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Auction format for the award of the 700 MHz and 3.6-3.8 GHz spectrum bands

Prepared by NERA on behalf of Telefónica UK for submission to Ofcom

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NON-CONFIDENTIAL VERSION

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Preface

Telefónica UK has asked NERA to review Ofcom's proposed auction format for the award of the 700 MHz and 3.6-3.8 GHz spectrum bands (hereafter "the award"), as set out in the consultation document dated 18 December 2018.[1] Our comments are primarily focused on Section 7 (Auction Design) and Annex 16 (Illustrative Auction Procedures), although where appropriate we also comment on related issues, including the definition of coverage obligations (Section 4), competition assessment (section 5) and defragmentation of the 3.4-3.8 GHz band (Section 6). We also comment on the separate but related issue of how administrative prices should be set for 3.6-3.8 GHz spectrum, which is the subject of a parallel Ofcom consultation.[2] Finally, we provide some comments on Ofcom's draft regulations for the award.[3]

Telefónica requested this review because they have grave concerns about the auction design, which is based around the combinatorial clock auction (CCA) format, proposed by Ofcom. Telefónica is sceptical about the merits of using the CCA format in general but have particular concerns about its use for this award, given the differences between the two available spectrum bands and the highly asymmetric position of the four UK MNOs in their existing spectrum holdings. While Telefónica appreciates the rationale for the proposal to repurpose auction revenues to fund otherwise uneconomic coverage obligations, it is concerned that the auction mechanism proposed by Ofcom could have unintended consequences, i.e. that it could lead to strategic bidding or create risk for bidders that leads to inefficient auction outcomes.

Telefónica's views are in part influenced by its very different experiences bidding in the last two UK awards. In 2013, the company participated in the UK 4G auction, which used a CCA format. It won 2x10 MHz of 800 MHz spectrum but failed to win any 2.6 GHz spectrum, whereas a leading rival, EE (now BT), that already had larger spectrum holdings, secured 2x35 MHz in the 2.6 GHz band. This outcome was peculiar and almost certainly inefficient for reasons (…✂…). In sharp contrast, Telefónica – as widely expected, given its small spectrum holding – secured the largest quantity of frequencies in the 2018 PSSR Award, which used the SMRA format. It is Telefónica's view that the PSSR format delivered an allocation outcome that was broadly efficient.

The lead authors of this report are Richard Marsden and Dr Soren Sorensen. Between them, they have more than 30 years of experience working on auction design and bidder strategy related to spectrum auctions. In 2017, they co-authored a chapter on strategic

[1] Ofcom, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands, Consultation, 18 December 2018 (hereafter, "the Consultation".

[2] Ofcom, Annual Licence Fees for UK Broadband's 3.4 GHz and 3.6 GHz spectrum, 17 December 2018 (hereafter, the UKB ALF consultation).

[3] This is the subject of a separate consultation: Consultation: Ofcom, Notice of Ofcom's proposal to make regulations for the award of the 700 MHz and 3.6-3.8 GHz spectrum bands, 31 January 2019.

bidding in CCAs in the Handbook of Auction Design, published by Cambridge University Press.[4]

- **Richard Marsden** leads NERA's spectrum policy and auctions practice. Since 1999, he has advised bidders participating in spectrum auctions and assisted governments in designing spectrum auctions. He is exceptionally experienced with both the SMRA and CCA formats that Ofcom is considering for the award. From 2004-10, he was a lead member of the DotEcon team that advised Ofcom on the development of the CCA format and the second price sealed bid round assignment round. At NERA, he has advised bidders in more than a dozen auctions using the CCA format, as well as designing an auction using the CCA (Mexico 2016). He has also worked on more than 20 awards using the SMRA format, both as a designer and strategy advisor.

- **Dr Soren Sorensen** is an Associate Director in NERA's spectrum policy and auctions practice with more than 15 years' consulting experience. His work spans spectrum auctions in more than 25 countries, including auction design and auction implementation for regulators, as well as advice on bidding strategies for mobile operators. He has extensive experience with advising bidders in auctions using CCA, SMRA, clock, sealed bid and various hybrid auction formats. He has advised a client in the last three Danish spectrum auctions that all featured novel ways of incorporating coverage obligations in the auction design.

For the avoidance of doubt, while this review has been funded by Telefónica UK, the opinions expressed within are the independent views of the authors. They are based on our long experience of working on spectrum auctions, including both SMRAs and CCAs, including many awards involving coverage obligations.

[4] Bichler, M and Goeree, JK, Handbook of Spectrum Auction Design, 2017, Cambridge University Press, pp748-763.

1. Introduction

We have reviewed Ofcom's proposal for a single stage combinatorial clock auction (CCA) to award spectrum at 700 MHz and 3.6 GHz together with two nationwide coverage obligations. There are many aspects of the proposed award that are innovative and admirable. However, taken together, the rules proposed by Ofcom are not the best ones to fulfil its duty to deliver an efficient, pro-competitive allocation of spectrum. On the contrary, they expose both society at large and the participating bidders to undue risk of a highly inefficient allocation and/or grossly asymmetric prices.

The following are the minimal set of changes to Ofcom's rules that we believe are necessary to reduce such risks for all stakeholders:

- **Allocate 3.6 GHz using Ofcom's SMRA format in a separate auction stage that precedes the allocation of 700 MHz**. The 3.6 GHz and 700 MHz bands are not closely linked and selling them in the same bidding stage invites strategic bidding that could distort the final allocation. The scale of a combined auction also increases risk for bidders unnecessarily.

- **Precautionary spectrum caps of 80 MHz at 3.6 GHz and 40 MHz at 700 MHz.** This modest level of intervention is pro-competitive, as it would ensure at least two winning bidders in each band, and is low risk, because the potential outcomes it eliminates are highly unlikely to be efficient ones. Such caps would substantially reduce the risk of bidders engaging in price driving in a CCA, as it is riskier to do so if the maximum size of bids is reduced. Such risks would be further reduced if Ofcom also adopts **a 140 MHz precautionary cap on each operator's total holdings in the 3.4-3.8 GHz band**.

- **Hold open an option to review annual licence fees (ALF) for H3G's existing holdings at 3.4-3.6 GHz in case the 3.6 GHz price outcome is very different from 3.4 GHz.** If H3G is allowed to bid for more spectrum at 3.6 GHz, this measure is necessary (…✂…).

- **Revisit approach to the assignment round.** Ofcom's standard second price sealed bid auction is not designed to cope with situations where intrinsic value differences between underlying frequencies are dwarfed by the strategic value of securing or blocking options to trade spectrum so as to secure contiguous blocks, as is the case in this award. A more interventionist approach is necessary to facilitate an efficient defragmentation of the 3.4-3.8 GHz band.

We propose two alternative award formats based on these principles that would also deliver Ofcom's objectives for the coverage obligations. Our designs suppose that the coverage obligations that are offered are viable, and that there would be demand for both lots at reserve price. We are advised by Telefónica, however, that this may not be the case. For the avoidance of doubt, the auction design changes that we propose

would also be advantageous if Ofcom decided to proceed with the award without any coverage obligations.

Ofcom's objectives

Ofcom's preference for a single-stage CCA format appears to be driven primarily by its objective of improving mobile coverage through allocation of obligations. It is a poor choice for its other main duties: promoting efficient allocation and downstream competition. The award design is vulnerable to strategic bidding behaviour that could prevent an efficient, pro-competitive outcome. It also fails Ofcom's own tests that an auction should be as simple as possible and can be expected to deliver an outcome that will perceived as fair and legitimate by all participants and stakeholders. There are better options that can meet all of Ofcom's objectives, including coverage, involving sequencing the award of spectrum and coverage obligations, and use of an SMRA format.

Product definition and competitive context

Based on an analysis of the available spectrum products and the competitive context in which they will be sold, we make of the following recommendations for the design of the auction:

1. **Spectrum packaging.** For 3.6 GHz and 700 MHz SDL, Ofcom should consider larger block sizes, more aligned with likely use cases. The choice of small blocks appears to be driven by the choice of a combinatorial format, but it is doubtful that bidders really need this flexibility, and a different approach would be sensible if, as we propose, the CCA is not used.

   Ofcom should also explore the potential benefits of defining separate coverage obligations for each Nation, which may facilitate more efficient allocation of coverage in the case that obligations are assigned in a separate bidding stage at the end of the award.

2. **Multi-stage sale with common positive price constraint.** The 3.6 GHz band should be sold in a separate stage from 700 MHz, as the demand linkages between the bands are weak. Selling the bands together may encourage strategic bidding and creates unnecessary risk for bidders. There is also a strong case for selling coverage obligations separately in a further stage to avoid distorting the assignment of 700 MHz, as Ofcom has recognised.

3. **Safeguarding competition.** Asymmetries in spectrum holdings are a threat to the maintenance of a four-player market. Ofcom should favour auction formats and rules that are likely to lessen rather than exaggerate existing asymmetries. Ofcom's proposal to use a multi-band CCA without meaningful spectrum caps puts its objective of diminishing spectrum asymmetries and safeguarding competition at risk.

Auction format

We agree that the CCA and SMRA are the two candidate formats most relevant to the award of the 700 MHz and 3.6 GHz bands. We find that Ofcom has overstated some of the disadvantages of the SMRA, while understating the disadvantages of the CCA. In particular, Ofcom has failed to appreciate the vulnerability of its proposed CCA design to extreme outcomes that could exacerbate asymmetry in spectrum allocation. We conclude that the CCA should not be used to award 3.6 GHz. The CCA could work in a more limited context for awarding coverage obligations together with 700 MHz.

The key arguments are as follows:

a) The SMRA is lower risk for Ofcom and for bidders, has limited scope for strategic behaviour, and is less likely to produce inefficient outcomes. SMRAs tend to deliver outcomes consistent with pre-auction expectations, with competition focused on marginal lots where the bidder with highest value is uncertain.

b) The CCA is higher risk for Ofcom and for bidders, has greater scope for strategic behaviour, and is more likely to produce inefficient outcomes. In particular, multi-band auctions using the CCA format are vulnerable to extreme outcomes that conflict with pre-auction expectations and are hard to relate to allocative efficiency. This is a particularly risky approach if – as in the UK – existing spectrum allocations are already highly asymmetric and there is an expectation that the auction should address this.

c) The CCA is particularly susceptible to price driving, especially where bidders have predictable asymmetric demands (e.g. as the case at 3.6 GHz, (…✂…). Price-driving can damage competition within the auction and may lead to auction outcomes that reduce competition downstream.

d) Budget-constrained bidders do not have a mechanism in a CCA to measure the risk of deviating from bidding to value. With a multi-band award, even bidders with high budgets could find themselves unable to express their full values (…✂…). This may lead to inefficient outcomes with 'unhappy' budget-constrained bidders – contrary to the core principle. Smaller-scale CCAs (e.g. an auction for 700 MHz and coverage only) are less vulnerable to this risk because budgets are less likely to be breached.

Alternative sequential stage auction designs

Ofcom's preference for the CCA design flows from its explicit preference to sell 700 MHz and the coverage obligations together and its implicit preference to sell 3.6 GHz and 700 MHz together. We recognise that the CCA addresses a key concern identified by Ofcom for this award: the aggregation risk between spectrum lots and the coverage obligation created by the positive price constraint. However, there are other ways that Ofcom can achieve this objective without resorting to a large, multi-band CCA.

We set out two alternative designs for the award:

A. **Two-stage allocation:** A separate bidding stage for 3.6 GHz using an SMRA format; followed by smaller-scale CCA for 700 MHz and coverage obligations but taking into account revenues from the 3.6 GHz auction stage in the positive price constraint.
B. **Three-stage allocation.** A 3.6 GHz allocation stage (using an SMRA); followed by a 700 MHz allocation stage (also SMRA); and finally, a coverage obligation allocation stage (second price sealed bid). We propose a voucher mechanism that would enable all bidders to compete for the coverage obligations while avoiding any requirement for Ofcom to make net payments to individual operators.

We have been mindful of Ofcom's objectives and stated limitations. We believe that our two designs are at least as good as Ofcom's proposed CCA in achieving each of Ofcom's four objectives for the award, and additionally would offer a greater likelihood of producing an efficient, pro-competitive allocation of spectrum. Moreover, they are much less likely to produce an extreme allocation outcome that worsens spectrum asymmetries. Our designs follow Ofcom's proposal to use unbundled coverage obligations and respect the intent of the positive price constraint.

Changes to the assignment round to facilitate defragmentation

Ofcom should attach higher priority to defragmenting the entire 3.4-3.8 GHz band. Having operators reshuffle their frequencies after the award would be a low-cost exercise that would bring significant benefits for UK consumers. This could be achieved either through industry consensus (with appropriate prodding from Ofcom) or by including all relevant frequencies in the assignment round. It should be unacceptable for any one operator to oppose such a move, especially given the important that the UK government attaches to positioning the country as a leader in 5G services. In similar situations, other countries – such as Spain and the United States – have found solutions to defragment bands. Ofcom should do so too.

Even if Ofcom is unwilling or unable to broker a broader solution to defragmentation, there are steps it can take to make it more likely that this award produces an assignment from which defragmentation can be realised through trading. We suggest a series of rules for the assignment round designed to allow potential trading partners to secure adjacent spectrum and prevent other parties from deliberately blocking them. Ofcom should make it clear that it is able and willing to reject trades that provide only partial solutions to defragmentation, unless the applicants can demonstrate that they made good faith efforts to find a multilateral solution or that their trade will not prevent such a solution from subsequently emerging.

Other tools that can mitigate risk for bidders and for Ofcom

Ofcom has a number of other tools at its disposal that can be deployed as part of the auction design to mitigate the risk of the award failing to deliver an efficient pro-competitive outcome. These are rules that can be expected to reduce the risk of inefficient allocation outcomes, including lots going unsold unnecessarily, or price outcomes that are too low, too high or too asymmetric between bidders relative to true market price. The choice of tools may vary depending on the auction format.

Spectrum caps are the most powerful tool available to Ofcom to eliminate extreme allocation outcomes that would almost certainly be inefficient, and likely only possible because bidders were not competing based on intrinsic values.

In addition to Ofcom's 37% cap on total holdings of usable mobile spectrum (consistent with the approach adopted in previous awards), we recommend that Ofcom implement the following precautionary spectrum caps:

1. Band-specific caps for the spectrum available in the auction:
    a. a 80 MHz cap in the 3.6 GHz band; and
    b. a 40 MHz cap across the 700 MHz paired and SDL bands.
2. A cap on holdings of spectrum in the wider 3.4-3.8 GHz band of 140 MHz, so as to prevent undue concentration of core 5G spectrum in the hands of one operator.

We strongly recommend that Ofcom adopt these caps within the context of an SMRA. Furthermore, in our view, if Ofcom were anyway to proceed with its proposal to use a multi-band CCA, it would be reckless not to impose precautionary caps, as the format would otherwise incentivise bidders to engage in overbidding. If Ofcom is not willing to implement such caps, then it must switch to an SMRA format so as to reduce the risk that the auction produces an extreme allocation outcome.

We also recommend that, if H3G is allowed to bid for more 3.6 GHz spectrum, then Ofcom must retain an option to review H3G's **ALF for its existing holdings**. Otherwise, (…✂…), outcomes that Ofcom recognises as undesirable.[5]

We also recommend some more modest changes to detailed auction rules:

1. **Reserve prices.** It makes sense to set robust reserve prices for 3.6 GHz and for 700 MHz paired, given abundant evidence that they have substantial value. This would underpin revenues to cover the coverage obligations in the unlikely event of a low competition scenario.

[5] Consultation, δ7.151 and δ7.199

2. **Eligibility points.** We recommend that Ofcom use a 1:1 eligibility points ratio in the 700 MHz band between 2x5 MHz paired lots and 10 MHz SDL lots. This would allow bidders to switch between these lots based on capacity.

3. **Information policy.** We support some measures to limit the information about demand provided to bidders. This is a helpful tool to discourage certain types of strategic behaviour in both in an SMRA or CCA. However, the benefits of such approaches should not be overstated. They are not a substitute for spectrum caps as a tool to prevent behaviour that could lead to extreme, inefficient outcomes. Ofcom's specific proposals for hiding information in a CCA are unlikely to deliver their objectives and may be counterproductive in the final primary round, frustrating calculation of a "knockout" bid for the supplementary bids round to secure spectrum won in the final primary round.

