Three's response to Ofcom's Consultation on Annual Licence Fees for UK Broadband's 3.4GHz and 3.6GHz spectrum.

Non-Confidential

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Executive Summary

1.1. Three welcomes the opportunity to respond to Ofcom's Consultation on Annual Licence Fees for UK Broadband's 3.4GHz and 3.6GHz spectrum Annual Licence Fees ('ALFs').

1.2. The Consultation sets out Ofcom's objective of ensuring the optimal use of UKB's spectrum, in line with the policy approach in its Strategic Review of Spectrum Pricing ('SRSP'). In our response, we explain why we believe that a different set of proposals is needed to meet Ofcom's objective.

1.3. The Consultation does not make a compelling case for applying ALFs to UKB's spectrum in the first place. Ofcom recognises that Three is the highest-value user of the spectrum and has every incentive to use it efficiently. Ofcom believes that that situation is unlikely to change in the future. It follows that ALFs have no role to play in promoting the optimal use of UKB's spectrum.

1.4. If Ofcom can make a convincing case to apply ALFs, we agree that the level of the ALF should be determined now (based on the 2018 PSSR auction results), rather than waiting for the results of the 3.6GHz auction scheduled for Spring 2020.

1.5. The Consultation considers two options to estimate the market value of UKB's spectrum based on the 3.4GHz bid data: the market-clearing price for 3.4GHz (£37.8m per 5MHz) and the marginal opportunity cost to others (£31.1m per 5MHz). We consider, however, that neither option is appropriate in this case.

1.6. Firstly, both options risk distorting bidders' incentives in future auctions (including the 2020 award). If either is used to set UKB's ALFs, Three will have raised its own ALFs through its bids in the 3.4GHz auction. Secondly, Ofcom appears to have grossly overestimated the market value of UKB's spectrum. This is for two reasons:

- Ofcom has overstated the marginal opportunity cost of UKB's spectrum to others – by implicitly including Three's winning bid for 20MHz of 3.4GHz in the calculation. We have estimated the correct marginal opportunity cost to reflect this; and
- Most importantly, because rivals' values for more 3.4GHz than they won at auction decrease with the amount of spectrum (as shown by their losing bids), any marginal cost calculation will grossly overestimate the market value of UKB's spectrum – taking the highest losing bid from a rival (O2) and applying that

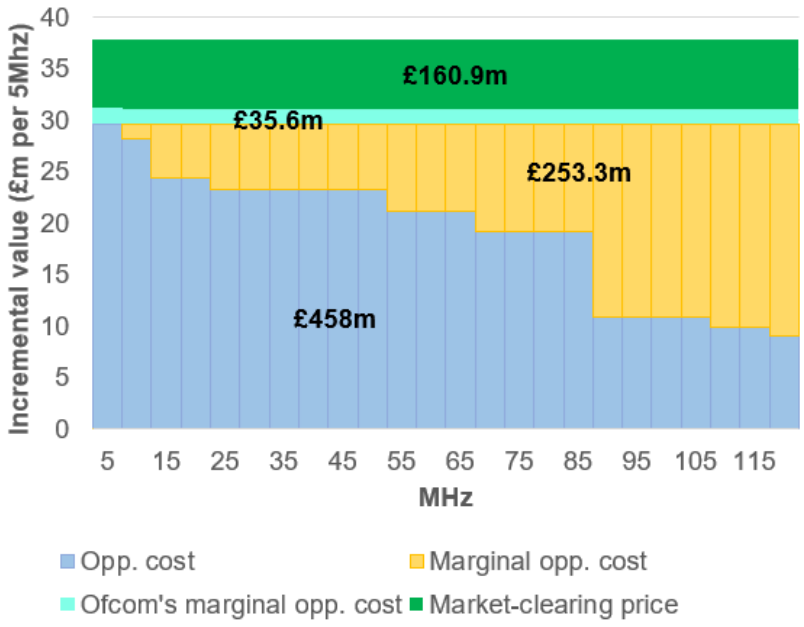
mechanically across 120MHz cannot reasonably be said to reflect market value.

1.7. Losing bids for 3.4GHz in the auction clearly indicate that Three could not sell UKB's spectrum for £37.8m or even £31.1m per block. In our view, these estimates are not consistent with the SRSP, nor with a conservative approach to setting ALFs. Since they also risk leaving spectrum unused, they would serve no purpose other than revenue extraction.

1.8. There is however a third option (the opportunity cost of UKB's 120 MHz) which is much better suited to meeting Ofcom's objectives and which is, in fact, the measure advocated by the SRSP. An ALF based on opportunity cost does not distort bid incentives, carries little risk of unused spectrum and extracts no more revenue than needed to ensure the optimal use of UKB's spectrum.

1.9. Figure 1 shows the different estimates of the lump-sum value of UKB's spectrum derived from the four different measures. The Figure shows the incremental values that Three's rivals expressed for an additional 120MHz of 3.4GHz (on top of the 3.4GHz they won, and excluding Three's bids as required for a correct opportunity cost calculation).

Figure 1: Opportunity cost extracts the minimum revenue consistent with optimal use



Source: Three (based on 3.4GHz auction bids).

1.10. The opportunity cost measure produces a market value of £458m for UKB's 120MHz holding in the band. This represents the (sum of the) decreasing values that Three's rivals expressed for that spectrum in the 3.4GHz auction (through their losing bids). This measure, which

gives an average value of £19.1m per 5MHz block, provides the best available estimate of the market value of UKB's spectrum.

1.11. A corrected version of marginal opportunity cost would extract a further £253.3m from Three (i.e. the delta between £29.6m and £19.1m, times 24 blocks) for no apparent reason, since that measure carries a greater risk of leaving spectrum unused. By mechanically applying the highest losing bid (after Three's bids have been removed) across all 120MHz, this vastly overstates the value of UKB's spectrum.

1.12. Ofcom's marginal opportunity cost would then add a further £35.6m (i.e. the delta between £31.1m and £29.6m per block, times 24 blocks). Finally, the market-clearing price for 3.4GHz adds £160.9m on top of that (i.e. the delta between £37.8m and £31.1m per block, times 24 blocks). As they are clearly inferior in terms of meeting Ofcom's objectives, those measures would serve no other purpose than revenue extraction.

