discrepancy or inconsistency, take precedence to anything in this description or in the published Information Memorandum."
- A13.4 The language we use throughout this annex is as close as possible to the one we use in the draft Regulations, for ease of reference.

Lot structure

Use of frequency generic lots

- A13.5 As discussed in further detail below, the award mechanism will consist of two distinct bidding stages. In the first stage (the 'principal stage'), the spectrum available will be offered as 'frequency-generic' lots grouped into two 'lot types'; one for each frequency band (2.3 GHz and 3.4 GHz). Each lot in 2.3 GHz and 3.4 GHz will be frequency generic and will correspond (respectively) to a 10 MHz and 5 MHz block of spectrum in the relevant frequency band. During this stage, bids will relate to a number of lots in each lot type, but not to specific frequencies within the lot type's frequency range. This first stage will allow Ofcom to determine the number of lots (i.e. the total bandwidth) to be assigned to each bidder in each band.
- A13.6 The specific frequencies assigned to each winner of frequency-generic lots will then be determined in a follow-up 'assignment stage'. In the assignment stage, Ofcom will determine, for each frequency band, the potential assignment band plans that minimise fragmentation of assignments. Further details on the selection of potential assignment band plans are provided in the subsection on the assignment stage below.
- A13.7 In the event there are several assignment band plans in which some bidders would be assigned different frequencies, such bidders will be invited to bid for their preferred option.

Lot types and spectrum packaging

A13.8 The spectrum available will be offered in two generic lot types

- 2.3 GHz: This lot type will contain four frequency-generic 10 MHz lots in the frequency range 2350-2390 MHz; and
- 3.4 GHz: This lot type will contain thirty frequency-generic 5 MHz lots within the frequency range 3410-3600 MHz.

Eligibility points

A13.9 As explained in more detail below, the principal stage will include a rule that the number of eligibility points used by a bidder in a round cannot exceed the bidder's eligibility limit for that round.

A13.10 For this purpose, each 2.3 GHz lot will be assigned four eligibility points, while each 3.4 GHz lot will be assigned one eligibility point.

A13.11 The number of eligibility points used by a bidder in a round is equal to the sum of the eligibility points associated with all the lots for which the bidder submits or maintains a bid in the round. As 2.3 GHz lots have double the eligibility points of 3.4 GHz lots on a per MHz basis, bidders may increase their demand in MHz when switching from 2.3 GHz lots to 3.4 GHz lots; if they do not increase their demand in MHz when switching from 2.3 GHz to 3.4 GHz, then they may lose eligibility. Conversely, bidders switching from 3.4 GHz to 2.3 GHz may have to reduce their overall demand in MHz.

A13.12 Information on how to determine a bidder's eligibility limit, and the number of eligibility points used by a bidder, is provided from paragraph A13.64 below.

Applications, initial deposit, 2.3 GHz bid limit, overall bid constraint and qualification

A13.13 Applicants will be required to provide Ofcom with a range of information, by a deadline specified by Ofcom, in order to apply to participate in the auction. Amongst other things, applicants will be required to specify their existing spectrum holdings in their application, as this information will be required for the implementation of the cap in MHz on the amount of mobile spectrum that is immediately useable (leading to a '2.3 GHz bid limit' for each bidder) in the 2.3 GHz frequency band, as well as the overall spectrum cap (leading to an "overall bid constraint" for each bidder).

A13.14 Along with their application, applicants will be required to submit an initial monetary deposit of £100,000, which might be forfeited in whole or in part if the applicant subsequently breaches the Regulations.⁷¹⁷ Any interest on deposits will be retained by Ofcom and passed to HMT.

A13.15 After the deadline for applications, Ofcom will notify each applicant of the name of every other applicant and its associates. Applicants will then need to ensure they meet bidder association rules, which will not allow for two or more associated applicants to participate in the auction. They will need to do so by a deadline specified by Ofcom, and it may be the case that some applicants have to withdraw

⁷¹⁷ If the applicant simply chooses to withdraw its application by the last day for withdrawal, or fails to qualify in the auction, then that bidder's initial deposit of £100,000 will not be forfeited for that reason.

their application to prevent another applicant from failing to qualify in the auction. Other qualification criteria to ensure that applicants are suitable to hold a licence will also apply. The provisions for qualification are similar to those used in recent awards by Ofcom, and are specified in the Regulations.

- A13.16 After the deadline for complying with the bidder association rules (referred to above), Ofcom will determine which applicants qualify to participate in the auction.
- A13.17 To do so, Ofcom may require additional information from specific applicants, which would need to be provided before a deadline specified by Ofcom.
- A13.18 Following the last day for withdrawals from the award, Ofcom will determine the list of qualified applicants (i.e. bidders), and return the initial deposit to any applicants who fail to qualify. Only qualified bidders will be allowed to participate in the auction.
- A13.19 Before the first round of the auction takes place, each bidder will need to provide an additional deposit to Ofcom of at least £900,000, which will determine the bidder's initial eligibility limit. This is in addition to the initial monetary deposit of £100,000 referred to above. The initial eligibility limit will determine the maximum number of bids that the bidder may submit in the first round of the auction.

The Electronic Auction System

- A13.20 The auction will be run over the internet using an Electronic Auction System (EAS). No specialist hardware or software will be required on bidder's terminals, as the EAS interface will run on a standard web browser. However, bidders will need to install authentication credentials, provided by Ofcom only to qualified bidders, on any computer they wish to use to access the system. As in previous auctions, Ofcom will allow bidders to submit bids by alternative means in the event that they experience technical difficulties with the EAS, subject to Ofcom granting permission to the bidder to do so and provided that the bids by alternative means are authenticated in accordance with the Regulations for the auction.
- A13.21 Ofcom also expects to make a stand-alone version of the software available to applicants, a few days after application. Applicants will be able to login both as bidders and as the auctioneer, allowing them to run internal mock auctions as part of their training.

The principal stage

- A13.22 The purpose of the principal stage is to determine the amount of radio frequency lots to be assigned to each bidder in each band, and the 'base price' that each winner of spectrum will be required to pay for the lots it has won.
- A13.23 Bidding in the principal stage will proceed in rounds, which consist of time windows scheduled by the auctioneer during which bidders are invited to submit 'bid decisions'. We refer in this document to "bid decisions" in order to reflect the fact that bidders are entitled, on their principal stage form(s), to do more than submit a new bid. In particular, bidders may indicate that they wish to withdraw the standing high bid status of bids made in previous rounds, or request that their eligibility limit be carried forward to the next round.
- A13.24 The submission of bid decisions is only accepted while a round is in progress, and is only processed once the round has finished. At the end of each round, bidders will be notified whether the auction will proceed to the next stage or a further

bidding round is needed, and given certain information about the results of the completed round (as detailed below).