2. Ofcom's objectives for the award

A good auction design is one that delivers the maximum benefits associated with the objectives of the seller, in this case Ofcom on behalf of the UK government and society. When designing spectrum auctions, one of the biggest challenges is that a regulator may have multiple objectives, and these may conflict to some extent. Conflicts are more likely when outside objectives, such as improving coverage obligations, are added to the standard objectives of promoting efficient allocation and strengthening competition. Our view is that the objective of promoting coverage has been given too much weight in Ofcom's design, whereas critical components of Ofcom's main duties have been neglected.

One of the first things that Ofcom does in the Consultation is to define its main objectives:

- *"improving mobile coverage;*
- *ensuring efficient allocation of spectrum;*
- *sustaining strong competition in mobile markets; and*
- *ensuring the timely availability of spectrum."*[6]

The first objective of "improving mobile coverage" is distinct from the others in that it is a broader policy goal that Ofcom has opted to link to this award. Unlike the other objectives, there is no statutory obligation on Ofcom to link coverage to this award. Rather, Ofcom has identified an opportunity to use this award as a mechanism to improve mobile coverage; the main rationale being that the award includes the 700 MHz band, which is ideal spectrum for wide-area coverage and in-building signal penetration.[7] It appears that the inclusion of 3.6 GHz is motivated primarily by a desire to bulk of the size of the award, so as to make it more likely that multiple operators spend enough money to compete for the coverage obligations.

It is not unusual for a regulator to apply coverage obligations as part of a mobile spectrum award. Ofcom has including obligations in several previous awards, as have most other regulators across Europe. Nevertheless, the inclusion of coverage obligations increases complexity and introduces a risk that the mechanisms used to further this objective could conflict with Ofcom's main duties when awarding spectrum.

The latter three objectives set out above – efficient allocation, strong competition and timely availability – are standard to any spectrum award. They are all essential elements

[6] Consultation, §1.3.

[7] Ofcom says in the Consultation, §2.43 that "*we consider that the particular characteristics of the spectrum available in this award mean that it has the potential to deliver significant wider social value through improved mobile coverage*".

in Ofcom's main duty, which "*is to secure optimal use of the spectrum*."[8] This duty is enshrined in Ofcom's statutory obligations under both domestic and EU law.

As Ofcom previously set out in its consultation on the 2.3 GHz & 3.4 GHz auction, this duty is "*more likely to be achieved through the following additional objectives:*

a) *The design should be simple where possible, without unduly compromising the efficient outcome of the auction.*

b) *The outcome of the auction should be perceived by all participants and stakeholders as fair and legitimate, and bidders should not feel that they would have bid differently when they see the final result."*[9]

Ofcom has proposed a CCA for this award. The choice of that format appears to have been largely driven by the complication of adding coverage obligation lots to the award. Including these lots may introduce aggregation risk for some bidders, as their willingness to take on a coverage obligation may be linked to purchasing 700 MHz spectrum. It also introduces an outcome constraint (Ofcom says that each bidder must pay a positive amount for a package of spectrum and a coverage obligation) that could not be easily addressed in a non-combinatorial format. Absent the coverage obligation, aggregation risk would be modest (see discussion in Section 3) and there would be no outcome constraints. Therefore, the rationale for using a CCA rather than the SMRA format that Ofcom used for the 2.3 GHz & 3.4 GHz auction would largely disappear.

This raises two questions:

1. *Can Ofcom be confident that the expected benefits from changing the auction format to accommodate coverage obligations outweigh the costs associated with using this more complex format?*

We judge not. As we explain in Section 4, there are significant risks associated with the proposed design that Ofcom has underestimated. In short, the design is vulnerable to strategic bidding behaviour that could prevent an efficient, pro-competitive outcome. It also fails Ofcom's own tests that it should be as simple as possible and can be expected to deliver an outcome that will perceived as fair and legitimate by all participants and stakeholders.

2. *Are there other approaches that could be adopted that simplify the auction design but still deliver on the goal of improving coverage?*

We are confident that there are better options. In Section 5, we set out two approaches, based around sequencing the award of spectrum and coverage obligations, which would diminish the risks identified above while still fulfilling Ofcom's coverage objective. (We

[8] Consultation, §2.38.

[9] Ofcom, Public Sector Spectrum Release (PSSR), Award of the 2.3 GHz and 3.4 GHz bands, Consultation, 7 November 2014, §6.12-6.13.

also understand that the industry is in talks with the government about possible approaches to addressing coverage outside of the auction. If this conversation is fruitful, it may be that the coverage obligations are no longer required, which would further strengthen the case for an SMRA design.)

3. Defining the products: 700 MHz, 3.6-3.8 GHz and coverage

Before selecting the auction format and developing detailed rules, it is necessary to undertake a rigorous analysis of the available spectrum products and the competitive context in which they will be sold. For this award, there are four distinct products: 700 MHz paired; 700 MHz SDL; 3.6 GHz; and the coverage obligations. In this section, we discuss the options for packaging the available products, explore the linkages between them, and examine the competitive context.

Based on our analysis, we make of the following recommendations for the design of the auction:

1. **Spectrum packaging.** For 3.6 GHz and 700 MHz SDL, Ofcom should consider larger block sizes, more aligned with likely use cases. The choice of small blocks appears to be driven by the choice of a combinatorial format, but it is doubtful that bidders really need this flexibility, and a different approach would be sensible if the CCA is not used.

   Ofcom should also explore the potential benefits of defining separate coverage obligations for each Nation, which may facilitate more efficient allocation of coverage in the case that obligations are assigned in a separate bidding stage at the end of the award.

2. **Multi-stage sale with common positive price constraint.** The 3.6 GHz band should be sold in a separate stage from 700 MHz, as the demand linkages between the bands are weak, and selling them together may encourage strategic bidding and creates unnecessary risk for bidders. There is also a strong case for selling coverage obligations in a further stage to avoid distorting the assignment of 700 MHz.

3. **Safeguarding competition.** Asymmetries in spectrum holdings are a potential threat to the maintenance of a 4-player market. Ofcom should favour auction formats and rules that are likely to lesson rather than exaggerate existing asymmetries.

   In particular, it should:

   a) Favour auction formats that are less vulnerable to extreme outcomes;

   b) Adopt precautionary, band-specific caps that eliminate the possibility of one bidder unilaterally blocking all rivals from acquiring spectrum in a band; and

c) Adopt rules, such as restrictions on information release, that make it harder for bidders tacitly to cooperate to block others from blocking specific rivals from acquiring spectrum in a band.

In subsequent sections of this paper, we set out proposals regarding the auction process, format and rules that could be adopted that would deliver on these recommendations, consistent with Ofcom's policy goals.

3.1. Options for packaging the bands and obligations

In the following paragraphs, we consider the options for packaging the available spectrum and coverage obligations into lots for award in the auction.

3.6-3.8 GHz

Ofcom proposes to award 120 MHz of spectrum in the 3.6-3.8 GHz band in 24 blocks of 5 MHz, to be sold on a generic basis. Winning bidders would be guaranteed contiguous frequencies within the available spectrum.

The available spectrum forms part of a broader band from 3.4-3.8 GHz that is all expected to be used to deliver 5G mobile. It is located at the upper range of frequencies considered suitable for deployment on mobile macrocells. As such, it is expected to be particularly useful for providing capacity and high-speed services in urban areas. For the foreseeable future, little deployment outside towns and cities is expected, owing to the limited propagation of the underlying frequencies and lower capacity needs in rural areas.

The likely bidders for this spectrum are the four MNOs. In particular, the three MNOs that only have 40-50 MHz each in the broader 3.4-3.8 GHz band (BT, Telefónica and Vodafone) can be expected to place a high value on increasing their holdings up to the 80-100 MHz level typically targeted by operators for 5G deployment. The fourth MNO, H3G, already has 140 MHz of spectrum, so may reasonably be expected to have a much lower incremental value for the spectrum. There could be interest from other parties, but the only entrant in the 3.4 GHz auction (Airspan) was outbid by a wide margin.

Demand for this spectrum will most likely be in units of 10 MHz:

- Most recent awards of spectrum in the 3.4-3.8 GHz band have been in units of 10 MHz or larger. For example, both Austria (February 2019) and Germany (forthcoming) have 10 MHz lots, whereas Switzerland (January 2019) has 20 MHz lots. Although two awards from 2018 – the UK and Spain – featured 5 MHz lots, all final allocations were in 10 MHz units.

- Although there were bids for spectrum in units of 5 MHz in the UK 3.4 GHz auction, most bids (more than 75%) were in units of 10 MHz, and the final allocation was exclusively in units of 10 MHz. Table 1 compares the percentage

of bids by each bidder for even numbers of lots (divisible by 10 MHz only) and odd numbers (also divisible by 5 MHz). Observe that four of the five bidders made all (or nearly all) their bids in units of 10 MHz. The only exception is Telefónica, but they tell us that (…✂…).

Table 1: Percentage of bids in PSSR award for even (divisible by 10 MHz only) and odd numbers of lots (also divisible by 5 MHz)

Bidder	Even Bids	Odd Bids	Percent Even Bids
Airspan	14	2	88%
EE	38	0	100%
H3G	37	0	100%
Telefónica	9	34	21%
Vodafone	32	5	86%

- The first wave of 5G equipment is focused on blocks of spectrum in units of 10 MHz. For bidders acquiring more than 15 MHz, there are no equipment options available to deploy odd 5 MHz blocks of spectrum.[10] While this may change in the future, it is unrealistic to expect bidders to have high value for small incremental blocks that might never be deployed.

- Operators deploying 5G in the UK (as well as elsewhere in Europe) are expected to adopt synchronised uplink/downlink ratios, thus negating the need for guard blocks between their holdings. Accordingly, it is unlikely that operators would place any significant value on acquiring additional spectrum to act as guard bands.

Notwithstanding the likely structure of demand, Ofcom proposes to sell the spectrum in 5 MHz blocks, based on the following rationale:

> "*Even though the winning amounts of spectrum were in multiples of 10 MHz, there were a number of bids in multiples of 5 MHz. This suggests that bidders found it helpful to have 5 MHz lot sizes. Given that the 3.6-3.8 GHz band is similar in nature to the 3.4-3.6 GHz band, we propose to have twenty-four 5 MHz lots*"[11]

This rationale does not stand up to scrutiny, given that Telefónica was the only bidder that made substantial use of the option to bid for 5 MHz lots, and (…✂…).

[10] Release 15 from 3GPP specifies nine different Channel sizes for 5G technology in 3.4 – 3.8 GHz (bands 77 and 78): 10, 15, 20, 40, 50, 60, 80, 90 and 100 MHz. Not that all options above 15 MHz are in units of 10 MHz.

[11] Consultation, δ7.145.

Ofcom's approach is presumably also influenced by its choice of auction format. With combinatorial bidding, offering smaller lots does not create aggregation risk, as bidders can aggregate any number of lots to form a larger block for 5G. However, having more packages than necessary does increase the complexity of the process.

We recommend that Ofcom revisit its decision to use 5 MHz lots, given the overwhelming likelihood that real demand will be in units of 10 MHz. Even if a combinatorial format is used, 10 MHz lots may be better a better choice, as fewer lots means simpler package bid options and fewer options for strategic bidding. If, as we propose, an SMRA-type format is used to sell 3.6 GHz, then 10 MHz blocks would be a better approach, as it will eliminate any risk of a bidder winning an unwanted 5 MHz block and constrain allocation outcomes to ones that are more likely to ensure full use of the spectrum.

Recommendation 1a:
Ofcom should consider selling 3.6 GHz as 12 blocks of 10 MHz, not 24 blocks of 5 MHz.

700 MHz paired

Ofcom proposes to award 60 MHz of spectrum in six blocks of 2x5 MHz to be sold on a generic basis. Winning bidders will be guaranteed contiguous frequencies within the available spectrum.

The available spectrum is also expected to be used to deliver 5G mobile. It is located at the lower range of frequencies considered suitable for deployment on mobile macrocells. As such, it is expected to be particularly useful for providing wide area coverage and in-building penetration. Given the limited quantity of spectrum available and its wide propagation, it is less useful for providing capacity in urban areas.

All four MNOs could have a strong business case to buy this spectrum. For, BT and H3G, this award is an opportunity to address their relative weakness in sub-1 GHz holdings, which may be valuable to them to extend the quality of their coverage. Telefónica UK and Vodafone already have substantial sub-1 GHz holdings, but the spectrum would nevertheless be a good fit with their rural cell grids, which are based on 800 MHz and 900 MHz. There may be interest from other parties, but given limited availability of spectrum in this band, the likelihood of any other party outbidding the MNOs seems remote.

We support this proposal to sell the spectrum in 2x5 MHz blocks. 2x5 MHz blocks are the base units of supply. While there is a significant likelihood that the spectrum could be purchased in 2x10 MHz blocks, it is also possible that bidders may target and win blocks of 2x5 MHz or 2x15 MHz. Unlike higher frequency bands, there is a potential business case to deploy a single block of 2x5 MHz, so selling the spectrum in larger blocks would risk closing off potentially efficient allocations.

700 MHz SDL

Ofcom proposes to award 20 MHz of spectrum in four blocks of 5 MHz to be sold on a generic basis. Winning bidders will be guaranteed contiguous frequencies within the available spectrum.

The available spectrum is also expected to be deployed as supplemental downlink spectrum to deliver 5G mobile. However, the ecosystem for the band is not well developed and the frequencies have not yet been widely awarded. When this spectrum was offered in recent auctions in Italy and Sweden, it went unsold. A single bidder, Sunrise, acquired a 10 MHz block in the Swiss auction in February 2019, but the other 5 MHz available went unsold.

Again, the likely bidders for this spectrum are the four MNOs. Given uncertainty over the ecosystem and lack of interest in the band elsewhere, the spectrum could have low value and might not even sell. Accordingly, there is a somewhat greater chance than the other bands that this spectrum could be acquired by a non-MNO. However, it is not obvious what the business case for a non-MNO would be to acquire this spectrum.

Ofcom proposes to sell the spectrum in 5 MHz blocks. This is smaller than the likely base unit of demand, which Ofcom agrees is probably 10 MHz. Again, the choice of smaller lots appears to be driven by the plan to use a combinatorial format, as this addresses aggregation risk. Ofcom says that this approach "*will still allow bidders with use cases of 5 or 15 MHz to bid for this amount.*"[12] This makes sense if such demand really exists – but we are not aware of any evidence to suggest it does. As Telefónica has previously proposed, 10 MHz blocks would also be equivalent in size to a 2x5 MHz lot at 700 MHz paired, so might facilitate more straightforward switching between the two 700 MHz bands in an auction.[13] This would seem desirable given that 700 MHz SDL may be an inferior substitute for 700 MHz paired.

We recommend that Ofcom look again at its approach to packaging the 700 MHz SDL spectrum. Two blocks of 10 MHz would be the approach most obviously in line with the (limited) evidence from demand elsewhere. If a CCA is used for this band, 10 MHz lots would simplify package bid options and may close off some strategic bid options. If an SMRA is used, then a change is essential so as to prevent bidders from being exposed to winning only 5 MHz, which would likely be too little to support deployment.

Recommendation 1b:
Ofcom should consider selling the 700 MHz SDL as two blocks of 10 MHz.

[12] Consultation, δ7.143

[13] Telefónica UK, "Response to Ofcom: Improving mobile coverage: Proposals for coverage obligations in the award of the 700 MHz spectrum band", May 2018, δ45.

Coverage obligations

Ofcom proposes to have just two, nationwide coverage obligations to be sold simultaneously with the available spectrum lots. The coverage lots will have identical obligations, so can be sold in a single category. Each obligation is associated with specific coverage requirements for each of the four nations.

In a previous response, Telefónica proposed that Ofcom decouple coverage obligations from specific spectrum lots. Ofcom's design delivers on this proposal albeit using a different award structure to that put forward by Telefónica. Ofcom's proposal to have independent coverage lots starting at a negative price is innovative, and a clear improvement on its previous proposal to encumber specific spectrum lots with obligations. Ofcom's approach allows some scope for operators to acquire the obligations independent of the amount of 700 MHz they buy. However, the positive price constraint may still limit scope for competition for those coverage lots. The inclusion of the coverage lots in the same stage as the spectrum also introduces aggregation risk for bidders, which appears to be driving Ofcom's preference for a CCA format.