1.13. Finally, recognising that Ofcom is offering 3.4GHz and 3.6GHz sequentially and two years apart, the opportunity cost calculation should take account of bidders' temporal preference for winning spectrum in the first auction, to gain a first-mover advantage in 5G. We have applied a discount factor of between 0.9 and 0.93 to the lump-sum value derived from the PSSR auction. This reduces the lump-sum value of UKB's spectrum from £19.1m to a range of £17.2 – £17.8m per 5MHz block.

1.14. We have commissioned two expert reports from Power Auctions and Frontier Economics, which develop the arguments summarised in this response. They form an integral part of Three's response and should be read in conjunction with it.[1]

[1] Power Auctions' report, *Determining lump-sum values for Annual Licence Fees for UK Broadband's 3.4GHz and 3.6GHz spectrum*.
Frontier Economics, *Setting Annual Licence Fees for 3.4 and 3.6 GHz spectrum.*

Contents.

1. ALFs have no role to play in respect of UKB's 3.4 and 3.6GHz spectrum.

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1.1. Ofcom proposes to set Annual Licence Fees (ALFs) for all 120MHz of UKB's spectrum in the 3.4-3.8GHz band. This is in line with the policy approach to setting spectrum fees set out in its SRSP.

1.2. The SRSP explains that the purpose of fees is to provide long-term signals reflecting the value of the spectrum (based on its opportunity cost) when spectrum markets do not exist, are immature or otherwise do not function well.

1.3. This section discusses whether it is necessary or justified to charge ALFs on UKB's spectrum (as envisaged by Principle 5 of the SRSP), particularly so shortly after the PSSR auction and Three's acquisition of UKB's spectrum.

1.4. Spectrum auctions, trading and ALFs are all intended to incentivise users to make efficient use of spectrum. Of the three possible roles for ALFs envisaged by the SRSP, Ofcom's only rationale is to give Three a long-term incentive to trade or return some of UKB's spectrum if it is no longer the highest-value user in the future. However, in its discussion of the appropriate level of ALFs, Ofcom finds that this is unlikely.

1.5. It follows that ALFs have no role to play in respect of UKB's spectrum. Three has every incentive to use UKB's spectrum efficiently, it already is the highest-value user for that spectrum (which is tradable anyway) and the consultation finds that this situation is unlikely to change in the future.

1.6. Moreover, Ofcom should be consistent with its proposed approach for the 3.6GHz spectrum to be auctioned in 2020, which will not be subject to an ALF during the initial period. That spectrum can also fall in value, particularly over a 20-year period. There is no more reason to be concerned about fluctuations in value leading to suboptimal use in one case than in the other.

Principle 5 of the SRSP and the role of ALFs in the presence of auctions and spectrum trading

1.7. The SRSP discusses the role of spectrum fees (AIP or ALF) in promoting optimal use of spectrum. It interprets 'optimal use' as synonymous with economic efficiency. Corresponding to the concepts of allocative, productive and dynamic efficiency, the SRSP sets out three possible roles for ALFs in promoting optimal use:[2]

[2] Para 3.14, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.

- Spectrum is allocated and assigned to those uses and users that will provide the greatest benefits to society;
- Individual spectrum users economise on their use of spectrum so there is no 'wasteful' use or underutilisation of spectrum; and
- Spectrum becomes available over time for new and innovative services, where these are of sufficient value to society, and more generally to accommodate changes in technologies and consumer demand for services that rely on spectrum.

1.8. The role of ALFs in promoting optimal use is to act as *"a proxy for market prices for scarce spectrum that has been assigned administratively…rather than auctioned"*.[3] ALFs ensure that users face a long-term signal of opportunity cost when spectrum markets do not exist, are immature or do not function well.[4]

1.9. Principle 5 of the SRSP then considers whether ALFs are needed to 'mimic' a well-functioning market when licences are tradable.

> **AIP principle 5: AIP and spectrum trading**
> Many secondary markets are unlikely to be sufficiently effective to promote the optimal use of the spectrum without the additional signal from AIP. Therefore AIP will likely continue to be needed to play a role complementary to spectrum trading for most licence sectors.

1.10. The SRSP set out Ofcom's intention "*to assess the roles of trading and AIP in each sector-specific fee review on a case-by-case basis… in order to reach a decision appropriate to the circumstances of the individual markets".*[5]

ALFs can play no role in respect of UKB's spectrum

1.11. Ofcom has assessed the potential role of ALFs in respect of UKB's spectrum, as envisaged by the SRSP. The first question that ought to be addressed is whether there is any need for ALFs at all, given that Three has only recently acquired UKB's spectrum (which is tradable anyway) and Ofcom has only just auctioned the 3.4GHz spectrum.

1.12. The Consultation (and Ofcom's recent statement on 900MHz and 1800MHz ALFs) effectively recognises that ALFs are not needed in this case to fulfil the first two roles envisaged by the SRSP:[6]

- Ofcom has recognised that MNOs may already be incentivised to make the most efficient use possible of their spectrum in the absence of fees set at market value. In the 900/1800MHz ALF

[3] Para 1.12, SRSP consultation.
[4] Page 28, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.
[5] Para 4.211.
[6] Ibid, para 3.14

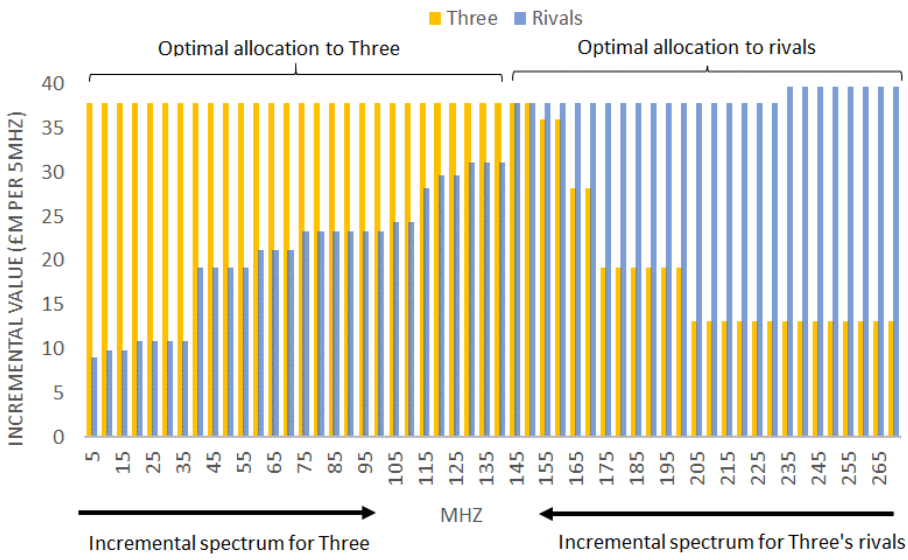
Decision, however, Ofcom did not rule out the possibility that they may not be the highest-value users of their spectrum;[7] and

- The current consultation recognises that Three is the highest value user of UKB's spectrum, as it was the marginal bidder for additional 3.4GHz in the auction.[8]

1.13. We agree. Three has several alternatives in order to meet exponential growth in data traffic, such as using its spectrum more efficiently, buying more spectrum (at auction or via trading) or deploying additional sites. Because these other alternatives are very costly and there are trade-offs between them, Three has every incentive to use UKB's spectrum efficiently without the need for an ALF.