Overview of the bidding process

A13.25 During the principal stage, bidders may submit bids for the (generic) lots available at prices announced by the auctioneer. These prices are known as the 'round price'. At the end of each round, Ofcom determines provisional winning bids for each lot. We refer to these provisional winning bids as 'bids with standing high bid status', or 'standing high bids' in this document.⁷¹⁸ These are bids which will become the winning principal stage bids unless they are replaced in subsequent rounds.

A13.26 The principal stage will end when there are no 'round events' in a round. This means that, in a round, (i) no bidders have submitted any new bids, (ii) no bidders have withdrawn the standing high bid status of any bids made in previous rounds, and that (iii) no 'eligibility events' have occurred (explained below from paragraph A13.68).

A13.27 When the principal stage ends:

- standing high bids will ordinarily become winning principal stage bids. The one exception to this is where the number of a bidder's standing high bids in the 3.4 GHz band does not meet that bidders' 3.4 GHz minimum requirement (if any), explained below. Standing high bidders will be required to pay the round price of their winning principal stage bids for the lots they have won (plus any additional price incurred as a result of bidding for specific frequencies in the assignment stage); and
- withdrawn standing high bids (i.e. where a bidder has indicated that it wishes to withdraw the standing high bid status of those bids) may also become winning principal stage bids, as explained below. In that event, winning bidders will be offered those lots at twice the round price (plus any additional price from the assignment stage).

Bids

A13.28 The bid submission process requires bidders to select the number of lots they wish to bid for at the price specified by the auctioneer (i.e. at the round price). However, this is not a package bid. Formally, where a bidder opts to bid for a number of lots this will be treated as separate bids for individual lots from that bidder. However, the principal stage is structured so that new bids will be subject to a common round price applying to all lots in a frequency band; this facilitates the making of bids through the EAS, as bidders will simply need to specify the number of lots sought in each category.

A13.29 Each bid must specify:

- the frequency band to which the bid applies; and
- the price that the bidder would pay for the lot if the bid is selected as a winning bid by virtue of being a standing high bid. We note that this price is

⁷¹⁸ In the Regulations we refer to these as "bids with standing high bid status".

the round price, as determined by the auctioneer for the round in which the bid was submitted.

- A13.30 Submitting a bid establishes a commitment to acquire, in the event that the bid is selected as a winning bid, a lot in the specified frequency band at a price equal to the round price.⁷¹⁹
- A13.31 Bidders may bid for several lots simultaneously. However, it is possible that only some of these bids may be selected as winning bids, subject to the provisions for minimum spectrum requirements in the 3.4 GHz band set out below. Notwithstanding this, the process for selecting standing high bids has been designed with the intention of minimising the number of potential bidders who win some, but not all, of the bids they made simultaneously for lots in a lot category. We refer to such bidders in this document as 'partial standing high bidders'.
- A13.32 A bid is only valid if it is submitted during a round in accordance with the Regulations.

2.3 GHz bid limit and the overall bid constraint

- A13.33 On the basis of a bidder's recorded spectrum holdings (which are determined shortly after the deadline for payment of the additional deposit, but before the start of the principal stage), Ofcom will determine the 2.3 GHz bid limit and the overall bid constraint that apply to each bidder.
- A13.34 The 2.3 GHz bid limit will establish a constraint on the number of bids the bidder can submit for 2.3 GHz lots during any principal stage round. Specifically, the bidder will not be able to submit bids for a number of 2.3 GHz lots that exceeds its individual bid limit. A bidder's 2.3 GHz bid limit will be between zero and four (inclusive).
- A13.35 The overall bid constraint will establish a limitation on the combination of the number of new bids and standing high bids assigned at the end of the most recent round⁷²⁰ that the bidder can submit for lots of the two lot types (2.3 and 3.4 GHz).
- A13.36 A bidder's 2.3 GHz bid limit and its overall bid constraint are irreversible and will apply throughout the auction. This means that, if a bidder subsequently divests all or part of its recorded spectrum holdings, its 2.3 GHz bid limit and its overall bid constraint will not be increased. Further, where a bidder's existing spectrum holdings are changed after they have been recorded (other than as a result of a divestment), this may be grounds for Ofcom to exclude that bidder from the award process and to forfeit its deposit if that change would affect that bidder's 2.3 GHz bid limit and its overall bid constraint.

3.4 GHz minimum requirement

- A13.37 In their application, bidders may specify a minimum requirement ('MR') of up to four lots in the 3.4 GHz band.
- A13.38 As a general rule, a bidder who specifies an MR will not be assigned any spectrum in the 3.4 GHz band if the number of lots it provisionally wins by virtue of being

⁷¹⁹ As noted, withdrawn bids may be offered to the bidder at twice the price at which they were made.

⁷²⁰ In the bands where the bidder does not submit new bids

standing high bidder at the end of the last principal stage round in the 3.4 GHz band is smaller than the MR it has specified.

- A13.39 The one exception to this rule is that, where a bidder withdraws standing high bids for 3.4 GHz lots, it may still win less spectrum than its MR if the number of unallocated lots at the end of the last principal stage round is less than its MR.
- A13.40 Specifying an MR will also establish a constraint on the bids that the bidder may submit for 3.4 GHz lots in any principal stage round. Specifically, the bidder will not be able to submit bids for fewer lots in this frequency band than the minimum required for them to meet their MR.
- A13.41 The specification of an MR is irreversible and cannot be modified after application or at any point during the auction. Therefore, a bidder who specifies an MR for 3.4 GHz lots in their application will not, under any circumstances, be able to submit bids for less 3.4 GHz spectrum than their MR.

The bidding process

- A13.42 The bidding process in the principal stage will require one or more rounds, each round consisting of a fixed time window during which bidders may submit bid decisions in accordance with prices announced by the auctioneer and the Regulations.
- A13.43 As explained above, a bid decision is only valid if it is submitted during a round in accordance with the Regulations.

Scheduling of rounds

- A13.44 The minimum notice period that will be provided before the start of a round is 15 minutes. We expect rounds to last 30 minutes, but we may choose different durations.
- A13.45 When a round is scheduled, the following information will be made available to each bidder:
- the start and the end time of the round;
 - the round price for each lot type for that round;
 - the bidder's own eligibility limit;
 - the number of eligibility events the bidder has left (explained below);
 - the number of rounds in which the bidder may still withdraw their standing high bids (explained below).