Telefónica also proposed that Ofcom consider breaking up the coverage obligations into nation-specific obligations. As Telefónica says, from an efficiency perspective, there is potentially a strong case for having regional rather than national coverage lots:

> "*There are significant differences between the networks and market positions of the four operators in each Nation. Hence, for example, the operator that is best placed to fulfil a coverage obligation in Northern Ireland is not necessarily best placed to fulfil an obligation for Scotland. An approach that decoupled obligations from specific lots could allow Ofcom to allocate a broader range of regional obligations – more precisely it could allow bidders to deliver obligations at the lowest cost which would be the most efficient outcome*."[14]

Ofcom's reasoning for having nationwide rather than regional coverage blocks is not clear. We recognise, however, that there would be disadvantages in introducing more coverage categories in the context of Ofcom's multi-band auction format. Firstly, increasing the number of categories of coverage blocks would significantly increase the number of package bid options under the CCA, thus increasing the complexity of the auction process. Ofcom may also be concerned that increasing the number of blocks may create scope for tacit agreements to emerge between operators on sharing out the obligations (as there would now be more obligations than MNOs). On the other hand, breaking down the coverage lots into smaller parts may make them accessible to bidders buying smaller quantities of spectrum.

The alternative auction formats we develop in Section 5 substantially address the downside risks. Under our first alternative format, 3.6 GHz is sold separately from 700

[14] Telefónica UK, Response to "Improving mobile coverage: Proposals for coverage obligations in the award of the 700 MHz spectrum band", May 2018, δ36.

MHz and the coverage lots, so this addresses the concern about there being too many packages (using 10 MHz lots for 700 MHz SDL would also help). Under our second alternative format, coverage obligations would be sold in a separate stage after 700 MHz. Here, there is scope to use information rules to mitigate incentives for tacit sharing of obligations.

Recommendation 1c:
Ofcom should explore the potential benefits of defining separate regional coverage obligations, which would work best if coverage obligations are assigned in a separate bidding stage at the end of the award.

3.2. Linkages between the bands and obligations

Ofcom has proposed a single stage allocation process in which all three bands and the coverage obligations are sold simultaneously. A key advantage of simultaneous award is that it may allow bidders to manage aggregation and substitution risk. This is most relevant when the bands are close substitutes or complements. This advantage must be weighed against the increased complexity of a multi-band award, and the potential for greater strategic play by bidders which could distort allocation outcomes.

For this award, it is apparent that the linkages between the available bands and obligations are rather weak:

- The 700 MHz and 3.6 GHz band lie at the extreme ends of mobile spectrum bands suitable for macrocellular deployment. Although they are both 5G bands, they will likely be deployed to address different priorities: 700 MHz for geographic coverage and in-building penetration; and 3.6 GHz for urban capacity. Accordingly, they are not substitutes. They are also not close complements: although an operator may benefit from having both, demand for the two bands is unlikely to be inter-dependent. Reflecting this, most European regulators have or plan to award these two bands in separate auctions.[15]

- There is no obvious linkage between 3.6 GHz and the coverage obligations, as the frequencies are too high to support wide-area coverage. When Ofcom was selling 2.3 GHz and 3.4 GHz spectrum, it explicitly ruled out applying coverage obligations to those bands because "*the technical characteristics of the 2.3 and 3.4 GHz spectrum mean that it is suited to adding capacity, but is not an effective means of extending existing levels of mobile coverage*."[16]

- 700 MHz could be used to fulfil the coverage obligations, so there is a potential complementarity between the two. However, all four MNOs already have other

[15] Telefónica Group surveyed 21 EU countries that have announced plans or held auctions for 700 MHz and 3.6 GHz. Of these, 16 countries have or plan to sell the bands separately and only 5 will sell them jointly.

[16] Ofcom, Consultation on 'Award of the 2.3 and 3.4 GHz spectrum bands: Competition issues and auction regulations', 21 November 2016, δ1.6.

spectrum they could use for coverage, so this complementarity may not be important.

It appears that Ofcom has manufactured a link between 700 MHz, 3.6 GHz and the coverage obligations so as to create a sufficiently large auction to accommodate the positive price constraint. The spectrum award offers an opportunity to raise money from the industry and redistribute a portion of it towards the goal of improving mobile coverage without the need for direct funding from government – and Ofcom may believe that it needs the revenues from both 3.6 GHz and 700 MHz to create competition for the coverage lots. Nevertheless, it should be recognised that this is an 'artificial' linkage resulting from limitations on Ofcom's regulatory powers rather than a 'real' linkage based on bidder's intrinsic demand for spectrum.

To meet Ofcom's objective of raising sufficient revenues to cover the costs of the coverage obligations, there is logic in selling everything available in the same award process, but only if this does not compromise efficient allocation of spectrum that is not suited to the delivery of coverage obligations – otherwise the collateral damage would be too high. Ofcom's design goes a step further in that it proposes not only to sell everything together in one award, but to allocate all products in a single stage auction in which bidders can make package bids across the four categories. The rationale to have a simultaneous process, as opposed to breaking up the award into stages is, however, weak. A simultaneous design does not address any meaningful substitution or aggregation risks.

We recommend that Ofcom look again at its approach of selling 3.6 GHz, 700 MHz and coverage obligations in the same simultaneous auction. This approach will not meaningfully reduce any demand-side risks for bidders. On the contrary, as we explain in the next Section, it may increase risk for bidders, by raising the stakes for bidders and introducing opportunities for strategic bidding behaviour. The case for a single allocation process thus appears to rest entirely on Ofcom's need to maximise available revenues to meet the positive price constraint for the award of coverage obligations. However, as we explain in Section 5, there are other ways that Ofcom could achieve this goal without combining everything in a single allocation stage.

We conclude that:

- There is a strong case for selling 700 MHz SDL in the same auction stage as paired spectrum. SDL spectrum is both an inferior substitute and potential complement for paired spectrum. Accordingly, it would be prudent to use an auction design that allows bidders to switch demand between the two categories in response to relative prices.

- The case for selling 3.6 GHz with 700 MHz is tenuous. The bands are not close substitutes or complements, notwithstanding their status as 5G pioneer bands. The bands could be sold sequentially in separate stages without exposing bidders to meaningful aggregation or substitution risk. Indeed, as we explain in

Section 4, a sequential process would likely reduce risk for bidders by closing off incentives for strategic bidding across the two bands.

- Coverage obligations should be offered either simultaneously with 700 MHz or in a subsequent stage. There are pros and cons of both approaches. Ofcom should weigh these carefully.

In Section 5, we set out two alternative designs for the award. Both involve selling 3.6 GHz in a separate auction stage, but as part of the same award. In this way, bidding for 3.6 GHz is isolated from the bidding for 700 MHz and unrelated coverage obligations, but the revenues can still be taken into account when determining eligibility to bid for coverage obligations. The first design follows Ofcom's proposal to sell 700 MHz and coverage obligations together, whereas the second design involves separating coverage obligations into a third stage, after the sequential awards of 3.6 GHz and 700 MHz.

Recommendation 2:
Ofcom should sell 3.6 GHz in a separate stage of the same auction, so as to prevent strategic bidding across 700 MHz and 3.6 GHz. It should also consider selling coverage obligation lots in a separate stage, following the allocation and assignment of the spectrum bands.

3.3. Competitive context

Auction design and packaging of products for sale must also take into account the competitive context in which the auction will take place. As Ofcom recognises, the UK has a competitive mobile market, with four network operators competing for retail and wholesale traffic. For example, Ofcom concluded that *"we consider that competition is generally working well, with strong competition between suppliers, commercial wholesale access and continued investment in new services"* in its Decision on the PSSR award.[17] These four operators also compete strongly for radio spectrum, as evidenced by recent auctions and private sales. Ofcom has identified the preservation of the four-player market structure as a priority.

One peculiar feature of the UK market is the exceptional level of asymmetry between the four UK mobile operators as regards spectrum holdings. Table 2 sets out percentage shares of mobile spectrum by operator. There are stark asymmetries not just in total holdings, but also with respect to different types of spectrum. The forthcoming award will add 200 MHz of new spectrum and covers both low and mid-band spectrum. It therefore has the potential to either significantly reduce or increase asymmetries.

[17] Ofcom, Award of the 2.3 and 3.4 GHz spectrum bands. Annexes to the statement. 21 July 2017. §A1.1.

Table 2: UK MNOs % share of usable spectrum by type

	Low band Sub-1.5 GHz (all)	Lower mid-band (4G*) 1500-3000 MHz	Upper mid band (5G*) 3000-5000 MHz	All usable mobile spectrum
BT / EE	6%	51%	15%	32%
H3G	18%	12%	52%	25%
Telefónica	32%	15%	15%	18%
Vodafone	44%	21%	19%	25%
Available (MHz)	169.6	477	270	916.6

Notes: Based on MNO holdings and available spectrum in 700, 800, 900, 1400, 1800, 2100, 2300, 2600, 3400 and 3600 MHz bands. The same bands as identified in Section 5 of the Ofcom consultation. Percentages may not add up to 100% due to rounding.
** The distinction between 4G and 5G spectrum is relevant for the launch of 5G services.*

We agree with Ofcom that some degree of asymmetry may be advantageous, as it may support network differentiation and spur broader competition. However, as Ofcom recognises, *"competition could be weaker as a result of a very asymmetric distribution of spectrum because some operators may struggle to compete strongly across certain services, for certain customer segments, or temporarily over some period of time."*[18]

The asymmetry in spectrum holdings in the UK is highly unusual. Prior to the PSSR award, Telefónica submitted a paper prepared by NERA that compared the holdings of UK mobile operators with their peers worldwide.[19] This revealed that just 16 of 320 operators across 100 countries had shares of usable spectrum at 15% or below, one of which was Telefónica. It had one of the lowest ratios of spectrum share to subscriber share worldwide, ranking 319th of 320 in our survey. Meanwhile, EE had a usable spectrum share of 45%, the joint highest level in Europe despite most other markets having only three operators. The situation has improved somewhat following the outcome of the PSSR award in which Telefónica won the largest amount of spectrum. Nevertheless, the asymmetry in UK spectrum holdings is still exceptionally high by global standards.

Such extreme asymmetry in distribution of an essential input into provision of mobile network services should raise concerns regarding the efficiency of spectrum use and potential for sustainable four-player competition in the UK market. There are good reasons for Ofcom to be more concerned about spectrum allocation now than in the past, as exceptional growth in consumer demand for data is placing unprecedented pressure on mobile networks, pressure that will continue with the launch of 5G services.

[18] Ofcom, Award of the 2.3 and 3.4 GHz spectrum bands, Competition issues and Auction Regulations, Statement, 2017, §6.13.

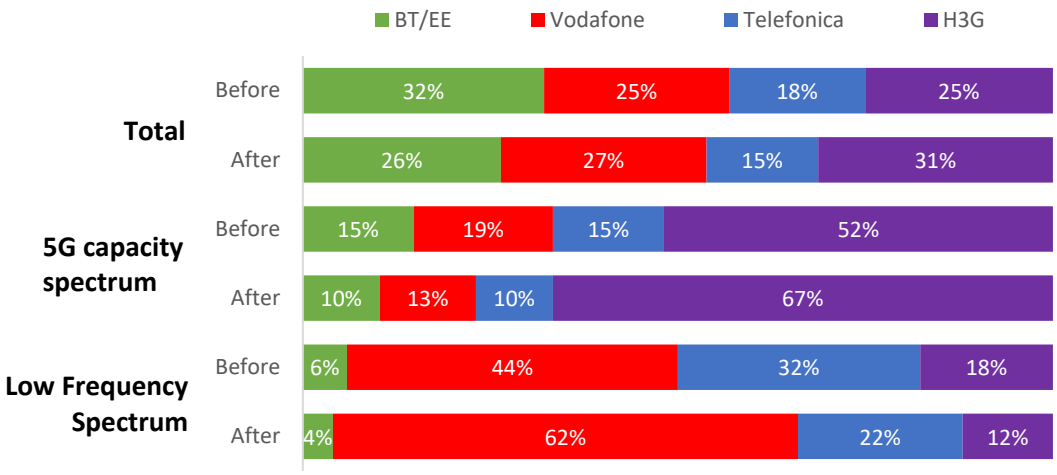
[19] NERA Economic Consulting, The case for a spectrum cap that promotes efficiency and competition in the PSSR Award, submitted to Ofcom by Telefónica UK, January 2017, Section 4.

Accordingly, we agree with Ofcom when it says in the consultation that it is more concerned about: *"significant asymmetries that persist in the medium to longer term than in the very short term, particularly as we do not currently have any plans to award further low frequency and mid frequency spectrum in the medium term."*[20] The award of 700 MHz and 3600 MHz is likely to be the last award of low and mid band spectrum in the UK for many years, so any asymmetry remaining after this award will likely endure and shape competition through most of the 5G era. A highly asymmetric outcome is a potential threat to the future of the health of the four-player market.

Under Ofcom's proposed rules, asymmetries could intensify significantly after the auction. In Figure 1, we imagine an outcome where Vodafone won all the 700 MHz spectrum and H3G won all the 3.6 GHz spectrum. In this case, no MNO would have more than 32% of spectrum, but Vodafone would have a 62% share of low-band spectrum (a 15:1 ratio over BT), while H3G would enjoy 62% of all 5G capacity spectrum (a 7:1 ratio over BT and Telefónica). This is just one of many extreme outcomes that would be permitted under Ofcom's proposed global 416 MHz (37%) spectrum cap.

At first view, such an outcome looks absurd because one cannot possibly imagine such an outcome based on an efficient set of bids. However, Ofcom must consider the risk that the set of bids collected in the auction are not efficient. (…✂…). In this case, the outcome in Figure 1 becomes possible, even though it is potentially disastrous for downstream competition.

Figure 1: Spectrum shares before and after the award in an extreme scenario permitted under Ofcom's caps



We understand that there could be a downside in adopting measures to prevent asymmetric outcomes in that this may reduce the range of outcomes that the market is able to test in the auction. At present, there is an inconsistency between Ofcom's

[20] Consultation, §5.81.

recognition that highly asymmetry spectrum shares could be a threat to competition and its unwillingness to take any substantial measures to close off such outcomes. Ofcom needs to ask itself whether it really wants to proceed with an auction that could produce an outcome as bizarre and worrying as the one illustrated in Figure 1.

Moreover, closing off or reducing the likelihood of extremely asymmetric auction outcomes is not difficult. Ofcom has multiple tools available to do this, including:

a) *Favouring auction formats that are less vulnerable to extreme outcomes*. As we explain in the next two sections, the likelihood of an extreme outcome would be much less if the awards of 700 MHz and 3.6 GHz were broken up into separate stages, and if an SMRA is adopted for 3.6 GHz. We argue that it is ill-advised, bordering on reckless, to propose a multi-band CCA – a format often associated with unlikely, unpredicted outcomes – in a situation where Ofcom is expecting the market to find a solution that lessens rather than deepens spectrum asymmetries.

b) *Precautionary, band-specific caps*. With minimal (probably zero) risk of closing off an efficient outcome, Ofcom could embrace band-specific caps, common to all bidders, that eliminate the possibility of one bidder buying an entire band. We suggest a common 40 MHz cap at 700 MHz and 80 MHz cap at 3.6 GHz. This simple approach should ensure a minimum of two winners in every band, and eliminates the possibility that one MNO could unilaterally block all rivals from acquiring spectrum in a band (a further advantage of these caps is that they would ensure a minimum of two bidders that spend enough to qualify to buy the coverage obligation).

c) *Rules that discourage coordinated bidding*. Precautionary caps cannot prevent an outcome in which two bidders bid strategically to jointly block rivals. Given that squeezing common caps further may be undesirable, Ofcom may consider other measures, such as restrictions on information release, that make it harder for bidders tacitly to cooperate to block others.

The alternative auction design proposals that we develop in Section 5 are based on these tools.

Recommendation 4:
Ofcom should favour auction formats and rules that are likely to lessen rather than exaggerate existing asymmetries in spectrum holdings. It should favour auction formats that are less vulnerable to extreme outcomes, consider precautionary, band-specific spectrum caps that close off some extreme outcomes, and adopt auction rules that make anti-competitive bid strategies difficult and risky to execute.

4. Pros and cons of candidate auction formats: SMRA and CCA

Ofcom focuses on two potential auction designs for this award: the CCA and SMRA. It proposes some changes to the CCA rules previously used in the UK, based on innovations in other countries (we discuss these in Section 7). If an SMRA is used, Ofcom proposes to adapt the hybrid clock-SMRA format that it developed for the 2.3 GHz & 3.4 GHz award. We agree that these are candidates for allocating this spectrum and see no great benefit from exploring alternative formats. Accordingly, we focus our discussion here on the pros and cons of these two approaches.

We have reviewed the criteria that Ofcom has used to compare the two formats. Ofcom identifies a long list of relevant issues but it does not group these into categories, and there is little effort to relate each factor to its primary obligation of promoting an efficient, pro-competitive allocation outcome. As a result, Ofcom overstates the relevance of some factors (such as aggregation risk and tacit collusion) and underplays others (such as price driving and complexity).