1.14. Three has also been shown to be the highest-value user for UKB's spectrum. Figure 2 shows the incremental values for extra 3.4GHz that MNOs expressed in the auction, up to a supply of 270MHz (UKB's 120MHz plus the 150MHz on offer). Three's values are measured from left to right, with the first 120MHz representing its value for UKB's spectrum (£37.8m per block as a minimum, since that is what Three paid for the extra 20MHz it won at auction). Rivals' incremental values are sorted in descending order and measured from right to left.[9]

Figure 2: ALFs play no role in ensuring that UKB's spectrum is held by the highest-value user.



[7] https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130547/Statement-Annual-licence-fees-900-MHz-and-1800-MHz.pdf, para. 5.35. Also current Consultation, para 3.22.

[8] Para 3.34, https://www.ofcom.org.uk/__data/assets/pdf_file/0013/130540/Annual-Licence-Fees-for-UK-Broadbands-3.4-GHz-and-3.6-GHz-spectrum.pdf.

[9] Where the incremental value is for more than 5MHz we average it by the number of 5MHz blocks. For instance, rival values for 130MHz, 135MHz and 140MHz are £31.1m per 5MHz, corresponding to O2's highest losing bid for 15MHz, which is used by Ofcom to estimate marginal opportunity cost.

Source: Three (based on PSSR Auction bid data).

1.15. In summary, the existing allocation of the 270MHz is already optimal. Moving from left to right, Three's value for each additional 5MHz block is significantly greater than rivals' incremental values for that spectrum, certainly for the first 120MHz (i.e. UKB's spectrum), and beyond that for a further 20MHz (as would be expected, since Three won that spectrum in the PSSR auction).

1.16. Even if, contrary to the evidence from the 3.4GHz award, other MNOs had a higher incremental value than Three for some of UKB's spectrum, their ability to bid for 3.6GHz in next years' auction would mitigate any inefficient allocation of UKB's spectrum anyway.

1.17. There is only one justification left to impose an ALF on UKB's spectrum in the consultation – i.e. the third condition in the SRSP, or ensuring long-term efficiency:[10]

"*Setting ALFs at market value is intended to provide operators with long-term price signals. Although H3G as the licence-holder may be a particularly high-value user of the UKB 3.4 GHz and 3.6 GHz spectrum, and new spectrum awards may play some role in addressing the demand of other operators, efficient use of this spectrum may also come from other users being able to access the UKB 3.4 GHz and 3.6 GHz spectrum in the future. This increases the possibility that H3G may not necessarily be the highest-value user of the entirety of its 3.4 GHz and 3.6 GHz holdings in the long term*". [Emphasis added]

1.18. Hence, the only purpose of ALFs in this case is to cover the risk that Three's valuations for some of UKB's spectrum may fall below rivals' valuations over time, such that Three may no longer be the highest-value user for that spectrum in the future.

1.19. However, at the same time the Consultation indicates that this is unlikely. Ofcom considers that there is little risk that Three's value for UKB's spectrum could fall below the market clearing price of £37.8m, forcing Three to return some of UKB's spectrum for which it was the highest-value user if the market-clearing price is used to set the ALF.[11]

1.20. It follows that ALFs have no role to play here. If Three's valuations for UKB's spectrum are unlikely to fall below the market-clearing price in the future, they are even less likely to fall below rivals' valuations (which are significantly below the market-clearing price for 3.4GHz).

1.21. In short, the case-by-case assessment envisaged by the SRSP should conclude that ALFs have no role to play in respect of UKB's spectrum. Three has every incentive to use UKB's spectrum efficiently, it already is the highest-value user for that spectrum and the Consultation finds that that situation is unlikely to change in the future.

[10] Para 4.21, https://www.ofcom.org.uk/__data/assets/pdf_file/0013/130540/Annual-Licence-Fees-for-UK-Broadbands-3.4-GHz-and-3.6-GHz-spectrum.pdf.
[11] Para 3.34.

1.22. In any event, UKB's licences are tradable and this provides additional incentives for UKB's spectrum to find its way into the hands of the highest-value users, should Three no longer be the highest-value user in the future. Simply put, UKB's spectrum will be used in the way the market considers most valuable without the need for ALFs.

Ofcom should be consistent with its proposed approach for the 3.6GHz spectrum to be auctioned in 2020

1.23. Moreover, the role envisaged for ALFs in the Consultation is inconsistent with Ofcom's proposals for the award of 700MHz and 3.6GHz spectrum, which is scheduled for 2020.

1.24. The auction Consultation includes a draft of Ofcom's proposed licences for the 3.6GHz spectrum. As per Ofcom's traditional approach, ALFs will not be payable for the initial 20-year period of the 3.6GHz licences (i.e. until 2040).[12]

1.25. The rationale must be that the auction can be expected to put the 3.6GHz into the hands of the highest-value users, without the need for further intervention during the initial period. But the same reasons apply to UKB's ALFs. Ofcom has only just awarded the 3.4GHz spectrum, and Three has been shown to be the highest-value user of UKB's spectrum (because it was the marginal bidder for additional 3.4GHz spectrum in the auction).

1.26. Ofcom should then provide a compelling reason as to why ALFs may be needed to promote the optimal use of UKB's 3.4 and 3.6GHz spectrum, but not the 3.6GHz spectrum that Ofcom will award in 2020. The value of the 3.6GHz spectrum is also liable to fluctuate over time, particularly over a 20-year period.

1.27. There is no more reason to be concerned about fluctuations in value leading to suboptimal use in the one case than in the other. Ofcom should either attach ALFs during the initial 20-year period to the 3.6GHz spectrum to be auctioned in 2020 or, more appropriately, waive the ALFs on UKB's 3.4GHz and 3.6GHz spectrum until 2038, which is 20 years after the 3.4GHz auction.