Bid submission during a round

- A13.46 In each round, bidders can make a single submission of bid decisions using the EAS. Therefore, bidders should submit all of the bids they wish to submit in a given round simultaneously, and specify any withdrawals or requests to carry forward their eligibility limit in the same submission. When a round is in progress, each bidder's EAS interface will provide a bid form.

A13.47 To make a submission, a bidder will need to:

- specify, using the principal stage form provided by the EAS,
 - a) the number of lots in each lot type for which they wish to submit a bid at the round price for that lot type. We note that:
 - i) bidders may not specify a bid amount for a lot that differs from the round price for that lot type;
 - ii) in the first round, each bidder must submit a bid for at least one lot. Any bidders who do not do so will be excluded from the auction and will not receive a refund of any of their deposit. In subsequent rounds, however, bidders may decide to not place any bids for 2.3 GHz or 3.4 GHz lots;
 - iii) any bid submitted by a bidder for 2.3 GHz lots must not breach the 2.3 GHz bid limit set for that bidder, and any bid submitted by a bidder for 3.4 GHz lots must correspond to at least the bidder's MR;
 - b) if it wishes to withdraw the standing high bid status of bids for a particular lot type that it has made in a previous round. This is only possible if the bidder has not used withdrawals in 5 previous rounds, it holds standing high bids, and it is a partial standing high bidder in respect of those bids. The combination of new bids in the round and, where a bidder has not submitted new bids for either lot type, the standing high bids assigned at the end of the most recent round for that lot type cannot exceed the overall spectrum cap;
 - c) if it wishes to request to carry forward its eligibility limit (this is only possible if an eligibility event has not occurred on three occasions, if the bidder is using a number of eligibility points which is smaller than the bidder's eligibility limit in the round and if it is not submitting any bids and/or withdrawals). This will also not be available for bidders in the first principal stage round;
- send the completed bid form to the auction server, so that the bid can be checked for validity against the Regulations;
- provided that the submission is valid according to the Regulations, confirm the submission using the confirmation form provided in the bidder interface of the EAS.

A13.48 The submission process is only completed when the bidder confirms its submission. Submissions sent to the server to check validity but not confirmed will be discarded by the EAS.

A13.49 Upon receipt of a valid submission, the EAS interface will provide a confirmation page. Conversely, if the submission process fails, the EAS interface will revert to the bid form. It is the responsibility of the bidder to check (through its bidder interface) that its submission has been successfully received by the auction server, and to alert Ofcom if it suspects any problems have occurred.

A13.50 Once the auction server has received a confirmation of a valid submission in a round, the bidder will not be able to revise or withdraw this submission, or submit any further bid decisions in respect of that round.

Bidding for lots when the bidder holds standing high bids

A13.51 Bidders may not submit any bids for lots in a lot type from which they are, at the same time, withdrawing existing standing high bids.

A13.52 After the first round, a bidder holding standing high bids in a lot type may submit further bids for that lot type. However:

- If the round price for that lot type has *increased* relative to the round price of the bidder's standing high bids, that bidder may only submit bids at the new round price if it is bidding for at least as many lots as it holds standing high bids on. If a bidder submits bids at the new price level, then the bidder's standing high bids at the earlier price level will be discarded (regardless of whether the new bids become standing high bids, and independently of the bids submitted by other bidders); or
- Conversely, if the round price for that lot type has *not increased* relative to the round price of the bidder's standing high bids, that bidder may only submit bids for strictly more lots than the number of lots on which it holds standing high bid status. If a bidder submits new bids for that lot type, any standing high bids held by the bidder will be cancelled. Therefore:
 - i) the bidder must specify the total number of lots it wishes to bid for at the prevailing round price; and
 - ii) as previous standing high bids are cancelled, there is no guarantee that the bidder will hold any standing high bids after bids for the round have been processed.

Round prices

A13.53 For each round, Ofcom will specify the round price per lot for each lot type.

A13.54 In the first round, the round price for each lot type will be the respective reserve price. These will be £10m per 2.3 GHz lot and £1m per 3.4 GHz lot.

A13.55 In subsequent rounds:

- the round price for a lot type will increase if the number of standing high bids for that lot type with a price that is equal to the round price in the most recent round is equal to the total number of lots available in that lot type; and
- otherwise, the round price for the lot type will remain unchanged.

A13.56 Therefore, round prices will not decrease over the course of the rounds.

A13.57 The amount of the increase in round prices, when applicable, will be determined at Ofcom's discretion and may vary across lot types and across rounds.

A13.58 We expect round prices to be specified in whole thousands of pounds.

Determination of standing high bids

A13.59 At the end of each round, the EAS will determine which bids for each lot type have standing high bid status. Standing high bids are determined for each lot category independently.

A13.60 To do so, the EAS will firstly consider the following bids:

- i) the standing high bids in the lot type at the beginning of the round that have not been cancelled during the round (as a result of a withdrawal, or a standing high bidder submitting new bids in respect of that lot type); and
- ii) the new bids in respect of that lot type submitted during the round.

A13.61 Secondly, the EAS will then order the bidders who made those bids as follows:

1. first, take in random order those bidders whose bids are at the current round price (regardless of whether they maintained previous standing high bids or submitted new bids in the current round);
2. next, take in random order those bidders who (i) maintained standing high bids with a bid amount lower than the current round price and (ii) are standing high bidder on the number of lots they bid for in that lot type when they submitted these bids;
3. finally, if there is a bidder who (i) maintained its standing high bids with a bid amount lower than the current price and (ii) is a partial standing high bidder, that bidder is placed last.

A13.62 Finally, the EAS will then select the standing high bids by taking the bids submitted by each of these bidders in the order established in the previous step, until there are no more lots available.

A13.63 This approach ensures that:

- i) there can be at most one partial standing high bidder in each lot type; and
- ii) bids at the same price level are treated equally (regardless of whether they have been submitted in an earlier or later round), except for standing high bids from a partial standing high bidder, which is outbid first.

Box 1: Example of the determination of standing high bids

Consider the 2.3 GHz lot type, with four lots available and four bidders (A, B, C and D). Suppose that the principal stage progresses as shown by the table below. The bids and prices shown are purely illustrative.