We find that Ofcom has overstated some of the disadvantages of the SMRA, while understating the disadvantages of the CCA. In particular, Ofcom has failed to appreciate the vulnerability of its proposed CCA design to extreme outcomes that could exacerbate asymmetry in spectrum allocation. We conclude that the CCA should not be used to award 3.6 GHz. The CCA could work in a more limited context for awarding coverage obligations together with 700 MHz.

4.1. Criteria for comparing the auction formats

We identify four categories of criteria for comparing the two auction formats:

1. ***Risk for bidders*.** Bidders in a multi-band award face a number of risks that could prevent them from bidding straightforwardly based on intrinsic valuations. If there are linkages between lots, either within or across bands, bidders may be exposed to **aggregation or substitution risk**. If a bidder has a **budget constraint**, it may be obliged to make inefficient trade-offs between spectrum lots. Finally, if an **auction design is unduly complex**, bidders may struggle to identify an optimal strategy.

2. ***Risk for the seller*.** In most auction contexts, the primary concern of a seller is to avoid low revenue outcomes, owing to **lots selling too cheaply** (below market price) or **lots inefficiently going unsold**. For Ofcom, raising revenue is not a primary concern, so avoiding unsold lots (including, in this case, the coverage obligations) is more important than achieving full market value. Nevertheless, prices should not be so low that they are inconsistent with the broader desirable outcome to realise a good outcome for UK taxpayers. Developing a process that is robust to **legal challenge** is a further relevant criterion.

3. ***Strategic bidding*.** Ofcom would prefer that bidders compete based on intrinsic valuations. Auction rules that encourage strategic deviation from straightforward bidding, such as **demand reduction**, **tacit collusion** or **price driving**, are undesirable, as such behaviour could undermine the efficiency of the auction outcome.

4. ***Outcome efficiency and fairness*.** Ofcom's primary objective for an auction is achieve an **efficient, pro-competitive outcome**. Given concerns about the asymmetric allocation of existing spectrum holdings in the UK, it is important that the format provides a path to reduce these asymmetries if it would be efficient to do so. The **outcome should also be fair**. Prices above the market prices are undesirable, as they may depress downstream investment. Asymmetric prices may be acceptable if they reflect real differences in valuations between bidders and are necessary to support allocative efficiency but are otherwise undesirable.

Amongst these categories, the fourth one – efficiency and fairness – is by far the most important, as it relates directly to Ofcom's statutory duties. Risks to bidders and sellers only matter if they are serious enough that they are likely to drive bids that lead to inefficient allocations and/or unduly high or asymmetric price outcomes for bidders. Likewise, Ofcom should not be unduly concerned about strategic bidding unless it is likely to lead to outcome inefficiency and/or prices that are unduly high, low or asymmetric.

The magnitude of the potential impact of specific risk factors is very important. In a multi-band auction setting, there is likely no set of rules that can guarantee a perfectly efficient outcome, but rules that are likely to deliver a near-efficient outcome and avoid highly inefficient outcomes should be preferred. Likewise, Ofcom should be wary of rules that could deliver very high or asymmetric price outcomes that cannot be obviously explained by underlying valuations.

4.2. Ofcom overstates the disadvantages of the SMRA

We now assess the merits of the SMRA for the purposes of awarding the 700 MHz and 3.6 GHz spectrum and coverage obligations available in this award, based on the criteria set out above. We conclude that Ofcom has overstated the disadvantages of the SMRA. It would be an excellent format for awarding 3.6 GHz if sold in a separate auction stage. It would also be a good format for awarding the 700 MHz bands, but is not suitable for addressing the positive price constraint required if 700 MHz is sold together with the coverage obligations.

SMRA risk for bidders

The SMRA is generally a low risk auction format for bidders buying spectrum. The format facilitates switching between available spectrum lots, so it typically good at addressing substitution risk. The pay-what-you-bid approach is helpful to bidders in managing budget constraints. The format also has simple, well-established rules

(notwithstanding the scope to vary activity and information rules), so complexity risk is low. One potential concern with the SMRA is its vulnerability to aggregation risk: bidders who have synergy value across lots or bands may be vulnerable to winning an unwanted or low-value subset of their demand.

Fortunately, for this award, aggregation risk across bands is likely minimal for the four main bidders. The 3.6 GHz and 700 MHz bands will be deployed differently, so the business cases are only weakly related. All four operators already have some sub 1-GHz spectrum and some spectrum in the 3.4-3.8 GHz bands. This implies that whatever synergies might exist between these two bands can be realized using spectrum from their existing holdings. An entrant would face somewhat greater risk, but this could be addressed by implementing specific measures for new entrants, for example, allowing them to specify a spectrum floor.

Aggregation risk within bands is likely to be minimal too. The available spectrum is incremental to the existing portfolios of the MNOs, so valuations per lot should typically be descending, and even small packages should be viable. The risk of winning very small amounts of spectrum could also be addressed by adjusting lot sizes, as described in section 3.1.

We recognize that aggregation risk between spectrum lots and coverage obligations represents a unique challenge of this award owing to Ofcom's positive price constraint. Without this constraint, aggregation risk would be low for MNOs because the coverage obligations could be met with existing low-band spectrum and may not be very sensitive to the volume of 700 MHz spectrum acquired. However, the positive price constraint creates a linkage because a bidder's ability to acquire a coverage obligation is dependent on spending sufficient money on acquiring spectrum. This constraint means that the SMRA is not a good format for awarding spectrum and coverage obligations simultaneously. However, as we explain in Section 5, this downside could alternatively be addressed by sequencing the sale of 3.6 GHz, 700 MHz and coverage obligations in stages of the same award.

SMRA risk for the seller

From the perspective of a seller, the SMRA has significant strengths: it can be designed to minimise the risk of lots going unsold, and the simplicity of the format makes it robust to legal challenge. The version of the format used by Ofcom for the PSSR award scores well on these criteria. The rules identify standing high bidders each round and allow withdrawals in only limited circumstances, this minimising the risk of lots going unsold. The format was also used successfully to allocate spectrum in contentious circumstances, producing results that were accepted by all bidders.

The SMRA also has a potential weakness: if demand is limited, it can be vulnerable to low revenue outcomes (see discussion below of demand reduction and tacit collusion). This is a risk for this award, given there are only four strong bidders and there is a large amount of spectrum available. However, Ofcom has specifically said that it has no

revenue objective, so this factor should not be given significant weight in assessing the merits of the SMRA.

SMRA vulnerability to strategic bidding

The original SMRA format with full information and individual, frequency-specific lots is well known to encourage strategic bidding behaviour, especially in situations where some bidders have predictable, asymmetric demand.[21] Over time, innovations in lot design (use of generic lots in categories with common prices), activity rules and information policy have reduced the scope for strategic play. The format that Ofcom developed for the PSSR award made full use of such innovations. Nevertheless, some risks remain.

For the forthcoming award, Ofcom identified three potential risks related to strategic bidding behaviour: demand reduction, tacit collusion and price driving. Ofcom's SMRA design is most vulnerable to demand reduction and/or tacit collusion. Owing to the uniform price rule, bidders that moderate their demand early – either unilaterally or multilaterally – may be able to close the auction at lower prices than if they simply bid according to value. This may result in lower revenues for the seller and could reduce outcome efficiency if some bidders reduce demand too much or too little relative to others.

Ofcom highlights these factors as potential disadvantages of the SMRA but it does not provide any evidence to suggest that this award would be more vulnerable to such actions than the PSSR award, where Ofcom decided that such risks were acceptable.

There are a number of reasons to believe that demand reduction should not be a big concern for this award:

- With four MNOs, there is no obvious focal point for a shared outcome in the 700 MHz band. (…✂…).
- A bidder's willingness to engage in demand reduction tends to be guided by its perception of fair share outcome, based on intrinsic valuations. Thus, even if demand reduction occurs in an SMRA, it is highly unlikely that the auction outcome will diverge markedly from the efficient solution. Typically, the format slightly advantages bidders for smaller quantities of spectrum, as they have less price incentive to reduce demand.
- There are tools available to make tacit collusion more difficult and/or less profitable, including restricting information about demand and using robust reserve prices.

[21] Cramton, Peter. "Spectrum Auction Design." Review of Industrial Organization, vol. 42, no. 2, 2013.

The SMRA is also relatively robust to price driving tactics, which is a significant advantage for this award, given the asymmetries between the bidders. (…✂…).

SMRA risk of inefficient or unfair outcome

Overall, the SMRA scores very highly in likelihood that it will produce a reasonably efficient auction outcome. It is generally a low risk format for bidders, so is likely to encourage them to bid based on realistic spectrum targets. Ofcom's version of the format has low risk of lots going unsold inefficiently. The format is somewhat vulnerable to demand reduction and tacit collusion, but such behaviour – if it occurs – is unlikely to result in an outcome that deviates substantially from the efficient one. Demand reduction could result in a price outcome below the market level, but the price level is irrelevant for efficiency. Robust reserve prices can also be used to ensure any such windfalls are modest. In short, the only significant disadvantage of the SMRA for this award is that it offers no good mechanism for managing the positive price constraint if coverage obligations are sold simultaneously with spectrum lots.

The SMRA can also be expected to produce outcomes that are perceived as fair by all bidders. Bidders will pay identical (or near identical) prices per MHz in each band. This is a particularly attractive feature for 3.6 GHz, where all spectrum is incremental to existing holdings, and there is no obvious efficiency rationale for allowing differential pricing.

Ofcom should also consider the broader track record of the SMRA. Table 3 provides a summary assessment of the outcome of recent 4G and 5G awards in leading economies that used an SMRA format. Observe that the award has a solid track record of producing allocation outcomes that spread spectrum across multiple bidders and lessen rather than increase existing asymmetries, and typically does so at moderate prices. (This table should be compared to the track record of multi-band CCA, as shown in Table 4.) Such outcomes might be characterised as dull and predictable, which is exactly what the UK needs right now, given the starting point of a highly asymmetric spectrum allocation in an otherwise competitive market structure.

Table 3: Track record of recent SMRAs in major economies

	Impact of allocation on relative position of MNOs	Price outcome relative to global benchmarks	Comments
Germany 4G (2015)	Reduced spectrum asymmetries between the 3 MNOs	Moderate symmetric	Competitive auction; outcome broadly in line with expectations
USA regional AWS-3 (2015)	Some increase in spectrum asymmetries	Very high symmetric	Exceptionally competitive auction; multiple winning bidders but some MNOs unsuccessful

USA regional 600 MHz (2018)	Reduced spectrum asymmetries between MNOs	Moderate symmetric	Competitive auction; MNO with smallest spectrum share was main winner
UK 2.3 GHz & 3.4 GHz (2018)	Reduced spectrum asymmetries between MNOs	Moderate symmetric	Competitive auction; outcome broadly in line with expectations
Spain 3.5 GHz (2018)	Reduced spectrum asymmetries between MNOs	Moderate symmetric	Competitive auction; all MNOs secured 80-90 MHz of spectrum across 3.4-3.8 band
Switzerland 5G (2019)	Some increase in spectrum asymmetries	Low symmetric	Competitive auction; outcome broadly in line with expectations
Austria regional 5G (2019)	Balanced outcome, no impact on relative spectrum share	Moderate symmetric	Competitive auction; outcome broadly in line with expectations

Notes: Green indicates little or no impact on allocation, or low and symmetric prices; orange indicates modest increase in spectrum asymmetry, or moderate and/or modestly asymmetric prices; Red indicates significant increase in spectrum asymmetry, or high and/or highly asymmetric prices.

In conclusion, the SMRA would be an excellent format for awarding 3.6 GHz if sold in a separate auction stage. It would also be a good format for awarding the 700 MHz bands, but is not suitable for addressing the positive price constraint required if 700 MHz is sold together with the coverage obligations.

4.3. Ofcom understates the disadvantages of the CCA

We now turn to the merits of the CCA for the purposes of awarding the available spectrum and coverage obligations, again using the criteria set out above. We conclude that Ofcom has overstated the advantages and understated the disadvantages of the CCA. In particular, it has underestimated the risk of a grossly inefficient allocation and asymmetric price outcome if 3.6 GHz is sold together with 700 MHz and the coverage obligations using a CCA.

CCA risk for bidders

The CCA uses package bidding to eliminate aggregation risk and substitution risk. We agree that these are general advantages of the CCA. However, we do not believe they are particularly relevant to this award. As discussed above, bidders would likely face very little aggregation and substitution risk for spectrum in this award if an SMRA is used, so a CCA is not adding much value here. Aggregation risk within bands can also be substantially addressed by using slightly larger lot sizes (we propose two 10 MHz lots at 700 SDL and twelve 10 MHz lots at 3.6 GHz). We note that for the PSSR auction, where Ofcom was selling two more closely linked bands, it preferred the SMRA over the CCA.

With respect to other risks, the CCA scores substantially worse that the SMRA:

- it is a more complex format for bidders, especially when used for a large multi-band award with several categories and many lots; and
- it is known to create extreme risk for bidders with budget constraints.

These are serious concerns that should not be swept aside. On complexity, there is an emerging academic literature based on lab experiments that highlights the poor performance of the CCA design relative to the SMRA in more complex settings. Studies by Kagel, Lien and Milgrom (2010)[22], Scheffel and Bichler (2012)[23], Bichler, Shabalin and Wolf (2013)[24], and Bichler, Goeree, Mayer and Shabalin (2014)[25] all conclude that bidders struggle in settings where there the number of package bid options is large.

The efficiency of the CCA is predicated on the idea that bidders will submit bids that follow consistent set of valuations. This is, however, impossible if bidders face hard budget constraints that prevent them from expressing their full valuation for larger, potentially winnable packages. In a CCA, such bidders face a difficult choice of either bidding full value for smaller packages and thereby reducing the differential bid for larger packages or submitting lower bids for smaller packages and expressing their full differential for larger packages instead.[26] The first strategy maximises the chance of winning one of the smaller packages whereas the latter maximises the chance of

[22] Kagel et al. compare the efficiency of the Porter CCA and the SMRA in lab experiment. They find that bidders tend to focus on only one or two packages in the Porter CCA. Their decision to bid for certain packages is predominantly driven by profitability at current clock prices. In simple valuation setups in which simulated bidders achieve an efficient allocation by simply bidding on the most profitable packages each round, the CCA achieves higher efficiency than the SMRA in the lab experiments. In more difficult setups in which simulated bidders cannot identify the efficient allocation by simply bidding on the most profitable package each round, the CCA had lower average efficiency in the lab experiments, and substantially lower frequencies of 100 percent efficiency, than the corresponding SMRA auctions. (Kagel, Lien and Milgrom, 2010, Ascending Prices and Package Bidding: A Theoretical and Experimental Analysis, American Economic Journal: Microeconomics 2, pages 160–185).

[23] Scheffel and Bichler find "*that the limited number of packages that bidders evaluate to be the greatest barrier to efficiency, much more so than differences in the auction formats*." This suggests that the efficiency of the CCA potentially worsens in more complex settings as bidders will find it even harder to identify the right packages to bid for. (Scheffel and Bichler, 2010, On the Impact of Cognitive Limits in Combinatorial Auctions: An Experimental Study in the Context of Spectrum Auction Design, http://dss.in.tum.de/files/bichler-research/2010_scheffel_cognitive_limits.pdf)

[24] Bichler et al. ran extensive lab experiments to compare the performance of both the SMRA and the standard CCA. They find that bidders do not bid for all relevant packages in the CCA and focused primarily on bids that are likely to win given the specific valuation structure and the prices in the clock rounds. This has a dramatic impact on the efficiency of the allocation. The CCA achieved much lower efficiency than the SMRA in their experiments. (Bichler, Shabalin and Wolf, 2013, Do Core-Selecting Combinatorial Clock Auctions always lead to high Efficiency? An Experimental Analysis of Spectrum Auction Designs, Experimental Economics, Vol. 16(4), pages 511-545.)

[25] Bichler et al. test a number of different formats in lab experiments and find that simplicity of the bid language and the payment rule have a substantial positive impact on the auction outcome. Their results suggest that simpler bidding languages and payment rules (such as those used in the SMRA) have a significant positive impact on the auction outcome. The CCA, however, uses a complex bid language and payment rule and achieves the worst outcomes in their lab experiments. (Bichler, Goeree, Mayer and Shabalin, 2014, Spectrum Auction Design: Simple Auctions For Complex Sales, Telecommunications Policy, 38:613–622.)