[12] https://www.ofcom.org.uk/__data/assets/pdf_file/0014/130730/Annexes-19-26-licences-and-licence-procedures.pdf

2. If a case can be made to apply ALFs to UKB's spectrum, Ofcom is right to determine the level now.

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1.1. In this section we explain why, if a case can be made for having ALFs for UKB's spectrum, Ofcom should determine the level of the ALFs now (based on the 2018 PSSR auction results), rather than waiting for the auction of 3.6GHz spectrum in 2020. This is for the following reasons:

- First, we agree that the long-term value of 3.4GHz and 3.6GHz spectrum is likely to be the same;
- Second, introducing a link between UKB's ALFs and the outcome of the upcoming 3.6GHz auction would distort the auction itself;
- Third, having a link between the 3.6GHz auction and UKB's ALFs would provide rivals with incentives to bid beyond their intrinsic valuations to raise UKB's ALFs; and
- Finally, given the proposed CCA format and the inclusion of coverage obligations for the 3.6GHz auction, Ofcom may find it very difficult to infer robust 3.6GHz prices from the auction bid data.

1.2. Given these factors, we agree with Ofcom's provisional conclusion to determine the level of UKB's 3.4GHz and 3.6GHz ALFs now, based on the 2018 PSSR auction. We also agree with Ofcom that it should not revisit its decision after the upcoming 3.6GHz auction.

The long-term value of 3.4GHz and 3.6GHz spectrum is likely to be the same

1.3. We agree with Ofcom's provisional conclusion that the long-term value of UKB's 3.4GHz and 3.6GHz is likely to be the same.

1.4. As Ofcom states in its Consultation, the 3.4GHz and 3.6GHz bands are part of the wider 3.4-3.8GHz band, which is the primary band for 5G services in Europe. Early 5G handsets will support the entire 3.4-3.8GHz band, not just part of it. Apart from short-term constraints on 3.6GHz spectrum, there is no reason to believe both bands should have different value to MNOs in the long term.

1.5. As Ofcom states, following its recent decision to grant UKB's 3.6GHz licence variation request, the technical licence conditions for both UKB's 3.4GHz and 3.6GHz spectrum are aligned.[13] Short-term constraints on the use of UKB's 3.6GHz spectrum, mainly related to satellite earth stations, are expected to be removed by June 2020.

1.6. Once these short-term constraints are removed, the long-term value of UKB's 3.4GHz and 3.6GHz spectrum is likely to be same (on a per-MHz basis). Hence, it seems appropriate to set ALFs for this spectrum by reference to the results of the 3.4GHz PSSR auction that completed in April 2018.

Using results from the upcoming 3.6GHz auction to set the level of UKB's ALFs would distort the 3.6GHz auction

1.7. If Ofcom proposed instead to use auction bids and prices from the upcoming 3.6GHz auction in the calculation of UKB's ALFs, Three's bidding incentives in that auction could be significantly distorted, leading to an inefficient outcome.

1.8. In effect, Three could increase its own ALF by bidding in the auction. This would be an indirect tax on Three, as it would need to consider in its bids for 3.6GHz not only the value of that spectrum but also the potential for Three's bids to increase its ALF. Given that UKB holds 120MHz in the band, even a modest increase in the auction prices could result in a significant impact on its ALFs.

1.9. The best example of the potential impact is provided by Ofcom's current ALF proposals for UKB's 3.4GHz and 3.6GHz spectrum. As discussed in Section 1, Three was the marginal bidder for 3.4GHz in the PSSR auction and its highest losing bid for an additional 10MHz set the market price. If Ofcom uses the market-clearing price of £37.8m per block to set UKB's ALFs, Three would have raised its own ALFs by around £9m a year compared to Ofcom's current proposal (i.e. UKB's ALF bill would be £52m instead of the £43m per annum proposed by Ofcom).

1.10. The logical conclusion is that Three would have strong incentives to reduce its demand for 3.6GHz beyond its true intrinsic valuation. This could then lead to an inefficient allocation of spectrum, contrary to Ofcom's duty to ensure the efficient allocation of spectrum, including that spectrum is held by the highest value user(s).

1.11. Given the potential for such significant distortions to the upcoming 700MHz and 3.6GHz auction and the negative impact on the efficient use of spectrum, we agree that Ofcom should determine the level of UKB's 3.4GHz and 3.6GHz ALFs now, based on the 2018 PSSR auction. We also agree that Ofcom should not revisit its decision after

[13] Para 2.14, https://www.ofcom.org.uk/__data/assets/pdf_file/0013/130540/Annual-Licence-Fees-for-UK-Broadbands-3.4-GHz-and-3.6-GHz-spectrum.pdf.

the 700MHz and 3.6GHz auction, in line with its general policy on ALF reviews.[14]

Having a link between the 3.6GHz auction and UKB's ALFs would give rivals incentives to bid beyond their valuations to raise UKB's ALF

1.12. Ofcom proposes a Combinatorial Clock Auction ('CCA') format for the upcoming 700MHz and 3.6GHz auction in Spring 2020. The CCA uses a second-price rule to set prices for packages won by winning bidders. This is well-known to provide incentives for bidders to submit price-driving bids, i.e. bids above their intrinsic valuation, to raise prices paid by other bidders.

1.13. This can happen because in a CCA, a winning bidder's price is unaffected by its own bids and is set instead by the bids of others. In the 2020 700MHz and 3.6GHz auction, it may be possible to submit bids in the supplementary round which have little chance of winning (based on the information and outcome of the clock rounds), with the sole intention of raising rivals' prices.

1.14. If a mechanical link were established between UKB's ALFs and prices and bids in the 3.6GHz auction, rivals would have an additional incentive to submit 'price-driving' bids with the aim of raising the ALFs payable by UKB.

Ofcom would find it difficult to infer robust auction prices for 3.6GHz given the proposed CCA format and the inclusion of coverage obligations

1.15. Even if it were possible for Ofcom to use the upcoming 3.6GHz auction prices to set UKB's 3.4GHz and 3.6GHz ALFs without distorting the efficient allocation of spectrum, Ofcom would find it difficult to infer robust auction prices for 3.6GHz spectrum.

1.16. Ofcom has had major difficulties in inferring market values from the 2013 4G auction for 800MHz and 2.6GHz spectrum, for the purposes of setting 900MHz and 1800MHz ALFs. The 4G auction was a CCA auction where MNOs bid for packages of spectrum.