Round	Price	Round bids				Order	Standing high bids at the end of the round [price]			
		A	B	C	D		A	B	C	D
1	10	3	3	2	1	BDAC	-	3 [10]	-	1 [10]
2	11	2	-	2	1	ADCB	2 [11]	-	1 [11]	1 [11]
3	12	-	2	E	-	BDAC	1 [11]	2 [12]	-	1 [11]
4	12	-	-	2	1	DBCA	-	2 [12]	1 [12]	1 [12]
5	13	-	-	-	-	BCD	-	2 [12]	1 [12]	1 [12]

At the end of **round 1**, there are four bidders who have bid at the current round price. The EAS generates a random order for this group of bidders (BDAC). There are no other bidders to consider. The EAS will select standing high bids by taking the bids submitted by each of these bidders in order. Bidder B bid for 3 lots and becomes standing high bidder on 3 lots. The next-ranked bidder, D, bid for 1 lot and becomes standing high bidder on 1 lot. There are no residual lots available, so A and C do not become standing high bidders.

In **round 2**, the round price increases because Ofcom was able to assign four standing high bids at the round price of 10. Bidders A, C and D submit new bids (although bidder D would not need to submit a new bid at the new round price, as it is a standing high bidder at the previous round price, it may do so if it wants).

The EAS will first consider the bids at the current round price and generates a random order for the corresponding group of bidders (ADC).

Bidder B has maintained standing high bids with a bid amount lower than the current round price and will only be considered afterwards.

Therefore, the overall order of bidders is ADCB. Bidder A bid for 2 lots and becomes standing high bidder on 2 lots. The next-ranked bidder, D, bid for 1 lot and becomes standing high bidder on 1 lot. The next-ranked bidder, C, bid for 2 lots but there is only one residual lot available, so C becomes a partial standing high bidder on 1 lot. Bidder B is not standing high bidder on any lots.

In **round 3**, the price again increases because Ofcom was able to assign standing high bid status to four lots at the round price of 11. Bidder B bids at the new price, bidder C submits a request to carry forward its eligibility limit (we refer to this as "E" in the table above. We will explain how this request works later in this annex) and the other bidders simply maintain their standing high bids.

Bidder B is the only bidder to have bid at the current round price, so B will be considered first by the EAS.

Then, the EAS will consider bidders who maintained standing high bids with a bid amount lower than the current round price and who are standing high bidders on the number of lots they bid for when they submitted those bids – this applies to A and D. The EAS generates a random order for this group of bidders (DA).

Finally, any bidder who maintained standing high bids but was standing high bidder on strictly fewer lots than it bid for in the round in which it submitted its standing high bids is ordered last by the EAS – this applies to C.

Therefore, the overall order of bidders is BDAC. Bidder B bid for 2 lots and becomes standing high bidder on 2 lots. The next-ranked bidder, D, was standing high bidder on 1 lot and retains this standing high bid. The next-ranked bidder, A, was standing high bidder on 2 lots but there is only 1 residual lot available, so A is made standing high bidder on only 1 lot. Bidder C is not standing high bidder on any lots.

In **round 4**, the price is unchanged because Ofcom was unable to assign four standing high bids at the price of 12. Bidders C and D submit new bids.

Bidders B, C and D now have bids at the current round price. The EAS generates a random order for this group of bidders (BDC).

Bidder A maintained a standing high bid with a bid amount lower than the current round price, and was standing high bidder on strictly fewer lots than it bid for in the round in which it submitted its standing high bids, so A is ordered last.

Therefore, the overall order of bidders is BDCA. Bidder B was standing high bidder on 2 lots and retains these standing high bids. The next-ranked bidder, D bid for 1 lot and becomes standing high bidder on 1 lot. The next-ranked bidder, C, bid for 2 lots but there is only 1 residual lot available, so C becomes standing high bidder on 1 lot. Bidder A is not standing high bidder on any lots.

In **round 5**, the price goes up to 13. No bidder places bids at the new round price, nor submits a request to carry forward its eligibility limit or withdraws standing high bids. At the end of the round, we consider the bidders that maintained their standing high bids from the most recent round. These are bidders B, C and D. The overall order of bidders is BCD. Each bidder retains their standing high bids from the round before.

Let us suppose there are also no bids or withdrawals either in 3.4 GHz. As will be explained later in the annex, this means the principal stage ends. The standing high bids become winning bids. The base price for the lots won by each bidder is 12.

Eligibility rule

A13.64 The number of eligibility points used by a bidder in a round cannot exceed the bidder's eligibility limit for that round. To assess a bidder's compliance with the eligibility rule, we need to firstly calculate that bidder's eligibility limit in the relevant round.

A13.65 Each bidder will start each round with a given eligibility limit. In the first round, this will be determined by the amount of the bidder's 'additional deposit'. In subsequent rounds, the bidder's eligibility limit will be equal to the number of eligibility points used by the bidder in the most recent round provided that an eligibility event did not occur in that round.

A13.66 The number of eligibility points used by a bidder in a round is calculated as:

- i) the sum of the eligibility points assigned to all lots for which the bidder submits bids in the round; plus
- ii) where the bidder does not submit bids for a particular lot type in that round, the sum of eligibility points assigned to all lots in that lot type for which the bidder held a standing high bid at the end of the most recent round, provided that the standing high bid status of those bids was not withdrawn by the bidder in the round (more on withdrawals in the next section).

A13.67 As explained at paragraph A13.10 above, each 2.3 GHz lot will be assigned four eligibility points, while each 3.4 GHz lot will be assigned one eligibility point. Accordingly, where a bidder submits three bids in a round for 3.4 GHz lots and does not submit any bids for 2.3 GHz lots (but has standing high bids for two 2.3 GHz lots from the previous round), then that bidder will have used 11 eligibility points in that round (i.e. $(3 \times 1) + (2 \times 4)$).

Eligibility events

A13.68 Eligibility events result in bidders preserving their eligibility limit from one round to the next, even though they used a number of eligibility points which is smaller than their eligibility limit. There is a limit of 3 eligibility events per bidder in the course of the principal stage.

A13.69 An eligibility event may occur as a result of either:

- A bidder submitting a valid request to carry forward its eligibility limit in its principal stage form; or
- The EAS automatically carrying forward the bidder's eligibility limit when a bidder:
 - a) does not submit a valid principal stage form within a round; and
 - b) the number of eligibility points used by the bidder from standing high bids is less than its eligibility limit for the round; and
 - c) the limit of 3 eligibility events is not met.

A13.70 The EAS will not make any other default submissions.

A13.71 In turn, a bidder's request to carry forward its eligibility limit will be valid only if:

- a) the number of eligibility points used by the bidder from standing high bids is less than its eligibility limit for the round;
- b) the bidder does not submit any new bids or withdraw any standing high bids in the same round;

- c) the limit of 3 eligibility events is not met.