[26] Marsden, R. and Sorensen, S. (2017), "Strategic Bidding in Combinatorial Clock Auctions – A Bidder Perspective", chapter 35 in Bichler, M and Goeree, J, Handbook of Spectrum Auction Design (Cambridge University Press).

winning a larger package, but is more risky as it exposes the bidder to leaving the auction empty-handed. (…✂…).

Together, these factors suggest a strong case for not using the CCA for larger, multi-band awards, such as a combined award of 3.6 GHz and 700 MHz and coverage obligations. The inclusion of 3.6 GHz greatly increases the number of possible packages and likely adds needless complexity to Ofcom's auction design given limited linkages with the other products. Increasing the scale of bidding in a single auction stage also increases the risk that a bidder could face budget constraints in the supplementary round.

CCA risk for the seller

When compared to the SMRA, the CCA offers both benefits and risks for the seller. A general strength is that it is less vulnerable to low revenue outcomes in case demand is weak, owing to weaker incentives for demand reduction. However, Ofcom not put any weight on this factor, as it has no revenue objective. In theory, the format should also minimize the likelihood of lots going unsold inefficiently given it has the potential to explore all combinations of bids; however, in practice, this benefit is often lost as bidders may fail to submit a full set of bids, thus eliminating potentially efficient outcomes. As identified above, academic studies suggest this risk grows significantly the larger the number of package options there are available to bidders.

The outcome of a CCA may also be more vulnerable to legal challenge than an SMRA. In a CCA, each bidder faces considerable outcome uncertainty – it is often unclear which of its packages it will end up winning. As the process ends in a sealed bid, there is no opportunity for bidders to challenge the outcome by bidding again. The only option that bidders then have is to challenge the final allocation in court. In the short history of the CCA, this has already happened twice, once in Austria and once in the Netherlands. In both cases, the regulator prevailed but the fact that the CCA is often linked to controversial outcomes should remain a concern.

CCA vulnerability to strategic bidding

We strongly disagree with Ofcom's assessment that the risks of strategic bidding under a CCA are benign. Ofcom points out correctly that the CCA is good at reducing incentives for demand reduction and undermining incentives for tacit collusion, but more vulnerable than the SMRA to price driving. However, to present these issues as equivalent is a mistake. As discussed previously, demand reduction and tacit collusion may be undesirable but they are unlikely to result in outcomes that deviate widely from the efficient outcome. In contrast, price driving behaviour in a CCA is a much greater threat to the integrity of the auction, opening up the possibility of wildly inefficient outcomes and/or highly asymmetric prices that cannot be explained by real differences in valuation.

There is a growing academic literature that explores the incentives for strategic bidding in CCAs.[27] In certain situations, the CCA generates strong, mutually destructive incentives for aggressive bidding. This can have unpredictable results for both allocation and pricing. The format tends to favour bidders who are more aggressive, with bidders that play cautiously exposed to paying higher prices for equivalent spectrum. In the worst cases, aggressive bidders may overplay their hands, causing them to win too much spectrum, or inflict budget stress on other bidders who are then unable to submit an appropriate set of valuation-based supplementary bids. This is not an abstract point. We are aware of multiple mobile operators who have experienced exactly these problems in actual CCAs for 4G spectrum.

In our experience, incentives for strategic bidding tend to be worse when:

- *winning bidders set each other's prices* (as opposed to situations where bidders that win nothing set a common price for everyone) – this situation, which is common in multi-band auctions where competition is primarily between incumbent operators, creates incentives for bidders to exaggerate their value for larger packages of spectrum;
- *bidders have predictable demand* – this may create opportunities for bidders to identify packages that they are particularly unlikely to win that can be used to set price for rivals and/or to try to pressure rivals to back down elsewhere;
- *there are known asymmetries between bidders* – this may create options for some bidders to exert pressure on rivals that cannot be reciprocated; and
- *multiple spectrum bands or related products are sold together* – which creates a high stakes environment in which bidders are particularly worried about bad relative outcomes and generally increases the likelihood that the above conditions apply.

We are very concerned that all these conditions appear to apply to the auction format proposed by Ofcom for this award:

- Ofcom is proposing a large, multi-band award with four different categories of lots auctioned together: 700 MHz FDD, 700 MHz SDL, 3.6 - 3.8 GHz, and coverage obligations.
- (…✂…).
- H3G holds 140 MHz in the 3.4-3.8 GHz band while the other three operators hold only 40-50 MHz each. (…✂…).

[27] See, in particular: Bichler, M and Goeree, J, Handbook of Spectrum Auction Design, 2017, Cambridge University Press, Part II and Part V.

- Bidding for 200 MHz of spectrum across four categories is a high-stakes environment. The preference for a CCA exacerbates this problem because pricing is opportunity cost based, so individual bidders face the risk of paying significantly more than rivals for winning equivalent spectrum.

We are particularly concerned about (…✂…)

In annex 1, we illustrate our concerns with two examples based on plausible valuation structures:

- Example 1 shows that (…✂…).
- Example 2 shows that (…✂…).

To repeat, these kind of situations can and do occur in CCAs. Ofcom may be of the opinion that such behaviour in this auction is unlikely, perhaps because it does not think any of the bidders will want to take such risks. This is beside the point. Ofcom is not in a good position to judge the extent to which individual bidders may engage in such tactics. It is in a position to prevent such behaviour by selecting a format and rules that prevent such tactics.

CCA risk of inefficient or unfair outcome

Table 4 provides a summary assessment of the outcome of recent multi-band (or multi-region) 4G and 5G awards in leading economies that used a CCA format. Observe that the CCA, when used in multi-band settings, has a track record of producing extreme outcomes, either in terms of allocation or price. When compared to the SMRA (see Table 3), it is much more likely to be associated with outcomes that increase asymmetries in spectrum allocation and price outcomes that are very high and/or highly asymmetric across bidders.

There is a natural tendency for regulators to defend the peculiar outcomes of auctions using the CCA on the basis that the outcome was “efficient” based on the bids received. This defence misses the point. CCAs, by design, always produce the most efficient outcome based on the bids received. They may, however, fail to elicit an efficient set of bids, in which case the outcome will only be as good as the bids received. As highlighted above, there is a growing academic literature based on lab experiments that show that combinatorial auction are often less efficient that simpler formats in situations where bidders are expected to submit many bids. The peculiar track record of the CCA in allocating mobile spectrum is consistent with this finding in the literature that missing bids (whether due to complexity, budget constraints or other issues) are a serious problem with the format.

Of the eight CCAs surveyed in Table 4, six are associated with outcomes that either exacerbated spectrum asymmetry or strange price outcomes. There are two exceptions: Canada 2500 MHz and Ireland regional 3.5 GHz. We do not think it a coincidence that these two auctions happened to feature much tighter spectrum caps which had the effect

of (a) reducing the number of bid options; and (b) preventing bidders from targeting more extreme allocation outcomes in their bids.

Table 4: Track record of recent multi-band/region CCAs in major economies

	Impact of allocation on relative position of MNOs	Price outcome relative to global benchmarks	Comments
Switzerland 4G (2012)	Some increase in spectrum asymmetries	Highly asymmetric prices	Wide range in price levels between MNOs which cannot easily be reconciled with differences in spectrum
UK 4G (2013)	Significant increase in spectrum asymmetry	Moderate, some asymmetry	Very strange allocation outcome; low prices relative to bid levels
Australia 4G (2013)	Significant increase in spectrum asymmetry	Moderate to high fairly symmetric	Unbalanced outcome may be more attributable to low competition and high reserve prices than use of CCA
Austria 5G (2013)	Significant increase in spectrum asymmetry	Exceptionally high	Very unbalanced outcome in 3-player market with very high prices for all bidders
Canada regional 700 MHz	Fragmented allocations, increased asymmetry	Highly asymmetric prices	Fiercely competed auction resulting in fragmented allocations that look highly inefficient
Canada regional 2500 MHz	Balanced outcome, reduced spectrum asymmetry	Moderate, some asymmetry	Competitive auction with relatively predictable outcome, assisted by tight spectrum caps
Netherlands 5G	Some increase in spectrum asymmetry	Exceptionally high	Outcome attributable to combination of CCA and entrant reservation which limited spectrum for MNOs
Ireland regional 3.5 GHz (2017)	Balanced outcome, no impact on relative spectrum share	Low some asymmetry	Competitive auction with relatively predictable outcome, assisted by precautionary spectrum caps

Notes: Green indicates little or no impact on allocation, or low and symmetric prices; orange indicates modest increase in spectrum asymmetry, or moderate and/or modestly asymmetric prices; Red indicates significant increase in spectrum asymmetry, or high and/or highly asymmetric prices.

For the forthcoming award, Ofcom should be especially concerned about the risk of strange bids distorting allocations because it proposes to experiment with inclusion of zero-eligibility coverage obligations. In a multi-band setting, there is a real risk that a bidder that expects to secure the coverage obligation may try to exploit this to win more spectrum.

This risk has been highlighted by Ofcom's own auction advisors, DotEcon, in a report on this issue to ComReg: *"in auctions with package bidding such as CCAs, coverage obligations could create an opportunity for an operator to exploit its relatively strong position in competing for the coverage lot to leverage its cost advantage to obtain more spectrum. It can do so by bidding only for the coverage lot if it is packaged with a large amount of other spectrum."*[28]

Ofcom may come to the conclusion that some degree of distortion to the 700 MHz outcome may be acceptable to secure its coverage goals, but it makes no sense to us to also risk distorting the outcome at 3.6 GHz.

In conclusion, Ofcom is taking a huge risk in proposing a multi-band CCA for this award. There is a material risk that such a format will produce an unexpected outcome that it is hard to explain on efficiency grounds. Even if the outcome is fairly efficient, it is quite likely that prices could vary widely between bidders, based largely on their aggression and willingness to engage in strategic over-bidding, rather than any real differences in value. Ofcom's approach is especially risky given (a) the context of high asymmetry in UK spectrum holdings, and the potential for these to be inefficiently exaggerated if the auction goes wrong; and (b) the importance of the 3.6 GHz band to the UK's 5G future, an issue that is very important to government policy. Ofcom could mitigate these risks by selling 3.6 GHz separately using an SMRA, and introducing precautionary spectrum caps to close off extreme bidding behaviour. It will have few if any options to mitigate a bad outcome after an award, given there are no further awards of substitutable spectrum in the pipeline.

[28] Coverage obligations and spectrum awards, a report from DotEcon Ltd, 2018. p48

5. Alternative sequential stage auction designs

Ofcom's preference for the CCA design flows from its explicit preference to sell 700 MHz and the coverage obligations together and its implicit preference to sell 3.6 GHz and 700 MHz together. We recognise that the CCA addresses a key concern identified by Ofcom for this award: the aggregation risk between spectrum lots and the coverage obligation created by the positive price constraint. However, as we set out in this section, there are other ways that Ofcom can achieve its objective without resorting to a large, multi-band CCA, with the inherent risks.

We set out two alternative designs for the award:

A. **Two-stage allocation:** A separate bidding stage for 3.6 GHz using an SMRA format; followed by smaller-scale CCA for 700 MHz and coverage obligations but taking into account revenues from the 3.6 GHz auction stage in the positive price constraint.
B. **Three-stage allocation.** A 3.6 GHz allocation stage (SMRA); followed by a 700 MHz allocation stage (SMRA); and finally, a coverage obligation allocation stage (second price sealed bid). We propose a voucher mechanism that would enable all bidders to compete for the coverage obligations while avoiding the any requirement for Ofcom to make subsidy payments.

We have been mindful of Ofcom's objectives and stated limitations. We believe that our two designs are at least as good as Ofcom's proposed CCA in achieving each of Ofcom's four objectives (as discussed in Section 2) and should offer a greater likelihood producing an efficient, pro-competitive allocation of spectrum. Moreover, they are much less likely to produce an extreme allocation outcome that worsens spectrum asymmetries. Our designs follow Ofcom's decision to use unbundled coverage obligations and respects Ofcom's positive price constraint.

This section is in four parts. We begin with some general comments on the challenge of selling coverage obligations within a spectrum award, in particular when the seller is subject to a positive price constraint. We then describe our two alternative designs for the allocation stages of the award. The final part addresses the design of the assignment rounds, which should be straightforward for 700 MHz but is very challenging for 3.6 GHz owing to the related issue of defragmenting the wider 3.4-3.8 GHz band. We propose changes to Ofcom's standard approach that should increase the likelihood of efficient defragmentation.

5.1. Coverage obligations and the positive price constraint

Ofcom's auction design has two novel and innovative features:

- unbundled coverage obligation lots; and
- a positive price constraint.

Ofcom proposes to sell two coverage obligations in exchange for a maximum discount in the order of £350m. The obligations are to be sold as lots in the auction. These lots are offered at a negative price with bidders competing up the price and thus competing down the implicit subsidy.

We agree with Ofcom that this innovation has the potential to allocate more efficiently the coverage obligations, as opposed to the traditional approach of bundling coverage obligations with spectrum lots. This approach gives the market a role in defining the 'right' combination of spectrum and obligations. It makes pricing in the auction simpler and more transparent, as there will be just one category of 700 MHz spectrum, as opposed to encumbered and unencumbered categories. It also lessens the risk that spectrum may go unsold; as could happen if a coverage obligation bundled with spectrum is too onerous.

We understand that Ofcom considers it has no power to accept negative bids. As stated in the Consultation, "*Ofcom is required under the Communications Act 2003 to pay auction receipts into the Consolidated Fund, and has no power to pay any part of those receipts to third parties, such as bidders in an auction."*[29] This is an important limitation because adding a coverage obligation to a package of spectrum could result in a net negative bid amount, which (if permitted) would imply that Ofcom would have to compensate the bidder to take the obligation.

The positive price constraint presents a challenge for auction design:

1. It may oblige bidders to bid for packages different from their true preferences. For example, at some prices, a bidder may want to bid for a package worth £100m of spectrum and the maximum available obligation discount of £350m. This is not a valid bid in Ofcom's proposal.

2. It may cause one or both of the coverage lots to go unsold, even if there is demand for the obligations at the starting price.

If Ofcom believes that total auction proceeds are likely to surpass the discounts provided by the coverage lots, Ofcom's CCA format has the potential to solve both issues.[30] However, we believe that our SMRA designs can solve them at least as well as Ofcom's CCA. Our two-stage design includes a CCA format for allocation the 700 MHz band and the coverage obligations. This achieves the same benefits of Ofcom's proposal without the opportunities for strategic bidding. In our three-stage design, there is an additional

[29] Consultation, §7.96.

[30] Key arguments contained in the Consultation are as follows. In relation to the unbundled coverage obligations, Ofcom has explained that "*a key driver in the choice between formats for this auction are the coverage obligations.*" In relation to the positive price constraint, Ofcom has expressed that "*a bidder who requires more spectrum than it would otherwise to take on the coverage obligation has a difficult decision, as it will not know whether it is going to win a coverage obligation*" [underline added] and "*bidders could strategically win more spectrum in the first stage … The strategic intention would be to make it unprofitable for other bidders to bid on the coverage obligation (given the positive price constraint).*"

benefit: Ofcom can adjust the number and the maximum discount of coverage lots after the spectrum stages. If all the spectrum is not valuable enough to offset the coverage lots, the lots will go unsold regardless of the mechanism.

5.2. Approach 1: Separate stage for 3.6 GHz

Our first approach is a relatively modest departure from Ofcom's proposal, but offers very significant advantages. We propose that the allocation stage for 3.6 GHz be separated from the other lots. 3.6 GHz lots would be awarded first using a single-band SMRA, followed by a smaller-scale CCA for 700 MHz and the coverage obligations. Crucially, however, these would not be separate awards but rather separate stages of the same award; therefore, the revenues from the 3.6 GHz stage could still be taken into consideration when determining if a bid fulfils the positive price constraint.

By removing the bidding link between 3.6 GHz and 700 MHz, and not using a CCA in a band where spectrum asymmetries are a particular problem, the risk that the auction is distorted by budget constraints, price driving, missing bids or other such concerns is greatly reduced. We believe this design strictly improves Ofcom's proposal without disrupting its main features.

We are less concerned about strategic bidding in a smaller-scale CCA that is focused only on 700 MHz and coverage obligations. Price driving in this band alone is risky because the outcome is less predictable. Further, Ofcom could largely eliminate this risk by introducing a simple precautionary cap of 40 MHz per bidder. The smaller size of the auction means less risk for bidders: bidders are less likely to hit budget constraints because less money is at risk; and bidding is less complex as fewer lots means fewer bid options.