1.17. The major source of the difficulty is that CCA auctions do not produce separate prices for the different spectrum bands, leading to an inference problem. Indeed, it is quite possible that there is no unique decomposition for any bidder.

1.18. This issue would be exacerbated by Ofcom's proposals to include coverage obligations in the upcoming 700MHz and 3.6GHz auction.[15] Bids for 3.6GHz spectrum could then bear little relation to MNOs' intrinsic values, as Three's bids for 3.6GHz could be biased by the link

[14] Ofcom's SRSP, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.
[15] Para 1.6, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf.

to ALFs and bids for 3.6GHz could be inflated by the subsidy provided by the coverage obligations.

3. The opportunity cost of UKB's spectrum is not equal to marginal opportunity cost applied across all 120MHz.

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1.19. This section presents the different candidate measures of lump-sum value to set ALFs for UKB's 120MHz, based on the 3.4GHz values that MNOs expressed in the PSSR auction. It serves as an introduction to the arguments developed in Sections 4 to 7.

1.20. Ofcom's assessment of the lump-sum value of UKB's 3.4 and 3.6GHz spectrum explores the question of which measure (market-clearing price or the marginal opportunity cost to others of UKB's spectrum) best meets Ofcom's objectives.

1.21. Ofcom finds that the market-clearing price and marginal opportunity cost to others are different due to the specific results of the 3.4GHz auction. Ofcom has therefore reviewed the appropriateness of both measures against its Statutory Duties and the Fee Principles in the SRSP.

1.22. Ofcom's provisional view is that, in principle, both measures could provide a measure of market value and promote optimal use consistent with the SRSP. Ofcom proposes to use the marginal opportunity cost to others, as the market-clearing price may be higher than necessary to promote optimal use.

1.23. The Consultation frames the debate as a choice between two options: the market-clearing price or Ofcom's measure of marginal opportunity cost. There is however another option – the opportunity cost of UKB's spectrum – which is better suited to promoting optimal use, does not risk distorting bidders' incentives in future auctions and which is, in fact, the measure advocated by the SRSP.

The opportunity cost of UKB's holding is not equal to the marginal opportunity cost applied across all 120MHz

1.24. Shortly after the PSSR auction Ofcom published the bid data for 2.3GHz and 3.4GHz spectrum.[16] The most relevant evidence for an

[16] https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards/awards-archive/2-3-and-3-4-ghz-auction

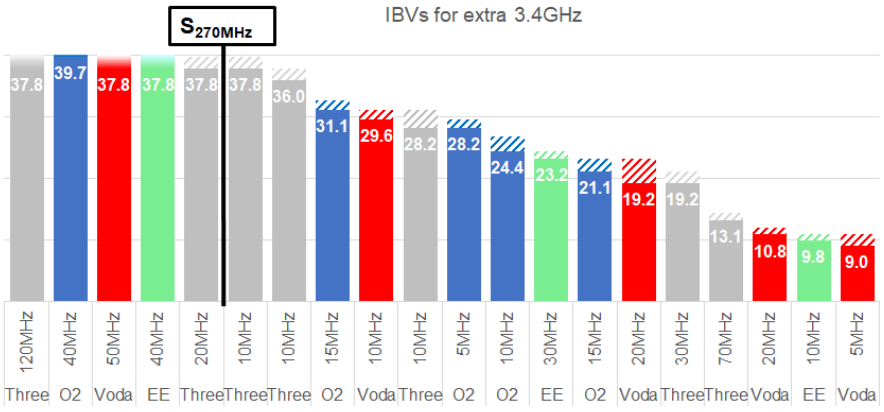
assessment of the value of UKB's spectrum to Three's rivals comes from their losing bids for 3.4GHz in the auction. These losing bids are for 3.4GHz spectrum in addition to their current holdings of 3.4GHz.

1.25. The incremental values that MNOs placed on holding additional 3.4GHz spectrum (beyond what they ultimately won in the auction) can be ascertained by looking at the prices at which they reduced their demand for 3.4GHz in the auction. This can be used to estimate the market value of UKB's holding.

1.26. The bid data indicates that the opportunity cost (or benefit denied) to non-Three users of UKB's 120MHz is significantly lower than the marginal opportunity cost applied across all 120MHz, because of the decreasing valuations for 3.4GHz that bidders expressed in the auction. The opportunity cost is also much lower than the market-clearing price for 3.4GHz applied across UKB's 120MHz.

1.27. Three was the highest losing bidder for 3.4GHz in the PSSR auction. Three effectively set the market price for 3.4GHz when it declined to bid for 30MHz at a price of £39.7m (per 5MHz block) and was awarded instead its Standing High Bid of 20MHz at a price of £37.8m per block. Demand then equalled supply and the auction closed. Figure 3 shows the incremental values for 3.4GHz bid by MNOs in the auction.

Figure 3: Incremental bid values for extra 3.4GHz spectrum in the PSSR auction



Source: Three (based on PSSR Auction bid data)

1.28. To the left of the 270MHz supply (UKB's 120MHz and the 150MHz on offer at the auction), all winning bidders were willing to pay at least £37.8m per 5MHz (in the case of Telefónica, £39.7m) for the spectrum they won. Three was willing to pay £37.8m but not £39.7m per block for the 20MHz won, so its value for UKB's 120MHz must also be at least £37.8m per 5MHz.

1.29. The far right of Figure 3 shows that in round 26, Vodafone demanded 100MHz at a price of £10.8m per 5MHz block, having previously bid for 105MHz at a price of £9m per block. This means that Vodafone valued

the additional 5MHz by at least £9m but less than £10.8m. These ranges are shown in Figure 3 as dashed areas.

1.30. Moving towards the bar showing the 270MHz supply, in round 62 Three bid for 30MHz at a price of £37.8m per 5MHz, rather than the 40MHz it had bid for at £36.0m per block. Therefore, Three valued an incremental 10MHz somewhere between these two prices. In round 67, Three declined to bid for 30MHz at a price of £39.7m per block and the auction closed.