A13.72 An eligibility event cannot happen in the first round.

A13.73 To prevent the EAS from carrying forward the bidder's eligibility limit automatically, bidders may submit a decision not to place any new bids in the round. When they check the selection containing no new bids, the EAS will inform that they will lose eligibility if they submit it.

Withdrawal of standing high bids

A13.74 Partial standing high bidders in a lot type may withdraw all of their standing high bids in that lot type in the course of a round. Full standing high bidders in a lot type – that is, bidders that hold standing high bids for exactly the same number of bids they placed in that lot type – may not withdraw their standing high bids in that lot type.

A13.75 By withdrawing the standing high bid status of its bids in a band, the bidder frees up eligibility points which can be used to place bids in the other band.

A13.76 A bidder may withdraw all its standing high bids in the lot type where it is a partial standing high bidder, while maintaining any other standing high bids in a different lot type. However, a bidder may not withdraw only some of their standing high bids in a given lot type.

A13.77 A bidder may submit its withdrawals along with bids for a different lot type, but may not withdraw standing high bids and bid at the same time for lots of the same lot type.

A13.78 A bidder may only withdraw standing high bids in at most five rounds during the auction.

A13.79 In the event that lots remain unallocated (that is, with no standing high bids assigned to them) at the end of the last principal stage round as a consequence of a withdrawal, those lots will be offered to the bidder who withdrew. The offer price per lot will be equivalent to twice the round price of the withdrawn bids.

A13.80 The bidder will be given the choice to accept or refuse the offer of those lots at the grant stage and, if it does refuse that offer, the amount payable by that bidder will be equivalent to the original price of the withdrawn bids for which it is liable (i.e. at the round price, as opposed to twice the round price).

Information released at the end of each principal stage round

A13.81 At the end of each round, the EAS will process the submissions in the round and determine whether a further round is needed. In the event that a further round is needed, the EAS will determine which lot types require a price increase. Information about a completed round will be made available to bidders only after the auctioneer approves the results for the round.

A13.82 The 'active bids' in each lot type in a given round are defined to be, for the purposes of the description in this document:

- the standing high bids in that category at the beginning of the round that have not been cancelled (as a result of a withdrawal, or the standing high bidder submitting new bids in that category); and
- the new bids for lots in that category submitted in the round.

A13.83 'Excess demand' is a concept defined in the Regulations. Excess demand for lots in a lot type in a given round is the total bandwidth corresponding to all active bids in that category minus the total bandwidth corresponding to all the lots available in that category.

A13.84 If a further round is needed, the following information will be made available to each bidder on the EAS interface:

- the number of bids submitted by the bidder in the most recent round;
- the number of bids with standing high bid status currently held by the bidder and the respective round prices;
- whether the bidder withdrew the standing high bid status of any of its bids in the most recent round;
- the number of rounds in which the bidder may still withdraw the standing high bid status of its bids;
- the number of times an eligibility event can occur in respect of that bidder;
- the bidder's eligibility limit for the next principal stage round;
- the bidder's financial exposure⁷²¹ after the end of the most recent round;
- for each lot type, after the first round, the smallest positive multiple of 20 MHz that is strictly greater than excess demand in that lot type in the most recent round (i.e. whether excess demand for that lot type in the round was less than 20 MHz, 40 MHz, 60 MHz, 80 MHz, etc.).

A13.85 At this stage, no further information will be released about the bids submitted by other bidders.

A13.86 If the principal stage has ended, the following information will be made available to each bidder on the EAS interface:

- a message informing the bidder that the principal stage has ended; and

⁷²¹ Broadly speaking, a bidder's financial exposure is the sum of (i) the number of standing high bids held by the bidder in each lot type at the end of the round, multiplied by the round price at which the bids were made, and (ii) the number of withdrawn standing high bids which would be deemed winning bids if that principal stage round was the final principal stage round, multiplied by the round price at which the bids for those lots were made. For clarification, this is not the price at which the lots would be offered to the bidder in the event that it won them, but the price which would be paid if the bidder was to refuse the withdrawn lot licence containing these lots. The price the bidder would pay if it was to reject the withdrawn lot licence, called "refusal payment", might also include an additional price from the assignment stage.

- the names of the winning principal stage bidders and, in respect of each of them, the number of lots won in each lot type and the associated round price for those winning bids.

A13.87 The EAS will provide the functionality to view and download the information provided after each completed round, once approved by the auctioneer.

End of the bidding process

A13.88 The bidding process ends after the first round in which no bids or withdrawals are submitted, and where no eligibility event occurs.

Determination of winning principal stage bids

A13.89 At the end of the bidding process, bids with standing high bid status will become winning principal stage bids, except where a bidder has fewer standing high bids for 3.4 GHz lots than its MR.

A13.90 In the event that there are unallocated lots as a result of a withdrawal of standing high bid status in the course of the principal stage, the bidder who last withdrew and caused those lots to be unallocated will win those lots. This is the case notwithstanding any MR specified by that bidder.

Determination of base prices

A13.91 The Regulations introduce the concept of the 'base price' for winning principal stage bids. This is intended to reflect a bidder's total liability for those bids, as at the end of the principal stage. In particular:

- for each standing high bid that became a winning principal stage bid, the base price is referred to as the 'base price A'. It will be equal to the round price at which the winning bid was submitted; and
- for each withdrawn standing high bid that became a winning principal stage bid, the base price is referred to as the 'base price B'. It will be equal to the twice the round price of that bid.

Box 2: Worked up example of principal stage

This example takes the point of view of a particular bidder and assumes the same spectrum packaging of the award (four lots available in 2.3 GHz and thirty lots in 3.4 GHz), a number of bidders and the principal stage progressing as shown. The bids and prices are purely illustrative.

Round	2.3 GHz lot type				3.4 GHz lot type				Financial Exposure	Eligibility points used
	Price	Decision	Outcome	Number of SHBs	Price	Decision	Outcome	Number of SHBs		
1	10	No bid	No SHB	4	3	Bid, 16 lots	SHB, 6 lots	30	18	16
2	11	Bid, 3 lots	SHB, 3 lots	4	4	Withdraw	No SHB	24	51	12
3	12	No bid	No SHB	4	4	No Bid	No SHB	26	12	12
4	13	Bid, 3 lots	SHB, 2 lots	4	4	No Bid	No SHB	28	32	12
5	14	No bid	SHB, 2 lots	4	4	No Bid	No SHB	28	32	8

In **round 1**, the bidder bids for sixteen 3.4 GHz lots and becomes standing high bidder on 6 lots of that lot type. It used 16 eligibility points, and so its eligibility limit for round 2 will be 16. The bidder's financial exposure is given by its standing high bids. At the price of 3, the financial exposure is therefore 18 (i.e. 6×3).