The auction would proceed in 3 stages:

- **Stage 1: 3.6 GHz allocation using an SMRA format**:
    - We propose that Ofcom use a simple single-band version of the hybrid clock-SMRA format that it developed for the PSSR award. With no switching required, this format is straightforward to design.
    - The spectrum should be packaged into 12 lots of 10 MHz, so as to remove risk that bidders win unusable or low-value 5 MHz chunks of 5G spectrum. Optionally, the ability to specify a "minimum requirement" up to 20 MHz could be offered to non-MNOs, to protect such bidders from winning a very small package. Such a minimum is not needed for MNOs given that expected to seek to aggregate any spectrum they acquire with their existing holdings in the wider 3.4-3.8 GHz band. Taken together, these measures should eliminate any meaningful aggregation risks.
    - Ofcom should tweak the pricing rule used in the PSSR award, such that all bidders pay a uniform price equal to the lowest winning bid. Such a

rule would be fair to all operators, and more in line with Ofcom's obligations not to discriminate between operators.

- With an SMRA, applying spectrum caps is less important than in a CCA, as the uniform price rule combined with the risk that you may win a subset of your demand creates a powerful disincentive to overbid for strategic reasons. Nevertheless, we recommend that Ofcom consider a number of caps to promote pro-competitive outcomes (see Section 0).
- As an SMRA produces a band-specific price, it will be straightforward to use this outcome as a benchmark for ALF in the 3.4 GHz and 3.6 GHz band. Ofcom should therefore not rule out the possibility of revising H3G's ALF if the outcome of this auction reveals a higher or lower market price than that estimated based on the outcome of the PSSR award.

- **Stage 2: 700 MHz and coverage obligations using a CCA format**
  - We propose that Ofcom use the same CCA format that it has proposed for a broader multi-band award. There would now be for three instead of four categories.
  - The 700 MHz spectrum can be packaged into six lots of 2x5 MHz (paired) and two lots of 10 MHz (SDL). This would mean there are only 10 lots in total, a significant simplification with respect to package bid options.
  - Optionally, Ofcom could break up the coverage obligations, creating two obligations for each of the UK nations (England, Northern Ireland, Scotland and Wales). Having eight coverage obligation lots would be manageable within a CCA design, as with fewer spectrum lots, the impact on the number of bid options is not so great.
  - The positive price constraint can be implemented as proposed. The only change is that any winning prices from the prior 3.6 GHz allocation stage would be taken into account when determining if a bid fulfils the positive price constraint.
  - We propose some modest changes to the activity rules and information rules proposed by Ofcom. (These apply whether or not 3.6 GHz is included in the award, as described in Section 7.)
  - We strongly recommend that Ofcom introduce a precautionary spectrum cap of 40 MHz (4 lots) across the paired and SDL bands. This is 50% of the available spectrum or two-thirds of the more valuable paired spectrum. As discussed in Section 3.3, such a measure would be most unlikely to cut off any potential winning or price-setting bids, but would cut off options for price driving and would ensure at least two winning

bidders, which should also increase the likelihood that both coverage obligations are sold.

- **Stage 3: Assignment Stage**
    - There would be separate assignment processes for each of the three spectrum bands so as to assign specific frequencies to bidders that win generic spectrum allocations. We discuss the best approach for each band below in Section 5.4.

This approach offers the same benefits as Ofcom's proposed design while reducing the associated risks for Ofcom and for the bidders:

- This approach replicates Ofcom's innovations with respect to unbundled obligations and the positive price constraint.
- There is no additional aggregation risk. This approach deals with aggregation risk by: (a) using a CCA format for the 700 MHz band and the coverage obligations; and (b) within bands, using slightly larger lot sizes for 3.6 GHz and 700 MHz SDL.
- There is no meaningful aggregation risk between the 3.6 GHz and the coverage obligations. The only benefit of a simultaneous award was that bid amounts are larger so may more easily absorb the benefit the coverage obligations better. The same benefit can be achieved by netting the bids for the 3.6 GHz against any package containing the coverage obligations in the second stage.
- The design provides greater flexibility to Ofcom with respect to defining the coverage obligations. Not only is the design flexible with respect to any changes in maximum discount, but it could also cope with a larger number of coverage obligations.
- This approach is much less vulnerable to risks that can distort the auction outcome, such as price driving or budget constraints. This massively de-risks the auction for both bidders and for Ofcom. Risk can be further reduced by also adopting spectrum caps.

In short, we see no downside to Ofcom implementing this approach, other than the administrative burden of running an extra auction stage (which may anyway be offset by avoiding the time sink of running a more complicated CCA).

5.3. Approach 2: Sequential Auction

Our second design is fully sequential with three allocation stages: 3.6 GHz, 700 MHz, and coverage obligations. It is inspired in part by analysis of this issue by DotEcon, who point out that: "*the need for a combinatorial format can be avoided if the assignment of*

coverage obligations and the assignment of spectrum is separated into distinct stages."[31]

In order to increase competition in the coverage stage and circumvent the positive price constraint, our second design introduces a further innovation: bidder vouchers. The vouchers are an asset that Ofcom may sell to bidders to absorb any 'extra' discount not covered by that bidder's positive payments for 3.6 GHz and 700 MHz spectrum.[32] We propose that Ofcom accepts vouchers as payments for a broad range of operators' obligations related to mobile spectrum including future primary spectrum awards and annual licence fees (ALF).

This approach offers further benefits when compared to our Approach 1 with respect to fulfilling Ofcom's objectives for the award. By delinking the allocation of coverage obligation from the allocation of 700 MHz, the risk that the latter is distorted by the former is largely eliminated. Furthermore, the use of bidder vouchers opens up the scope for all MNOs to compete for the coverage obligations, regardless of whether they spend a sufficient amount of money in this specific award. This addresses a flaw in the design that Ofcom itself has highlighted: that it cannot be sure that winners of 700 MHz spectrum are necessarily the parties that can most efficiently fulfil the coverage obligation. This approach is also much more flexible: without the constraints of having to tailor the design of coverage obligations to mesh with spectrum lots in a package bid auction, Ofcom will be free to revisit the optimal design of the obligations.

As the issue of vouchers is innovative, we asked Telefónica's external Counsel to consider whether Ofcom would be permitted to take such an approach. Their preliminary view was that such a measure was possible and would be consistent with the relevant statutory framework, as like Ofcom's auction design, this approach would not involve Ofcom paying out any money. They were of the opinion that Ofcom would need to amend the regulations for relevant ALFs and future primary awards to permit payment or part payment by voucher, and that Ofcom would need to consult on any such changes.

The auction would proceed in 4 stages:

- **Stage 1: 3.6 GHz allocation using an SMRA format**:
    - As described above for Approach 1.
- **Stage 2: 700 MHz allocation using an SMRA format**

[31] DotEcon, December 2018, Options for the design of the auction in the 700, 1500 and 2100 MHz bands, Prepared for RTR (the Austrian regulator).

[32] We also explored an alternative system of "transferable discounts" between bidders, a mechanism that allows bidders with 'extra' discount – i.e. a winning bid that would violate the positive price constraint – to transfer that extra discount to other bidders owing positive payments. This approach is also feasible but would be more complex to administer, as it would require a series of pre-auction bilateral deals between qualified bidders.

- We propose that Ofcom use the dual-band version of the hybrid clock-SMRA format that it developed for the PSSR award. These rules would permit switching between the paired and SDL categories.
- The 700 MHz spectrum should be packaged into six lots of 2x5 MHz (paired) and 2 lots of 10 MHz (SDL). This would support a simple 1:1 MHz ratio and eligibility points structure, thus facilitating easy switching between categories provided there was excess demand. Using larger blocks for SDL also removes exposure to winning a very small unusable amount of spectrum, which would otherwise be a concern in an SMRA format that can retain demand.
- As at 3.6 GHz, Ofcom should tweak the pricing rule used in the PSSR award, such that all bidders pay a uniform price equal to the lowest winning bid. Otherwise, the rules from the PSSR award can be carried over to this one largely intact, meaning very little new work is required by Ofcom.
- We recommend that Ofcom consider a precautionary cap of 40 MHz per bidder so as to ensure at least two winning bidders and guard against extreme outcomes that may increase spectrum asymmetry. Such a cap is less important than if a CCA is used, given that the lot retention rules in the PSSR format provide a powerful incentive not to overbid.

- **Stage 3: Coverage lots allocation using a second price sealed bid**
  - We propose that Ofcom award the coverage obligations using a second price sealed bid auction, similar to the standard format used for assignment rounds. A sealed bid may be acceptable if coverage obligations are being sold independently from spectrum, on the basis that bidder values should be largely fixed based on private estimates of roll-out costs, so price discovery is not required to alleviate common value uncertainty.
  - In the simple case where there are two coverage lots, each bidder would submit their best offer i.e. the smallest discount they would accept. The obligations would be awarded to the two operators that submit the lowest bids, and they would pay a price based on the third smallest discount. This approach provides excellent incentives for straightforward value-based bidding.
  - Unlike with Ofcom's approach, competition would not be limited to bidders that spent enough money on 3.6 GHz and 700 MHz spectrum. In the event that an obligation was awarded to a bidder with a negative net price, that bidder would be allocated vouchers with a value equal to the difference. Vouchers would be transferable between operators and could

be used to settle any financial obligation to Ofcom related to spectrum as may be permitted under the law. A detailed example is provided in Box A below.

- This format is very flexible and opens up an opportunity for Ofcom to explore alternative structures for the design of coverage obligation lots and the types of bids permitted. Two options stand out to us as worthy of further analysis:

  i. *Regional coverage obligations*. The design could be flexed to allocate a large number of coverage obligation lots. For example, Ofcom could divide the coverage obligations into four, one for each nation of the UK. It could go further, defining more local obligations. This approach would allow the market to explore a broader range of solutions for allocating rural coverage across the four MNOs.

  ii. *Joint bidding*. Ofcom could allow up to two MNOs to submit a joint bid to acquire two coverage obligation lots. It may be much more economic and more beneficial to customers to have two operators jointly roll out a rural network than having individual operators do this.

- **Stage 4: Assignment Stage**

  - As with Approach 1, there would be separate assignment processes for each of the three spectrum bands so as to assign specific frequencies to bidders that win generic spectrum allocations (see Section 5.4).

Box A: Bidder vouchers – an example

Table 5 provides an example of an auction outcome in which two bidders are allocated vouchers:

- Bidder C wins a coverage lot but has a negative price of £50m, so is allocated a voucher with this value, such that its net payment to Ofcom is zero.
- Bidder D wins a coverage lot but has a negative price of £150m, so is allocated a voucher with this value, such that its net payment to Ofcom is zero.

Ofcom collects total revenues from the auction of £1,300m and grants spectrum licenses, two coverage lots, and vouchers for £200m.

Table 5: Winning bids in vouchers example

Bidder	Spectrum Bids	Coverage Bids	Real Bid Value	Voucher component	Payment to Ofcom
A	£700m		£700m		£700m
B	£600m		£600m		£600m
C	£300m	-£350m	-£50m	£50m	£0m
D	£200m	-£350m	-£150m	£150m	£0m
Total	**£1,800m**	**-£700m**	**£1,100m**	**£200m**	**£1,300m**

Bidders C and D have the option to hold to their vouchers and use then to settle any relevant obligations with Ofcom (such as ALF payments). Alternatively, they could sell them to other bidders before auction payments are made. We propose that there is a time window between allocation of vouchers and the deadline for payment of fees from bidders with positive prices, so that the vouchers could potentially be traded immediately and used for settlement in this auction.

Table 6 provides an example of how the vouchers might be re-allocated in a private sale. Before cash fees for licences are paid to Ofcom, Bidder A acquires £200m in vouchers from Bidders C and D. (Presumably, Bidders C and D would be willing to sell the vouchers at a slight discount to their value, given they will otherwise lose real value over time). Bidder A uses the vouchers to partially pay for its winning bid in the auction. Ofcom receives £200m in vouchers and £500m in cash from Bidder A.

As a result of these transactions, the market facilitates allocation of the coverage obligations to the efficient operators in a situation where they might otherwise have inefficiently failed to win these obligations. This is done without violating the constraint that Ofcom cannot make payments to operators.

Table 6: Example of how vouchers could be re-allocated through private sale

Bidder	Voucher Purchases	Voucher payment to Ofcom	Cash payments to Ofcom	Ofcom Bids	Effective Payments
A	£200m	£200m	£500m	£700m	£700m
B	£0m	£0	£600m	£600m	£600m
C	-£50m	£0	£0m*	£0m*	-£50m
D	-£150m	£0	£0m*	£0m*	-£150m
Total	**£0m**	**£200m**	**£1,100m**	**£1,300m**	**£1,100m**

This approach offers the same benefits as our Approach 1 plus some additional benefits:

- As with Ofcom's proposal, this approach uses the unbundled obligations and is faithful to the positive price constraint while finding a way to consider a broader range of bids.
- Approach 2 has a particular edge in promoting competition and efficiency in the mobile market. Competition for the spectrum lots is not restricted to those bidders who also need big packages of spectrum as in Ofcom's proposed CCA. In this approach, all bidders can compete for the coverage lots without worrying about individual positive price constraints. Full competition for the coverage lots increases the likelihood that the coverage lots will be allocated to the operator with the lowest deployment cost, increasing the benefits to society.
- There is very limited spectrum aggregation risk. The use of vouchers offers a simple and powerful mechanism to prevent aggregation problems, as bidders are no longer forced to bid for larger amounts of spectrum to enjoy the full amount of the discount.
- The design provides maximum flexibility to Ofcom with respect to defining the coverage obligations. As obligations are sold in a separate stage, they do not need to be limited to two nationwide blocks and could be split on a UK nation basis or in smaller units.
- This approach is even less vulnerable to risks that can distort the auction outcome, such as price driving or budget constraints. This de-risks the auction for both bidders and for Ofcom. As with all approaches, risk can be further reduced by also adopting precautionary spectrum caps.

This approach is more administratively burdensome that approach 1. In addition to requiring an additional stage, Ofcom may need to revisit ALF regulations to allow for payment by voucher. Overall, however, these costs appear modest relative to the potential gains set out above.

5.4. Assignment of frequencies

Regardless of the approach adopted for the allocation phases, Ofcom will need to run up to three assignment processes to allocate specific frequencies to winning bidders, one each of 3.6 GHz, 700 MHz FDD, and 700 MHz SDL.

3.6 GHz assignment round

Owing to legacy allocation decisions, the 3.4-3.8 GHz band in the United Kingdom is fragmented. If the auction proceeds as proposed, a likely outcome is that all four MNOs will end up with at least two discontinuous blocks of spectrum, and just one (H3G) will have access to a block of 80-100 MHz, the amount identified as optimal for 5G

deployment. Even if H3G trades some of its spectrum prior to the auction, there is no guarantee that all operators would achieve contiguous large blocks.

As Ofcom recognises, this fragmentation is inefficient and would prevent the most effective deployment of 5G services in the band. There is currently no technical option to aggregate carriers within the 3.4-3.8 GHz band, and it is unclear when this will become available. This implies there will be a period of time when UK operators cannot use their fragmented blocks together, meaning they will have lower throughput and higher costs. Moreover, the United Kingdom may be the only country in Europe that has such fragmentation, putting UK consumers at a connectivity disadvantage. If the entire band had been allocated simultaneously, Ofcom would obviously have established rules that ensured that all winners of spectrum in this band receive contiguous frequencies.

There is a simple solution to this problem. Ofcom could require all existing holders of spectrum in the band to include their spectrum in the assignment round. This would allow the entire band to be re-planned in a way that is optimal for all operators and for UK society as a whole. Our understanding is that the costs to bidders of such a realignment would be minimal, as none have yet deployed 5G services.

Our team at NERA proposed and implemented a similar solution for the 1800 MHz band in Saudi Arabia, where legacy fragmentation threatened to impede the efficient deployment of 4G by preventing some operators forming 20 MHz blocks optimal for LTE. One of the operators who held an advantageous frequency position was initially resistant to the proposal, but ultimately accepted the change. Our understanding is that the operators were able quickly to implement the re-planning of the band at low cost and without disruption to customers – and this was in a band where the spectrum was already in use.

A similar precedent for moving incumbent operators to equivalent spectrum has also been established in the United States, where many broadcasters that were not bought out in the Incentive Auction were required to move to lower UHF frequencies to accommodate the new 600 MHz mobile band. In this case, a mechanism was established to compensate operators for the cost of relocation.