1.31. Based on this auction data (and ignoring temporarily the complication that Ofcom is auctioning 3.4GHz and 3.6GHz in two sequential auctions), it is possible to estimate four candidate measures of value for UKB's 120MHz (based on Ofcom's conservative approach of taking the lower bound of value in each case):

- **The market-clearing price** of 3.4GHz was £37.8m per 5MHz. This reflects the incremental value to Three of the 10MHz it did not win in the auction, or its highest losing bid for that spectrum;
- **Ofcom's marginal opportunity cost** of £31.1m per 5MHz. Ofcom takes Telefónica's highest losing bid for an extra 15MHz (£31.1m per 5MHz) as a proxy for what bidders other than Three would be willing to pay for some of UKB's spectrum (on top of the 3.4GHz they won). However, this reflects the marginal opportunity cost to other users of the spectrum acquired in the auction, not of UKB's holding;
- **A corrected marginal opportunity cost of UKB's spectrum to others** is £29.6m per 5MHz. Absent Three, Telefónica's £31.1m bid would have been fulfilled without any of the UKB spectrum. Telefónica would have won 15MHz of the 20MHz won by Three, so the next losing bid must be considered (Vodafone's bid for an extra 10MHz at a price of £29.6m per block). The sum of these losing bids is now 25MHz, more than the 20MHz won by Three. The correct marginal opportunity cost of UKB's spectrum is therefore set by Vodafone's value of £29.6m per 5MHz; and
- **The opportunity cost of UKB's 120MHz spectrum to others**. Consistent with the SRSP, this reflects "*the value of spectrum to the best alternative use or user that is denied access to it*".[17] It is the sum of rivals' incremental bid values for UKB's 120MHz absent Three (on top of the 3.4GHz they won, and after Three's 20MHz has been allocated to other bidders). The highest losing bid is £29.6m (i.e. Vodafone's value for 5MHz only) and the lowest losing bid is also Vodafone's £9.0m, adding up to 120MHz. This reduces the weighted average lump-sum value to £19.1m per 5MHz.

1.32. These measures obviously yield very different estimates of the value of UKB's spectrum to other users. The market clearing price of £37.8m

[17] Para 3.41, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.

per block values UKB's spectrum at £907.8m (£37.8m times 24 blocks in UKB's 120MHz holding).

1.33. By applying a linear ALF based on a lump-sum value of £31.1m per block (Ofcom's estimate of the marginal opportunity cost), Ofcom estimates the value of UKB's holding to be £746.8m. This is much greater than the true opportunity cost of UKB's holding for two reasons:

- Ofcom has not removed Three's winning bid for 20MHz from the calculation of marginal opportunity cost. As above, correcting this means focusing on the next losing bid of £29.6m. This estimates the value of UKB's spectrum to be £711.3m; and
- The marginal opportunity cost (whether £29.6m or £31.1m per block) applied to UKB's 120MHz vastly overestimates the true opportunity cost, which is £458m (£19.1m times 24 blocks). This is nearly 40% lower than Ofcom's estimate based on the marginal cost and 50% lower than Ofcom's estimated value based on the market-clearing price.

1.34. Due to these differences in the amount of revenue they extract from Three, these measures are not all equally suited to promoting optimal use. The rationale for ALF that Ofcom has provided is to give incentives to trade or return spectrum if in the future Three is no longer the highest value user. But clearly the measures which extract greater revenue have a greater risk of leaving spectrum unused in that event.

1.35. Because they use Three's bids for 3.4GHz in the calculation of opportunity cost, both measures considered by Ofcom also risk distorting bidding incentives in future auctions. The risks associated with setting ALFs based on the different candidate measures for the lump-sum value of UKB's spectrum are illustrated below.

Table 1: Risks of different candidate measures

Option	Distorts bid incentives	Unused spectrum if Three's values fall over time	Excess revenues
Market clearing price			
Ofcom's marginal opportunity cost			
Marginal opportunity cost (corrected)			
Opportunity cost			

Source: Three

Ofcom is proposing a different relevant marginal increment than the one it used in the 900MHz/1800MHz ALF decision

1.36. In it unclear why Ofcom has only taken 15MHz (or less) as the relevant marginal increment of 3.4GHz in its calculation of marginal opportunity cost. In its 900/1800MHz ALF decision Ofcom found that, as here, the highest losing bids for 800MHz and 2.6GHz were generally smaller for larger quantities of additional spectrum (with some exceptions arising from synergies).[18]

1.37. In the ALF decision, the "additional spectrum" added to each winning bidder's post auction holdings in the calculation of marginal opportunity cost was equal to the amount of spectrum won in the auction: 2x5MHz and 2x10MHz for 800MHz, and 2x15 MHz (Niche), 2x20 MHz (Vodafone) and 2x35 MHz (EE) for 2.6GHz.

1.38. Unlike Ofcom's proposal in the current consultation, the relevant increment was not the amount of spectrum in the highest losing bids (i.e. for 2.6GHz, losing bids for 2x10MHz from Telefónica and Three). The same approach now would use 40MHz (the amount of 3.4GHz won by BT and O2) and 50MHz (the amount won by Vodafone) as the relevant marginal increments.

1.39. For 800MHz, Ofcom used derived a candidate market value of £30m per MHz as a weighted average of the marginal opportunity costs of the 800MHz won by Three and Telefonica, not a single marginal opportunity cost figure. For 2.6GHz, Ofcom estimated a range of marginal opportunity costs depending on the excluded bidder and the amount of spectrum won by each winning bidder in the auction, and used its marginal bidder analysis to inform the choice of market value from within that range.

Roadmap to Sections 4 to 7

1.40. We discuss the risk that Ofcom's measures could distort bidding incentives in Section 4, and the risk of unused spectrum and excessive revenue extraction in Section 5. Section 6 discusses the practical implementation of ALFs reflecting the opportunity cost of UKB's spectrum.

1.41. Section 7 explains that Ofcom should account for the "5G premium" which, all else the same, will tend to inflate 3.4GHz auction prices compared to the upcoming 3.6GHz auction.

[18] https://www.ofcom.org.uk/__data/assets/pdf_file/0028/79534/annexes_1-7.pdf, para. A6.31

4. ALFs based on market-clearing price or Ofcom's marginal opportunity cost would distort bid incentives.

Executive Summary

1.42. This section discusses Principle 8 of Ofcom's SRSP, which is concerned with the use of market valuations (including auction values) in setting spectrum fees. Principle 8 states that Ofcom will not apply market values mechanically to set ALFs, to avoid affecting bidding incentives of ALF payers at auction.

1.43. However, this is precisely what Ofcom proposes to do. Both measures in the consultation (the market-clearing price and Ofcom's marginal opportunity cost estimate) include bids from Three in the calculation of the lump-sum value of UKB's spectrum. If Ofcom uses either of these measures, Three will have raised its own ALFs through its bids in the PSSR auction.