In **round 2**, as a partial standing high bidder in 3.4 GHz, the bidder is given the choice to withdraw its standing high bids in that lot type. Let us assume it exercises that option. Simultaneously, it submits 3 new bids for 2.3 GHz spectrum, becoming standing high bidder on 3 lots. Let us assume it has not been possible to assign standing high bid status on all lots in the 3.4 GHz lot type at the end of the round. The bidder used 12 eligibility points (3 lots in 2.3 GHz multiplied by 4 eligibility points). This will set a lower eligibility limit for round 3 (12 points).

The bidder's financial exposure at the end of round 2 is given by the sum of its standing high bids and any provisionally unallocated lots as the result of its decision to withdraw. The bidder has 3 standing high bids in 2.3 GHz at the price of 11, which equals 33. There are 6 unallocated lots in 3.4 GHz and therefore the bidder is liable for those 6 lots at the price of 3, that is 18. In total, its financial exposure as defined earlier is 51.

In **round 3**, the bidder is fully outbid in 2.3 GHz. Also, at the end of the round there are fewer provisionally unallocated lots in 3.4 GHz – 4. The bidder's financial exposure is $4 \times 3 = 12$. The bidder used 12 eligibility points (given by the 3 standing high bids in 2.3 GHz at the beginning of the round).

In **round 4**, the bidder bids again for three 2.3 GHz lots at the price of 13 and becomes standing high bidder on 2 lots. There are now 2 provisionally unallocated lots in 3.4 GHz. The bidder's financial exposure is $2 \times 13 = 26$, plus $2 \times 3 = 6$, in total 32. The bidder used 12 eligibility points.

In **round 5**, the bidder does not submit new bids for 2.3 GHz nor 3.4 GHz. Let us assume this is the last round of the principal stage. At the end of the round, the bidder became standing high bidder on 2 lots in 2.3 GHz and there were still 2 unallocated lots in 3.4 GHz. Bidder's total base price A (the base price for its standing high bids which became winning bids) is 26 (i.e. 2×13) and the bidder's total base price B (the base price for its withdrawn bids which became winning bids) is 12 (2 lots at twice the price of 3 at which the bidder bid). If the bidder refuses the withdrawn lot licence at the end of the assignment stage, its refusal payment will be 6 (2 lots at price of 3, and assuming there is no additional price in the assignment stage for this type of spectrum).

The assignment stage

A13.92 The specific frequencies assigned to bidders who have won lots in the principal stage will be determined in the assignment stage.

A13.93 The assignment of specific frequencies will be determined independently for each band.

Possible combinations of assignment stage options

A13.94 For the 2.3 GHz band, Ofcom will only consider combinations of assignment stage options in which each bidder is assigned a contiguous frequency block that corresponds to the bandwidth it won in the principal stage, and in which any unallocated spectrum forms a contiguous frequency block.

A13.95 For the 3.4 GHz band, it may not be possible to assign to each winner as a contiguous block for all of the frequencies it has won in the principal stage if the pre-existing licence holder in the 3.4 GHz band does not apply for a replacement licence. However, Ofcom will prioritise combinations of assignment stage options in which unnecessary fragmentation of assignments is avoided. Accordingly, Ofcom will only consider those combinations of assignment stage options in which the unassigned frequencies in each sub-band (i.e. above or below the pre-existing licence holder's lower block) form a contiguous frequency block. In addition, the range of assignment stage plans may be narrowed in accordance with the following procedures:

- if there are combinations of assignment stage options in which each bidder is assigned a single contiguous frequency range, then only these assignment options will be considered;
- if it is not possible to assign a single contiguous frequency range to each bidder, but there are combinations of assignment stage options in which each bidder who receives non-contiguous frequencies obtains its frequencies in two contiguous frequency blocks of at least 20 MHz each, then only these assignment options will be considered;
- of the remaining combinations of assignment stage options, only those in which the number of winners receiving non-contiguous frequencies is minimised will be considered.

A13.96 If there is only one assignment that meets these requirements, then bidders will be assigned the frequencies corresponding to the spectrum they won in the relevant lot type in accordance with this assignment. If there are multiple assignments that meet these requirements, then bidders who are assigned alternative frequencies in different assignments will be invited to submit bids for these alternative options.

A13.97 If a bidding process for the assignment stage is needed, Ofcom will schedule a single round of bidding (the 'assignment round') in which the relevant bidders may submit bids (the 'assignment stage bids') for their preferred assignment stage options. Ofcom would determine the assignment that would allow us to maximise the value of accepted bids. Bidders may then be required to pay a price (the 'additional price'), on top of their prices from the principal stage, for the frequencies they are assigned (if they submitted a bid for this option and other bidders had expressed a preference for an option that is not compatible with this). Bidders do not have to submit assignment stage bids to be assigned spectrum they won in the principal stage. Participation in the bidding process of the assignment stage is optional.

Assignment stage bids

A13.98 The 'assignment stage options' for each bidder are determined by Ofcom in accordance with our determination of possible combinations of assignment stage options.

A13.99 If there are several possible assignment stage options for a band, then at least two bidders will have multiple assignment stage options in that band. Any such bidders will have the opportunity to express their preferences within those options in the form of assignment bids.

A13.100 An assignment stage bid consists of:

- an assignment stage option; and
- a bid amount, specified in pounds, and which must be in whole thousands of pounds and at least zero.

A13.101 Submitting an assignment stage bid establishes a commitment to pay an additional price that would not exceed the bid amount in the event that the bidder is assigned the frequencies specified in the corresponding option.

Scheduling of the assignment stage round

A13.102 When the assignment stage round is scheduled, the following information will be made available to each bidder:

- the start and the end time for the round;
- the assignment stage options that the bidder may bid for.

Bid submission

A13.103 When the assignment stage round is in progress, participating bidders may submit a single list of assignment stage bids using the EAS.

A13.104 The interface of the EAS will provide an assignment stage form that lists all assignment stage options available to the bidder.

A13.105 To submit its list of assignment stage bids, a bidder will need to:

- enter the bid amount for each one of the assignment stage options it wishes to bid for in its assignment stage form (the bid amount for any options left blank will be set to zero);
- send the bid form to the auction server, so that it can be checked for validity against the Regulations;
- provided that all bids in the list are valid according to the Regulations, confirm submission of its assignment stage bids using the confirmation form provided by the bidder interface of the EAS.