In Europe, it is commonplace for national regulators to require band defragmentation when spectrum is awarded. Telefónica has taken part in such processes in Czech Republic, Slovakia and Germany. The UK is subject to the same Common Regulatory Framework as these countries, so it is hard to see why such an approach is so difficult in the UK. The process of moving frequencies within the same band is not complex and is inexpensive for operators. This is especially true at 3.4-3.8 GHz, where UK operators have not even deployed. Moreover, the United States (in a slight different context) demonstrates that this can be done even in a country with a very strong spectrum property rights regime.

Full band re-assignment and/or industry consensus could provide a path to defragmentation in the UK. We find it odd that Ofcom has not made a serious effort to

push one or both of these approaches. We understand that Ofcom may not have the power to coerce operators to participate, but (backed by the Government) it has considerable "soft power" to encourage all operators to engage a process that is manifestly in the broader national interest. Moreover, in the same way that it has proposed to use revenues from this auction to support coverage obligations, it could use them to offer compensation for the (minimal) costs of moving frequencies and (where appropriate) refund of 3.4 GHz assignment round fees from the PSSR auction.

The main barrier to a negotiated solution to defragmentation appears to be the strategic position of H3G's existing holdings. Ofcom recognises that a defragmentation plan can result in an assignment with continuous spectrum holdings for all operators *"only if all holders of spectrum in the 3.4-3.8 GHz band took part."*[33] Incentives to participate, however, are not symmetric. Ofcom further recognises that *"H3G's participation in any post auction or in auction process would be essential for all of the MNOs to achieve contiguity of their spectrum holdings in the 3.4-3.8 GHz band."*[34] and that, because H3G already has a contiguous block of 100 MHz, *"H3G may not have sufficient incentive to take part in any such process."*[35] *Ofcom also says that "the value that H3G places on winning new spectrum in the award or consolidating its holdings in the 3.4-3.8 GHz band into a single contiguous assignment may be less than the value it places on being able to engage in trading using its existing licences."*[36] Put differently, Ofcom appears to believe that there can be no resolution unless H3G is allowed to appropriate some of the value generated by other operator consolidating their spectrum holdings.

Ofcom's default proposal is to do nothing to address fragmentation, and instead rely on the secondary market to defragment the band after the award. There is a high risk that this approach will never deliver an efficient assignment for two reasons. Firstly, operators may have conflicting views on the value of defragmentation, so cannot agree on terms of trade. Secondly, subsets of operators may have strong incentives to cut bilateral deals that leave one or more rivals with permanently fragmented spectrum. Even supposing that there is no option for industry consensus or a grand assignment round, there are smaller measures that Ofcom could take to make it less likely that the band remains fragmented.

Ofcom's default proposal to use the standard second price sealed bid combinatorial auction also risks inflaming the issue. We are normally strong proponents of this approach (one of our team helped develop this format when consulting with Ofcom in the 2000s, and, since 2010, NERA has proposed this approach for several auctions that we have run for regulators). However, the format was developed to assign frequencies to winning bidders in situations where the value differences between assignment options are modest, for example because there are small differences in the vulnerability of

[33] Consultation, §6.21.

[34] Consultation, §6.32.

[35] Consultation, §6.27.

[36] Consultation, §6.23.

specific frequencies to interference. It was not designed to cope with situations where intrinsic value differences between underlying frequencies are likely to be dwarfed by the strategic value of securing or blocking options to trade spectrum so as to secure contiguous blocks.

In this context, the outcome of a standard assignment round may make defragmentation even harder to achieve:

- (…✂…)
- Bidders may bid and pay larger amounts of money to secure specific positions that they think are likely to be adjacent to their preferred trading partner but then find that that partner has ended up somewhere else in the band or has not won the necessary quantity of spectrum to support an efficient trade.

Ofcom offers only tenuous arguments in favour of post-auction spectrum trading. It says that *"it would require only two separate bilateral trades to achieve defragmentation in a number of reasonably likely outcomes to the principal stage."*[37] However, (…✂…). The efficiency loses in the allocation of spectrum could be very large.

There is a much better chance that defragmentation will be achieved if Ofcom intervenes in the assignment and trading processes to guide the market in this direction. We propose that Ofcom consider the following steps so as to maximise the likelihood of efficient post-auction trades:

1. *Provide full information about the allocation of 3.6 GHz spectrum to all bidders before the assignment round*. This will help bidders to understand their options for positioning themselves adjacent to potential partners. (We propose other rules to stop third parties exploiting information to try to block such trading options).

2. *Any assignment of new spectrum to H3G must be adjacent to their existing holdings*. This simple rule would prevent H3G from bidding strategically to block other bidders from options to trade without them so as to increase their windfall gains.

3. *Any parties that do not already have spectrum in the 3.4-3.8 GHz band should be allocated contiguous spectrum at the top of the band.* This rule would prevent third parties from acquiring spectrum in the middle of the band as a way to extract windfall gains from trades to defragment the band

4. *Give remaining parties the opportunity to form an industry consensus*. BT, Telefónica and Vodafone should be given an opportunity to agree between themselves their preferred positions in the remaining spectrum. In case only two parties reach agreement to occupy adjacency spectrum, they should be granted

[37] Consultation, §6.31.

this request, but the third bidder would then have first choice over their frequency position.

5. *Any remaining placements would be resolved in a bidding stage*. It is likely that rules 2-4 would fully resolve the assignment, but if this is not the case, an assignment bidding stage may be required. Ofcom should consider a revised format that reflects the importance of adjacent bidder allocations and the high value in this assignment compared with typical assignment rounds.

Even with these measures in place, (…✂…) the outcome would be that at least one operator has no route to defragmentation.

Ofcom has one more tool at its disposal to encourage trading solutions that support full band defragmentation. Ofcom is responsible for reviewing and approving all spectrum trades. It could issue guidance now that it would be minded to reject trades that provide only partial solutions to defragmentation, unless the petitioners can demonstrate that they made good faith efforts to find a multilateral solution or that their trade would not prevent such a solution from subsequently emerging. Trades that do not meet these criteria could be rejected on the basis that they are not consistent with Ofcom's duty to ensure that spectrum is used in the most effective way.

700 MHz assignment rounds

We agree with Ofcom that the standard second price sealed bid combinatorial auction is the appropriate format for the assignment of 700 MHz paired and SDL frequencies. Unlike at 3.6 GHz, there are no legacy allocation issues or fragmentation concerns that may affect frequency preferences. Bids are therefore likely to be based primarily on value differences associated with specific frequency placements, which are likely to be small.

The upmost SDL lot is immediately adjacent to the lowest paired downlink frequency lot. To minimize the number of frequency boundaries between bidders, it may be appropriate to prioritise allocating these lots to the same winning bidder, if possible.

Accordingly, we recommend that Ofcom consider the following rules:

- The assignment round for the paired band takes place first, so frequency placements for paired spectrum are determined before the SDL assignment round.

- If there is only one bidder that has won both paired and SDL spectrum, then that bidder would automatically be allocated adjacent paired spectrum. Practically, this means that this bidder would have only one bid option in each assignment round, and other bidders would not be able to bid on the associated frequencies.

- If two or more bidders have won spectrum in both paired and SDL bands, then those bidders would uniquely be offered options to bid on assignment options

that include the lowest paired lot. The bidder that secures this option in the paired assignment round would then be assigned the adjacent SDL option.

- If no bidders have won both paired and SDL spectrum, then there would be no constraints on bid options in the two assignment rounds.

These proposed rules are based on the assumption that no winning bidder has a strong preference to be adjacent to a specific other winning bidder, so as to facilitate future spectrum sharing. If Ofcom were to receive information that bidders care about this issue and Ofcom considers that it would be beneficial to facilitate such behaviour, then it would need to rethink the approach of using an auction for this stage.

6. Other tools that can mitigate risk for bidders and for Ofcom

Ofcom has a number of tools at its disposal that can be deployed as part of the auction design to mitigate the risk of failure. These are rules that can be expected to reduce the risk of inefficient allocation outcomes, including lots going unsold unnecessarily, or price outcomes that are too low, too high or too asymmetric between bidders relative to true market price. The choice of tools may vary depending on the auction format.

In this section, we make recommendations with respect to five tools that Ofcom can use to improve the likelihood that the auction is a success:

1. **Spectrum caps.** We propose additional spectrum caps as a safeguard against extreme allocation outcomes that could inefficiently increase spectrum asymmetries. Such measures are particularly important if a CCA is used for any part of the process.

2. **ALF for equivalent spectrum.** If H3G is allowed to bid for more 3.6 GHz spectrum, then Ofcom must retain an option to review H3G's ALF for its existing holdings. (…✂…).

3. **Reserve prices.** It makes sense to set robust reserve prices for 3.6 GHz and for 700 MHz paired, given abundant evidence that they have substantial value. This would underpin revenues to cover the coverage obligations in the unlikely event of a low competition scenario.

4. **Eligibility points.** We recommend that Ofcom use a 1:1 eligibility points ratio in the 700 MHz band between 2x5 MHz paired lots and 10 MHz SDL lots. This would allow bidders to switch between these lots based on capacity.

5. **Information policy.** We support some measures to limit the information about demand provided to bidders. This is a helpful tool to discourage certain types of strategic behaviour in both an SMRA or CCA. However, the benefits of such approaches should not be overstated. In particular, they are no substitute for spectrum caps as a tool to prevent behaviour that could lead to extreme, inefficient outcomes.

6.1. Spectrum caps

Alongside the choice of auction format, spectrum caps are the most powerful tool available to Ofcom to influence the outcome of the auction. By definition, any caps that prevent one or more bidders from bidding for some of the available spectrum would constrain the range of possible allocation outcomes. The main rationale for using caps is to protect competition in the downstream market, by eliminating undesirable outcomes, such as those that might unduly increase asymmetries in spectrum holdings. Caps may also be used to close off strategic bidding options, such as price driving, if

these involve bidding on larger packages. When setting caps, these benefits must be weighed against the risk that if caps are set too tightly, Ofcom may inadvertently eliminate an efficient outcome or constrain bids relevant for setting the market price.

A distinction may be drawn between:

- **Competition caps** – these are caps designed to support broader policy goals in relation to competition in the downstream market, for example Ofcom's 37% cap on holdings of usable mobile spectrum with the aim of preserving a 4-player market; and

- **Precautionary caps** – these are caps set in the context of a specific award that are designed to eliminate extreme outcomes, such as one or two bidders acquiring a disproportionate share of all the newly available spectrum and/or blocking one or more rivals from a key band.

In this section, we focus on the case for precautionary caps. It is beyond the scope of this report to explore the impact of asymmetric spectrum holdings on competition in the downstream market. Nevertheless, given the extent of existing spectrum asymmetry between the four UK operators, the rationale for competition-based caps is clearly strong and merits further exploration.

When deciding whether and how to set precautionary caps, there are three main considerations:

a) **The auction format.** If the regulator plans to use a format, such as the CCA, where bidders have strategic incentives to inflate demand, caps can act to check that behaviour and prevent extreme outcomes. Caps may be less important with formats, such as the SMRA, where bidders have incentives to moderate demand.

b) The importance of the available spectrum. If the award includes a large amount of spectrum or a band that is particularly important to the launch of new technology, then caps provide a first line of defence against unduly concentrated allocations that may raise future competition concerns.

c) **Pre-existing asymmetries between bidders**. If there are significant asymmetries between bidders, either in terms of market share or pre-existing holdings of relevant spectrum, some bidders may be able to exploit this in the auction to get a better outcome. Caps can be used to limit this power.

By way of example, consider the forthcoming spectrum auctions in Germany (2100 & 3500 MHz) and Canada (600 MHz regional). Both are high-value multi-category awards. In Germany, the risk of an extreme allocation outcome is constrained by the choice of an SMRA format and a starting point of three strong, fairly symmetric operators, so the regulator has decided not to impose any spectrum caps. In contrast, in Canada, where a CCA format is being used and the government has a policy of supporting the smaller, regional operators, there are no such guard rails, so the regulator decided to impose a

collective cap on the three national operators, so as to ensure that regional players will win at least 2x15 MHz.

Turning to the UK award of 700 MHz and 3.6 GHz, it is apparent that all of the factors that buttress the case for precautionary caps apply: Ofcom has proposed a CCA, not an SMRA; there is a large amount of spectrum available, including 5G spectrum that cannot be easily substituted with other bands; and the starting point is one of exceptional asymmetry in spectrum holdings, both generally and within the 3.4-3.8 GHz and sub-1.5 GHz categories. In short, the case for imposing spectrum caps to close off extreme outcomes is a very strong one, especially if a CCA is used.

In the consultation, Ofcom has indicated that it is minded to implement the 37% general cap. This is a prudent measure aimed at preventing any one operator from acquiring *"a share of around 40% of overall spectrum* [that] *may raise competition concerns."*[38] In practice, however, the cap only meaningful constrains one operator, BT. It eliminates certain outcomes in which BT extends its large spectrum lead and should also constrain BT's ability to engage in price driving behaviour. However, the cap does nothing to prevent other extreme outcomes with respect to holdings of 5G capacity spectrum or sub-1.5 GHz spectrum, nor does it constrain other bidders from engaging in price driving strategies. By itself, the cap puts BT at a strategic disadvantage within the context of the auction. While this may be acceptable given the broader competitive context, Ofcom should think hard whether measures that only constrain one operator are really sufficient to address its broader concerns about the competitive downside of extreme spectrum asymmetry.

In addition to the 37% cap, we recommend that Ofcom implement the following precautionary spectrum caps:

1. Band-specific caps for the spectrum available in the auction:
    a. a 80 MHz cap in the 3.6 GHz band; and
    b. a 40 MHz cap across the 700 MHz paired and SDL bands.
2. A cap on holdings of spectrum in the wider 3.4-3.8 GHz band of 140 MHz, so as to prevent undue concentration of core 5G spectrum in the hands of one operator.

The two band-specific caps that we propose have been calibrated such that they should not impose a meaningful constraint on any bidder that is following a value-based bid strategy. We see no plausible business case based on intrinsic value in which a single bidder would win more than 40 MHz at 700 MHz or 80 MHz at 3.6 GHz, given the needs of other operators, so the likelihood that such caps preclude an efficient outcome is minimal. The caps are pro-competitive as they will ensure that the auction produces at least two winners at 3.6 GHz and at least two winners at 700 MHz. They should also discourage strategic bidding for large packages: price driving is less likely because a

[38] Consultation, §5.102.

bidder attempting to price drive by bidding on packages of 40 MHz at 700 MHz or 80 MHz at 3.6 GHz, as opposed to the whole band, is at greater risk of overplaying their hand and winning too much spectrum at too high a price.

There is also a strong case for a 140 MHz cap on holdings within the wider 3.4-3.8 GHz band. We recognise that this measure may be more controversial than the band-specific caps, as it would constrain one operator, H3G, much more than the others. It is also the case that H3G's total holdings across all bands are lower than BT's holdings.

In the consultation, Ofcom analyses a scenario in which H3G acquires all the spectrum on the 3.6-3.8 GHz band. It argues that *"is not clear that H3G would have any advantage in the provision of early 5G applications"* and *"most users would be unlikely to notice this difference in speed."*[39] Ofcom further concludes that *"speed is not the only factor customers consider when choosing between providers, so having an advantage in this dimension would be unlikely to provide H3G with an unmatchable advantage over other operators when competing for customers."*[40] Essentially, Ofcom's argument is that H3G has no obvious business or strategic case to acquire more spectrum, so there is no reason to intervene to stop them doing so.

To our mind, this argument is wrong-headed. On the one hand, if – as may be inferred from Ofcom's arguments – H3G has no obvious business case to buy more 5G spectrum – then the downside risk of a precautionary cap that stops them doing so would be small. On the other hand, Ofcom is not well placed to judge what the minimum requirements in terms of access to 3.4-3.8 GHz are for operators and should be risk-averse to outcomes that could see one or more operators fall below this requirement. A precautionary cap that stops H3G from increasing its already huge holdings in the core 5G band reduces the risk of a bad outcome. (…✂…).

Ofcom has an objective to "*enable the industry to provide services with greater capacity .. and to pave the way for companies to take advantage of new wireless technologies, including 5G."*[41] It is widely recognised right now that every operator requires a strong position in 5G spectrum. H3G has that position already, whereas other operators may need to acquire more spectrum in this auction to be competitive. The current belief in the industry is that operators ideally require 80-100 MHz of contiguous spectrum. If H3G acquires 15 MHz or more in this auction, then at least one of the four MNOs cannot achieve that outcome. Ofcom has the power to prevent such outcomes with a simple precautionary cap of 140 MHz per operator.