1.44. In our view, the use of either measure in this case is therefore inconsistent with the SRSP and risks distorting bidding incentives. An opportunity cost calculation should exclude a winning bidders' bids. This is what Ofcom proposes to do to estimate base prices in the upcoming 700MHz and 3.6GHz auction. If calculated in that way, a lump-sum value based on opportunity cost (or marginal opportunity cost) does not risk distorting bidders' incentives.

1.45. ALFs will become payable on 2.1GHz and 1400MHz spectrum in 2022 and 2023 respectively. Ofcom may want to use values from the PSSR and the upcoming 700MHz and 3.6GHz award to inform those ALFs.

1.46. Ofcom should send a clear message to stakeholders in its Statement on UKB's ALFs that it will not use auction bids mechanically to set ALFs. In practice, this means not using the market-clearing price or its marginal opportunity cost estimate to determine the level of UKB's 3.4GHz and 3.6GHz ALFs.

The SRSP states that Ofcom will not apply market values mechanically to avoid affecting the bidding incentives of ALF payers

Principle 8 of the SRSP on the use of market valuations in setting spectrum fees

1.47. Principle 8 of Ofcom's SRSP is concerned with the use of market valuations in setting spectrum fees.

> **AIP principle 8: use of market valuations in setting AIP fee levels**
> We will take account of observed market valuations from auctions and trading alongside other evidence where available when setting reference rates and AIP fee levels. However, such market valuations will be interpreted with care and not applied mechanically to set reference rates and AIP fees.

1.48. In the SRSP Statement, Ofcom decided to take account of observed market valuations from auctions when setting spectrum fees. However, Ofcom would not apply those values mechanically as it did not want to affect the bidding incentives of ALF payers. Ofcom asked itself the following question:[19]

"*Whether it is possible to link AIP to observed market prices without distorting bidding or trading incentives. But care is needed in some cases. For example, if bidders expect the AIP fees they pay on some of their spectrum to be revised in light of the auction price of spectrum they are bidding for, they may have an incentive to bid less aggressively*"

1.49. Ofcom agreed that "*it is important that we find methods of using evidence from observed auction outcomes to inform AIP decisions without distorting bidding or trading incentives*".

Ofcom developed its Additional Spectrum Methodology (ASM) in its second 4G auction consultation to avoid adversely affecting bidders' incentives

1.50. In its second 4G auction Consultation in 2012, Ofcom proposed its ASM methodology to derive lump-sum values of 800MHz and 2.6GHz in the context of 900MHz and 1800MHz ALFs. This was "*in response to a concern from respondents that a direct link between prices in the auction and ALF could result in incentives that reduce auction efficiency*".

1.51. Ofcom agreed that, although there were mitigating factors, "*the underlying concern might in principle affect the efficiency of the auction in certain circumstances and that it is appropriate to consider how we might further mitigate this potential risk*".[20]

1.52. Ofcom's solution was to exclude all bids from an ALF payer in the calculation of opportunity cost, to prevent those bids from influencing the resulting ALF. ASM involves:

"*Calculating an estimate of the opportunity cost of an ALF payer retaining the spectrum to which the ALF applies, on the basis of bids*

[19] Para 4.264, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.
[20] Paras 8.11 to 8.14, https://www.ofcom.org.uk/__data/assets/pdf_file/0025/55276/combined-award-2.pdf.

made in the auction. This calculation excludes any bid that the ALF payer concerned may have made, in order to prevent its bids from influencing the estimate of full market value that results.

The approach involves calculating the aggregate value of what would be the winning combination of bids if spectrum equivalent to the ALF spectrum had hypothetically been available in the auction, excluding those bids made by the bidder whose existing spectrum we are estimate the value of".

1.53. We explain below that, unlike a true opportunity cost calculation, the ASM method does not really exclude *"any bid that the ALF payer may have made".* Neither does the market-clearing price in this case. If Ofcom applies either measure to set the level of UKB's ALFs, Three will have raised its own ALF through its bids for 3.4GHz in the auction.

Ofcom's calculation of lump-sum value should exclude all of Three's bids, both winning and losing

Opportunity cost cannot depend on the private value to the holder of the spectrum

1.54. According to the SRSP, optimal use of spectrum requires that spectrum is priced to reflect its opportunity cost.[21]

1.55. The opportunity cost concept is central to spectrum pricing (in auctions and ALFs) and is based on the idea of displaced alternatives. As the SRSP found, spectrum is a scarce and finite resource. Use of spectrum for one purpose or by one user will generally exclude or limit its use by others.

1.56. Opportunity cost reflects the value to the most valuable alternative users of the spectrum which must be displaced in order to produce the service in question. From the perspective of an MNO, opportunity cost reflects the amount which must be paid to bid the spectrum away from rivals, i.e. the 'market price'.

1.57. Opportunity cost is essentially a reflection of the strength of the excluded demands for spectrum from other users. It reflects what the use of the spectrum is worth to them, or their willingness to pay for it. This is the incremental value that they would have received if spectrum had been optimally allocated to them.

1.58. Hence, in principle opportunity cost can never depend on the value to the holder of the spectrum, as it would if Ofcom used the market clearing price to set UKB's ALF.

The opportunity cost of a winner's package should exclude all bids, both winning and losing, from that bidder

1.59. Ofcom observes its duty to promote optimal use in all its spectrum functions, including when awarding spectrum by auction. Indeed, Ofcom believes that in most circumstances auctions are the most

[21] Ibid, para 1.9.

appropriate way of allowing the market to determine the most efficient allocation of spectrum.[22]

1.60. The combinatorial clock auction (CCA) format that Ofcom used in the 2013 4G auction, and which it proposes to use again in the 700MHz and 3.6GHz auction in Spring 2020, uses opportunity cost pricing. The calculation of additional prices in the assignment stage of the SMRA that Ofcom used most recently in the PSSR auction also uses opportunity cost pricing.[23]

1.61. To determine the winning bidders in a CCA (and winning positions in an SMRA), Ofcom first selects the combination of bids of greatest total value.[24] To calculate the opportunity cost of a bidder's winning package, Ofcom then excludes that bidder (and all of its bids, both winning and losing) and re-calculates the solution to the Winner Determination Problem with only the other bidders.

1.62. This counterfactual (where the winning bidder is hypothetically excluded) normally reduces the total value of the winning bids by no more than the value of the excluded winning bid, as it is possible to reallocate the blocks won by the excluded bidder to other bidders.