A13.106 The submission process for a bidder will be blocked if any of the assignment stage bids in the list are invalid. In such a case, none of the assignment stage bids made by that bidder will be accepted, unless the bidder amends its list and completes the submission process of a valid list of assignment stage bids.

A13.107 The process of submitting a list of assignment stage bids is only completed when the bidder confirms the submission. A list sent to the server to check for validity but not confirmed will be discarded by the EAS.

A13.108 Upon receipt of a valid submission of a list of assignment stage bids, the EAS interface will provide a confirmation page, listing the assignment stage bids received by the EAS. Conversely, if the assignment stage bids submission process fails, the EAS interface will revert to the assignment stage form. It is the responsibility of the bidder to check (through its bidder interface) that its list of assignment stage bids has been successfully received by the auction server, and to alert Ofcom if it suspects any problems have occurred.

A13.109 Once the auction server has received a confirmation of a valid submission of a list of assignment stage bids in the assignment round, the bidder will not be able to revise or withdraw this submission, or submit any further assignment stage bids.

A13.110 Any bidder who fails to submit a list of assignment stage bids before the end of the assignment stage round will lose the opportunity to submit assignment stage bids. In this case, the bid for all of its assignment stage options will be set to zero by default.

Determination of winning assignments

A13.111 The determination of winning assignments stage bids will be calculated independently for each frequency band.

A13.112 For each frequency band, the EAS will sum the bid amounts of the bids that can be accepted in each alternative possible assignment plan. The winning assignment plan will be the one that yields the greatest value of accepted bids. If there are multiple assignment plans that yield the greatest value, one of these will be selected as the winning assignment plan at random.

Determination of additional prices

A13.113 The determination of additional prices is calculated independently for each frequency band. The total additional price to be paid by a bidder will be equal to the sum of its 2.3 GHz additional price (if any) and its 3.4 GHz additional price (if any) it has to pay.

A13.114 Additional prices to be paid by winning bidders for the specific frequencies awarded to them in the assignment stage are based on the concept of opportunity cost.

A13.115 For each band, the opportunity cost of assigning a subset of bidders their frequencies in the winning assignment plan is calculated as the difference between:

- the highest value of bids that could be achieved across all alternative assignment plans if all the bids from the bidders in the subset were set to zero; and
- the sum of bid amounts of bids that are accepted from bidders that are not included in the subset in the winning assignment plan.

A13.116 The standalone opportunity cost of a bidder is the opportunity cost of the subset of bidders that includes only this bidder.

A13.117 For a given frequency range, the additional prices must satisfy the following conditions:

- the additional price for each bidder cannot be negative;

- the additional price for each bidder cannot exceed the bid amount specified by the bidder for the assignment option it is assigned in the winning assignment plan;
- the sum of additional prices for each subset of bidders (including subsets containing a single bidder, and the subset containing all bidders) must be at least the joint opportunity cost for that subset of bidders;
- the total sum of additional prices must be the smallest across all possible sets of prices that meet the three conditions above.

A13.118 If there are multiple combinations of prices (one for each winning bidder) that satisfy the conditions above, then the additional prices will be the unique combination of prices that minimises the sum of squares of the differences between each bidder's additional price and their standalone opportunity cost across all sets of prices that satisfy all four the conditions above.

Frequencies associated with the withdrawn lot licence

A13.119 If a bidder won spectrum in a frequency band by virtue of being a standing high bidder at the end of the last principal stage round, and also by virtue of having withdrawn standing high bids, the withdrawn lot licence will include the lower frequencies included in that bidder's winning assignment stage option.

A13.120 For example, let us assume a bidder won 20 MHz of 3.4 GHz spectrum by being a standing high bidder at the end of the last principal stage round and 10 MHz by having withdrawn in 3.4 GHz. Also, let us assume the assignment stage winning option forms a contiguous block of 30 MHz, from 3450 to 3480 MHz. In that case, the lower frequencies (3450-3460 MHz) will be part of the withdrawn lot licence, and the upper frequencies (3460-3480 MHz) will be part of the 3.4 GHz licence.

Deposits

Top up deposits during principal stage

A13.121 At any point during the principal stage, Ofcom may require a bidder to increase its deposit up to an amount equal to the highest financial exposure of the bidder from previous rounds.

A13.122 In the event of a deposit call, Ofcom would specify a deadline for bidders to make any additional deposits, and provide details of how to make the additional deposit.

A13.123 If the bidder does not provide Ofcom with the top up deposit as required, it will not be allowed to submit a principal stage form in the next principal stage round nor in any subsequent principal stage round. In addition, the bidder will also be unable to submit an assignment stage form in the assignment stage and shall be deemed to have made a valid bid for a value of zero pounds for each of its assignment stage options.

A13.124 The bidder will not be excluded from the award process for not having provided the sufficient top up deposit, and it will still win any bids and withdrawn bids (which have already been made) that become winning bids. However, the bidder will not be granted a licence for its winning bids unless it provides Ofcom with the total auction sum payable, following the end of the assignment stage.

Required final principal stage deposit

A13.125 At the end of the principal stage, by a deadline to be specified by Ofcom, bidders need to have on deposit at least the sum of the total base price A in 2.3 GHz and in 3.4 GHz, and one half of the total base price B in 2.3 GHz and 3.4 GHz.

A13.126 If the bidder does not provide Ofcom with the required final principal stage deposit, it will not be excluded from the award process. However, it will not be allowed to submit assignment stage bids and will be deemed to have made valid assignment stage bids with a value of zero pounds for all of its assignment stage options.

Required assignment stage deposit

A13.127 During the assignment stage, by a deadline to be specified by Ofcom, bidders need to have on deposit at least the sum of the required final principal stage deposit (see above) and the amount which is the bidder's highest 2.3 GHz assignment stage bid for a 2.3 GHz assignment stage option, and the bidder's highest 3.4 GHz assignment stage bid for a 3.4 GHz assignment stage option.

A13.128 If the bidder does not provide Ofcom with the assignment stage deposit, all the assignment stage bids submitted by the bidder (if any) will be deemed to be invalid.

A13.129 As a result, the bidder will be deemed to have made a valid assignment stage bid with a value of zero pounds for all available assignment stage options.

Total auction sum

A13.130 After the end of the assignment stage, Ofcom shall notify bidders of their total auction sum payable. If a bidder has accepted any withdrawn lot licences, this amount will be the sum of a bidder's licence fees for its 2.3 GHz and/or 3.4 GHz licences, and its licence fees for the withdrawn lot licences. If a bidder has refused any withdrawn lot licences, this amount will be the sum of a bidder's licence fees for its 2.3 and/or 3.4 GHz licences, and the refusal payment for the withdrawn lot licences.