Ofcom's reluctance to impose such caps seems to stem from its belief that it would be unfair on other bidders not to allow them to bid on huge spectrum packages that could lift them up to equivalent spectrum shares to BT. However, it is neither likely nor

[39] Consultation, §5.244 and §5.245

[40] Consultation, §5.247

[41] Consultation, §1

desirable for a second operator to increase share to the point that it matches BT. This could leave the other two operators with under 30% spectrum share between them, which is around the threshold that Ofcom considers the minimum for an operator to remain competitive. An auction that produced such an outcome would almost certainly be one that had failed, having been undermined by strategic and/or anti-competitive bidding practices.

In conclusion, we urge Ofcom to reconsider the case for precautionary caps, including both band-specific caps and a 5G cap on total holdings at 3.4-3.8 GHz. Such caps are the most powerful tool available to Ofcom to eliminate extreme allocation outcomes that would almost certainly be inefficient, and likely only possible because bidders were not competing based on intrinsic values. In our view, if Ofcom proceeds with its proposal to use a multi-band CCA, it would be reckless not to impose precautionary caps, as the format may otherwise incentivise bidders to engage in overbidding. If Ofcom is not willing to implement such caps, then it must switch to an SMRA format so as to reduce the risk that the auction produces at extreme allocation outcome. For the avoidance of doubt, we still think that such caps would be beneficial if an SMRA is used.

6.2. ALF for 3.6 GHz

It is important that there is a reasonably level playing field between the bidders competing for 3.6 GHz spectrum. (…✂…).

We propose that Ofcom reserve the right to revisit the ALF that applies to H3G's spectrum in the 3.4-3.8 GHz band. (…✂…).

We recognize that this measure would also introduce demand reduction incentives for H3G, but this risk should be given low weight as:

a) similar incentives did not stop strong bidding by H3G in 3.4 GHz auction;

b) H3G already has 140 MHz, so it is rather unlikely that measures that may encourage it to bid less aggressively could affect the efficient outcome or price; and

c) any such concerns are outweighed by (…✂…).

6.3. Reserve prices

In any auction where bidders are buying spectrum in incremental blocks, there are incentives for demand reduction. These are stronger if an SMRA format is used instead of a CCA. As discussed previously, because demand reduction tends to be based around expected auction outcomes, it is unlikely to have much impact of the efficiency of the auction outcome, but it may result in lower prices. Although Ofcom has no revenue goal, the public good would be served if the award generates a reasonable return for the taxpayer, whether in terms of direct revenues or funds that can be repurposed for coverage.

Given the four-player market and asymmetric starting point in spectrum allocations, we think Ofcom should not be unduly concerned about the potential for low competition and low revenues in this auction. Nevertheless, it would be prudent to set robust reserve prices for the two bands which have known high value: 700 MHz paired and 3.6 GHz. Robust reserve prices will underpin revenue in either format and may also reduce the scope for unduly asymmetric price outcomes in a CCA.

In selecting reserve prices, Ofcom should continue to its policy of setting reserve prices below the expected market value, so as to avoid unsold spectrum, encourage participation and allow a margin for price discovery. There are well established UK benchmarks and foreign benchmarks for the 700 MHz paired and 3.6 GHz bands. Accordingly, our view is that Ofcom could safely set prices towards the upper end of its proposed ranges.

6.4. Eligibility points

Eligibility points are an important tool for facilitating switching of demand between substitute bands in an auction, and for managing activity. In section 3.1, we propose an alternative lot structure for 3.6 GHz and for 700 MHz SDL (both 10 MHz lots instead of 5 MHz). We also made the case that 700 MHz and 3.6 GHz are not substitutes, so no option to switch demand between these bands is necessary. The two 700 MHz bands are substitutes: although SDL spectrum is a very inferior substitute, it is possible that bidders may want to switch between them on a MHz basis once the price differential is large enough.

Accordingly, we propose an alternative eligibility point structure:

- 3.6 GHz: 1 point per 10 MHz lot (instead of 1 point per 5 MHz lot);
- 700 MHz paired: 1 point per 2x5 MHz lot (instead of 4 points); and
- 700 MHz SDL: 1 point per 10 MHz lot (instead of 1 point per 5 MHz lot).

At 700 MHz, this approach should diminish substitution risk if an SMRA is used. It is less important if a CCA is used (as package bidding eliminates substitution risk) but may aid price discovery by enabling more straightforward switching.

In Section 5, we proposed that 3.6 GHz be sold in a separate stage from 700 MHz. In this case, the eligibility points per lot for 3.6 GHz (and ratio with 700 MHz) is irrelevant, as no switching between these bands would be possible.

6.5. Information policy

Information is fundamental to realize the benefits of a dynamic auction in a partial common value setting. Without information about excess demand, there is little difference between a sealed bid and an open (multi-round) auction: bidders would have no meaningful price discovery. On the other hand, information can be abused for

strategic purposes. For example, a price driver may use demand information to identify the point at which its tactics become too risky to continue. Demand information may also facilitate tacit coordination in demand reduction.

It is widely recognised that a good compromise in a spectrum auction setting is to provide information only about aggregate demand, and not the demand of individual bidders. For this award, however, Ofcom proposes further restrictions on information:

- Only disclose the aggregate excess demand in multiples of 20 MHz after each clock round;
- No information about demand for the coverage lots; and
- Not to disclose any information about aggregate demand after the final round.

The fact that Ofcom thinks it necessary to propose these measures is recognition that its proposed format is vulnerable to strategic bidding. We agree it is appropriate to consider such measures in the context of this auction. However, tinkering with information rules will not substantially lessen the risks of strategic bidding in a CCA. They are not a meaningful substitute for precautionary spectrum caps as a safeguard against a multi-band CCA producing extreme allocation outcomes that exacerbate spectrum asymmetry.

In the context of a CCA, we are unconvinced that Ofcom's proposed limits on information are even helpful. They would do nothing to reduce incentives for price driving on large packages. They will also increase uncertainty for bidders about their ability to secure their final price outcome: while this may (helpfully) discourage price setting behaviour, it may also (unhelpfully) make life more difficult for bidders with budget constraints. We discuss Ofcom's proposed rules for the auction in detail in Section 7.

If Ofcom's ambition with these changes to information policy is to discourage unduly aggressive bidding, then it would be better off separating the sales of 3.6 GHz and 700 MHz, and using an SMRA instead of a CCA. Ofcom's proposal to reveal demand only in units of 20 MHz would make more sense in the context of an SMRA, as it may deter demand reduction at the margins.

7. Ofcom's proposed CCA rules

In this section, we offer comments on the "Notice of Ofcom's proposal to make regulations for the award of the 700 MHz and 3.6-3.8 GHz spectrum bands."

Our main comments remain:

- Ofcom should run a sequential award that uses an SMRA format for at least the 3.6 GHz award. The CCA is inappropriate for selling 3.6 GHz as it is susceptible to price-driving, and vulnerable to extreme and inefficient outcomes when bidders have predictable demands; and
- Ofcom should propose a full plan for defragmenting the 3.4-3.8 GHz band. Without a plan, there is a real risk that defragmentation will not happen, and UK consumers never fully enjoys the benefits that this key 5G band can deliver. Furthermore, the efficiency of the assignment round will be undermined if bidders are competing not for specific frequencies, but rather to gain or block trading options.

In addition to our main comments, we propose hereafter some comments on the detailed rules that should improve outcomes if a CCA is chosen despite its multiple and well-documented disadvantages.

(a) Determination of excess demand

We believe that there is an error in paragraph 30, which defines excess demand as follows:

30. There is excess demand in a given primary bid round if—

(a) the demand for any type of lot is greater than the number of lots of that type that are available in the award process (not including chain bids); and

(b) more than two bidders have indicated that it wished the coverage obligation to apply to its bid selection where the coverage discount is not zero.

Furthermore, paragraph 29(3), reads as follows:

29.(3) Where OFCOM have determined that there is no excess demand there shall be no further primary bid rounds but there shall be a supplementary bids round.

We suppose that Ofcom means "or" instead of "and". Otherwise, the auction could end when there is excess demand for spectrum just because there is insufficient demand for coverage obligations.

(b) Lot Structure

As in previous sections, we propose 2x5 MHz lots for 700 MHz FDD, 10 MHz lots for 3.6 GHz and one 20 MHz lot for 700 MHz SDL. Our main argument is that this lot structure better reflects the likely usage of spectrum and is in line with the international practice.

In this section, we develop a secondary argument. The lot structure can make items stronger or weaker complements, and the lot structure must guarantee enough substitutability to increase the confidence on the efficiency and price-discovery properties of the CCA.

As an example, consider two extreme lot structures for the 3.6 GHz band: three 40 MHz lots; or twenty-four 5 MHz lots. It is very likely that twice the value of one lot of 40 MHz is a better approximation (per MHz) of the value of 80 MHz than twice the value of one block of 5 MHz is an approximation of the value of 10 MHz. In this sense, lots of 40 MHz are more substitutable than lots of 5 MHz.

If lots do not have enough substitutability, competitive prices might not exist, and even if they exist, the CCA might not be able to find them. This problem is not avoided by bidding only on larger packages because prices are denominated per lot, and at least some bidders some of the time will bid for increments or decrements of 5 MHz, changing the price trajectory of the auction.

We propose that Ofcom eliminates the most obvious non-complementarities from the auction by adopting 10 MHz lots, which is more in line with demand in practice.

(c) Eligibility points

We propose that Ofcom adopts our lot structure and consequently adapts eligibility points as follows:

- 1 point – 700 MHz FDD 2x5 MHz lot
- 1 point – 700 MHz SDL 10 MHz lot
- 1 point – 3.6 GHz 5 MHz lot (but this is a separate auction)

If the lot structure is not modified, we suggest Ofcom align the points to reflect total spectrum amounts irrespective of perceived value differences. To the extent that lots are substitutes for capacity, this will allow switching on a per MHz basis.

(d) Relative Cap Activity Rule

We propose that Ofcom drops the use of chain bids as a requirement for a bidder to submit a relaxed primary bid. Specifically, we propose the following implementation of the Revealed Preference Constraint:

> Subsequent bid for package Y cannot be above the current package price of package X (which may be above PX) plus the difference in package prices when the bidder chose to bid for package X instead of package Y (i.e. PY - PX).

In the primary rounds, revealed preference constraints only apply to packages above eligibility. Using the terminology contained in the consultation, suppose that a bidder places a bid for package X at price PX when package Y was also available at a price PY.

The Revealed Preference Constraint (RPC) as defined by Ofcom reads as follows:

> *"Subsequent bid for package Y cannot be above the current highest bid amount for package X (which may be above PX) plus the difference in package prices when the bidder chose to bid for package X instead of package Y (i.e. PY - PX)."* underline added.

In Ofcom's implementation, the reference value of X is the current highest bid amount for package X. This is inconsistent with revealed preference principles.

The reason for imposing any kind of revealed preference constraint is as follows: suppose a bidder chooses X instead of Y when prices are P, then profit maximization would dictate that VX – PX ≥ VY – PY, where VX and VY are the bidder's valuation of X and Y, respectively. Suppose the same bidder prefers Y over X when prices are Q, then profit maximization would imply VY – QY ≥ VX – QX. These inequalities together imply that QY ≤ QX + (PY-PX). Our proposal is direct implementation of this principle.

The difference between both implementations of the revealed preference approach could be significant. In particular, Ofcom's proposed implementation may force bidders to bid for packages that are not value-maximizing. The following example follows an example developed by DotEcon to argue for the necessity and value of chain bids.[42]

Consider an auction with only two lots. Consider the decisions faced by a profit-maximizing bidder. The next table shows the valuations, prices and surpluses for the bidder in an eligibility-reducing round.

[42] Issues related to the Draft Information Memorandum, ComReg document 12/51. 25 May 2012

Lot	Eligibility	Price	Valuation	Surplus
A	10	€18m	€25m	€7m
B	5	€6m	€15m	€9m

Up to this round, the bidder had been bidding for lot A. However, given relative prices in this round, the bidder prefers lot B and bids for it. In the next round, prices and surpluses are as follows:

Lot	Eligibility	Price	Valuation	Surplus
A	10	€21m	€25m	€4m
B	5	€12	€15m	€3m

In this round, the bidder would like to bid for lot A. However, the bidder does not have enough eligibility and must bid subject to RPC. In Ofcom's implementation of RPC, it is not possible because the current highest bid for B is €6m and the price difference in the eligibility-reducing round was €18m - €6m = €12m. Thus, the maximum bid for A would be €20m (€6m+€12m) – a bid below current price and invalid.

DotEcon argues that the solution is to let the bidder submit a chain bid i.e. to 'retroactively' increase its bid for B up to €12 – the current price for B. In this case, the minimum chain bid would be to bid €7 for lot B. However, bidding €7 for lot B is not a value-maximizing bid because prices for B were never €7, i.e. the bidder never chose to bid €7 for lot B, the bidder was forced to bid €7 for lot B in order to bid for the value-maximizing lot A at bid €21.

In the straightforward implementation of RPC, the bidder does not need to submit a chain bid. The bidder can submit a bid for lot A because the current value of lot B is €12. Thus, the maximum bid that the bidder could place for lot A is €24 (€12 + €12).

We propose the Ofcom removes chain bidding from its design and adopts a straightforward implementation of revealed preference.

(e) Information policy

We propose that Ofcom reveals excess demand in full in each band and coverage lots during all rounds, including the final round.

Currently Ofcom is proposing:

- After each clock round, with the exception of the final round, to reveal aggregate excess demand in multiples of 20 MHz. If there is no aggregate excess demand, Ofcom would inform that "the excess demand is less than 20 MHz".

- After the final round, no aggregate demand.
- No information on demand for coverage lots.

Ofcom recognises that the limited information on aggregate demand during clock rounds can harm efficiency and budget-constrained bidders.[43] Furthermore, Ofcom recognises that providing no information on aggregate demand after the final round limits the ability of all bidders to calculate their knock out bids, increasing uncertainty over allocations and prices for all bidders.[44] Finally, Ofcom argues that no information on aggregate demand for coverage lots does no harm because there are no common value components in coverage lots.[45]

All these claims are directly against Ofcom's objectives. Ofcom is implementing a policy that can harm efficiency, increase uncertainty and treat budget-constrained bidders unfairly. Moreover, not providing information on coverage lots is akin to running a sealed-bid auction – contrary to the considerations that favour a dynamic CCA.

Ofcom argues that limiting information can reduce tacit collusion and price-driving.[46] The first claim directly contradicts Ofcom's claim that the CCA is not very vulnerable to tacit collusion.[47] We agree with Ofcom's claims that strategic collusion is not a prominent feature of the CCA and hence does not require a limitation of information.

In previous sections, we have identified price-driving as a major concern with this auction format. However, limiting information during the clock round and providing no information during the final rounds are not solutions to this problem. Hiding information in the last round is particularly ineffective, because a bidder that drops demand in the final round may have an advantage in terms of being able to infer the number of unallocated lots. As we have argued, the correct tool to prevent price driving is precautionary spectrum caps.

(f) Positive price constraint

We propose that Ofcom consider implementing our voucher mechanism to bypass the need for a positive price constraint, even if a CCA is used. As described at length in section 5, the positive price constraint may oblige bidders to bid on larger spectrum packages than they would desire to bid on. This will affect the price-discovery properties of the clock rounds. A voucher mechanism would prevent a

[43] Consultation, §7.184 and §7.185

[44] Consultation, §7.194

[45] Consultation, §7.197

[46] Consultation, §7.186

[47] Consultation, §7.74

situation where a bidder is obliged to bid on extra spectrum simply to remain in contention for the coverage obligation.

(g) Assignment stage

If Ofcom does not implement a plan to fully defragment the 3.4-3.8 GHz band, it should at least implement rules for the assignment stage that maximizes the probability of executing post-auction private transactions that reduce defragmentation. We propose that Ofcom enact the rules as described in Section 5.4.

Appendix A. Examples of how price-diving can distort outcomes if a multi-band CCA is adopted

(…✂…).

Qualifications, assumptions and limiting conditions

This report has been prepared for Telefónica UK to be included in their submission to Ofcom's consultation on the award of the 700 MHz and 3.6-3.8 GHz spectrum bands. It is anticipated that a redacted version of the report may be published on the Ofcom website, and that third parties may submit comments regarding the report to Ofcom in relation to the 700 MHz and 3.6-3.8 GHz spectrum award. With the exception of this purpose, this report is not intended for general circulation or publication, nor is it to be reproduced, quoted or distributed for any other purpose without the prior written permission of NERA Economic Consulting. There are no third party beneficiaries with respect to this report, and NERA Economic Consulting does not accept any liability to any third party.

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