A13.131 Where a bidder's total auction sum is less than the amount it has on deposit, Ofcom will specify a deadline by which it must pay the difference between the two amounts.

A13.132 A bidder that does not provide the total auction sum payable by the deadline shall not be entitled to the grant of any licences, nor a refund of its deposit. It shall also remain liable to pay the difference between its deposit and its total auction sum payable.

Withdrawn lot licence(s)

A13.133 After the assignment stage, bidders that won spectrum by having withdrawn the standing high bid status of their bids will be notified by Ofcom, and asked to indicate whether or not they wish to accept a withdrawn lot licence(s)⁷²² in respect of that spectrum.

⁷²² Where there is unallocated spectrum in both the 2.3 GHz and 3.4 GHz bands as a result of withdrawals, there will be separate withdrawn lot licences for each lot type. If the same bidder is

A13.134 Where a bidder indicates that it does not wish to accept a withdrawn lot licence, it must pay the refusal payment. This is half the total base price B (i.e. the round price for those withdrawn bids, as opposed to twice the price), plus any additional prices, if relevant.⁷²³

A13.135 Where a bidder accepts a withdrawn lot licence, it must pay the total base price B (i.e. twice the round price for those withdrawn bids), plus any additional prices, if relevant.⁷²⁴

Extraordinary events

A13.136 Ofcom retains powers to address extraordinary events that might otherwise compromise the auction, including:

- rescheduling a round that has been scheduled and has not yet started;
- rescheduling the end of a round in progress;
- cancelling a round in progress;
- cancelling one or more completed rounds and rolling back to a previous round;
- suspending the auction;
- cancelling the auction;
- cancelling some or all bids submitted by one or more bidders in earlier rounds; and
- excluding one or more bidders from the auction.

A13.137 Bidders who breach the Regulations may forfeit part or all of their deposit.

Information released at the end of the auction

A13.138 The auction ends with the completion of the grant stage. At this point, the following information will be released to all bidders:

- the frequencies assigned to each bidder that has been awarded spectrum; and
- the price paid by each bidder that has been awarded spectrum, including a breakdown of that bidder's base price and any additional prices.

A13.139 Ofcom will also publish a range of information on its website, including:

- the names of the winning bidders and the frequencies won by those bidders (and licence fees paid);

offered the separate withdrawn lot licences for each lot type it must either accept both or reject both licences.

⁷²³ Please see Regulation 99 (3) and (4).

⁷²⁴ See reference above.

- the names of the winning bidders (if any) that refused a withdrawn lot licence(s), including details of the frequencies that they refused and their refusal payment;
- the names of those winning bidders (if any) that failed to pay their total auction sum on time and who therefore failed to obtain licences under the auction, despite making winning bids; and
- details of all valid principal stage bids, withdrawals of standing high bid status and occurrences of an eligibility event during the auction.

Annex 14

Glossary of terms

3G	Third generation mobile phone standards and technology
4G	Fourth generation mobile phone standards and technology
5G	5G is the term used to describe the next generation of wireless networks beyond 4G LTE mobile networks. 5G is expected to deliver faster data rates and better user experience. Technical standards are still under development and are likely to include both an evolution of existing and new radio technologies.
AIP	Administrative Incentive Pricing
ALF	Annual Licence Fees
ARPU	Average revenue per user
BT/EE	A UK Mobile Network Operator (MNO)
CEPT	The European Conference of Postal and Telecommunications Administrations
CFI	Call for Inputs
CK Hutchison	Parent company of H3G
CMA	Competition and Mergers Authority
Communications Act	The Communications Act 2003
CPI	The Consumer Price Index (CPI) is a measure of inflation. It measures the changes in the price level of consumer goods and services purchased by households. The most significant item excluded in the CPI, but included in the RPI, is mortgage interest rate payments.
DCMS	Department for Digital, Culture, Media and Sport
EAS	Electronic Auction System
EC	European Commission
ECC	Electronic Communications Committee – One of the three business committees of the European conference of Postal and Telecommunications.
EIA	Equality Impact Assessment
EU	European Union

FDD	Frequency Division Duplex – a technology that deals with traffic asymmetry between uplink and downlink where separate frequency bands are used for send and receive operations in paired spectrum
GHz	Gigahertz. A unit of frequency of one billion (10^9) cycles per second
H3G	Hutchinson 3G UK Ltd – trading as Three - an MNO
HHI	Herfindahl-Hirschman Index, a measure of market concentration
ITU	International Telecommunications Union - Part of the United Nations with a membership of 193 countries and over 700 private-sector entities and academic institutions. ITU's headquarters are in Geneva, Switzerland.
LSA	Licence shared access of radio spectrum
LTE	Long Term Evolution. Part of the development of 4G mobile systems that started with 2G and 3G networks.
MHz	Megahertz. A unit of frequency of one million cycles per second.
MNO	Mobile network operator. We use this term to mean a mobile operator that controls access to a radio area networks covering the large majority of the UK population. We use this term to exclude those operators that have mobile networks that only cover specific areas rather than providing national coverage
Mobile Trading Regulations	Wireless Telegraphy (Mobile Spectrum Trading) Regulations 2011
MOD	The Ministry of Defence
MVNO	Mobile virtual network operator
NAO	National Audit Office
NRA	National Regulatory Authority. The relevant communications regulatory body for each country in the EU. Ofcom is the NRA for the United Kingdom.
O2	A UK MNO
OEM	Original Equipment Manufacturer
Ofcom	The Office of Communications
PES	A satellite Permanent Earth Station
PSSR	Public Sector Spectrum Release
RAN	Radio Access Network

RED	Radio Equipment Directive – a new EU Directive with requirements for radio transmitters and receivers
RF	Radio Frequency
RSPG	Radio Spectrum Policy Group - European advisory body on spectrum issues.
SDL	Supplementary Down Link – where unpaired spectrum is used for downlink transmission only
TDD	Time Division Duplex – a technology that deals with traffic asymmetry where the uplink is separated from the downlink by the allocation of different time slots in the same frequency band in unpaired spectrum.
TD-LTE	Time Division Long Term Evolution. Sometimes referred to as Long Term Evolution Time-Division Duplex.
UK Broadband	A UK supplier of fixed wireless mobile services with spectrum holdings in the 3.4 GHz band, now owned by H3G