1.63. The amount by which the fall in value is mitigated by allocating blocks to other bidders is the opportunity cost of the winning bid, as this is the alternative allocation that is precluded by awarding the spectrum to the winning bidder.

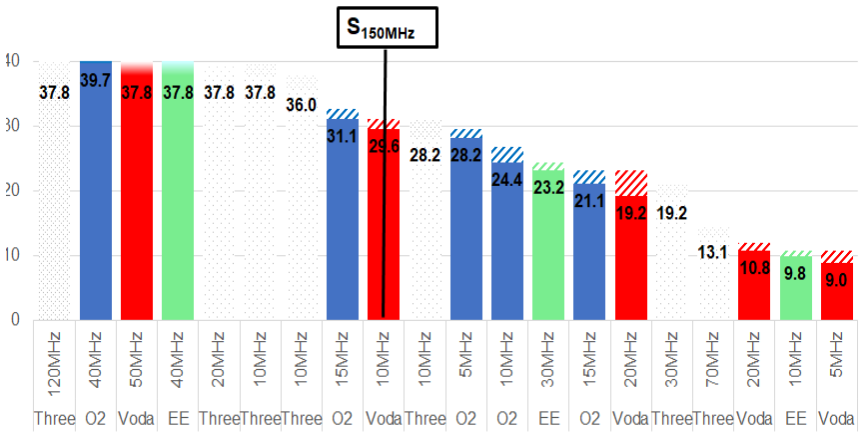
1.64. This means that, both in principle and in practice, with opportunity cost pricing a bidder's payment can never depend on its own bids (winning or losing). This gives bidders an incentive to bid their true values, which is a key prerequisite for the resulting allocation of spectrum to be efficient, i.e. for spectrum to be in the hands of the operators who value it the most.

A lump-sum estimate based on either opportunity cost or the corrected marginal opportunity cost will not distort bidding incentives

1.65. Figure 4 shows the incremental bid values for 3.4GHz spectrum from the PSSR auction but, compared to Figure 3, it excludes all of Three's values (in the dotted pattern) as required for the opportunity cost calculation.

[22] Para 2.43, https://www.ofcom.org.uk/__data/assets/pdf_file/0019/130726/Award-of-the-700-MHz-and-3.6-3.8-GHz-spectrum-bands.pdf.
[23] By contrast, the Principal Stage of an SMRA auction uses a first-price or 'pay as you bid' rule.
[24] Subject to not allocating more spectrum than is available and accepting at most one bid from each bidder (or exactly one bid in the assignment stage of an SMRA).

Figure 4: Incremental bid values for 3.4GHz spectrum excluding Three's bids



Source: Three (based on PSSR auction data)

1.66. The marginal opportunity cost of UKB's spectrum to others is £29.6m per 5MHz. Excluding all of Three's bids, Telefónica's £31.1m bid would have been fulfilled without any of the UKB spectrum. Telefónica would win 15MHz of the 20MHz won by Three. The next losing bid was placed by Vodafone, who reduced demand by 10MHz (from 60MHz to 50MHz) at a price of £29.6m per block. The marginal opportunity cost of UKB's spectrum is therefore set by Vodafone's incremental value of £29.6m.

1.67. The opportunity cost of UKB's 120MHz spectrum to others is the incremental value of non-Three bidders for UKB's 120MHz (on top of the 3.4GHz they won). This is the sum of rivals' decreasing marginal values, from Vodafone's £29.6m to Vodafone's £9.0m value for 5MHz at the right side. The aggregate amount denied to others by Three continuing to hold the 120MHz is £458m, with a weighted average lump-sum value of £19.1 million.

1.68. As both calculations of opportunity cost exclude Three's bids for 3.4GHz in the auction, they would not distort bidding incentives in future auctions.

By contrast, using the market clearing price to set UKB's ALF risks distorting bidding incentives

1.69. The same cannot be said of the market-clearing price for 3.4GHz in this instance, as Three was the highest losing bidder for 3.4GHz in the auction. Three effectively set the market price when it reduced demand and was awarded its Standing High Bid for 20MHz at a price of £37.8m per 5MHz.

1.70. The market-clearing price of £37.8m per block reflects Three's highest losing bid for an extra 10MHz in the auction. Using it means using Three's bids to set Three's ALF. The effect, as the graph makes plain, is that Three would have raised its own ALF by around £9m a year

higher (i.e. UKB's ALF bill would be £52m instead of the £43m per annum proposed by Ofcom).

1.71. In our view, this is clearly inconsistent with Principle 8 of the SRSP. Using the market clearing price to set UKB's ALF in this instance is also clearly inconsistent with Principle 1 of the SRSP and with Ofcom's general approach to ALFs. Ofcom has made it crystal clear in both contexts that: 1) the ultimate aim of spectrum fees is to reflect opportunity cost, not the market price per se; and 2) opportunity cost is the value of the spectrum to other users, not the private value to the current holder.

1.72. The SRSP says the following:[25]

"When discussing setting AIP fees to reflect the value of spectrum we have usually meant that these fees would be set at the price that would emerge in a well-functioning market. In a well-functioning market, the price of spectrum would be equal to the value of that spectrum in the next highest value use, rather than the value that the current user (for example, a company) might place on the spectrum" [Emphasis added]

1.73. Ofcom made similar statements in the context of the 900MHz and 1800MHz ALFs. Ofcom's 2015 ALF Statement clarified the distinction between opportunity cost and value to the holder unambiguously:[26]

"Taking Vodafone's holdings of 900 MHz as an example, we are not therefore seeking to establish Vodafone's value of its 900 MHz licence. Instead it is the value that is denied to other operators by Vodafone continuing to hold this spectrum that is relevant to the marginal opportunity cost and market value. In particular, it is the value to the other operator that would gain the highest value if it were to acquire Vodafone's 900 MHz frequencies (or part of them).

Below we refer to this highest-value alternative holder of the spectrum as the marginal operator or marginal bidder...The market value of spectrum for the purpose of ALF therefore depends on the value to the marginal operator (i.e. the highest-value operator that does not hold that specific spectrum)". [Emphasis added]

1.74. Hence, spectrum fees aim to reflect the market price only indirectly. The ultimate goal is to reflect the opportunity cost which, by definition, can never depend on the value to the current holder. Where the market-clearing price and opportunity cost are different, such as in the PSSR auction, opportunity cost provides the correct guide for pricing purposes.

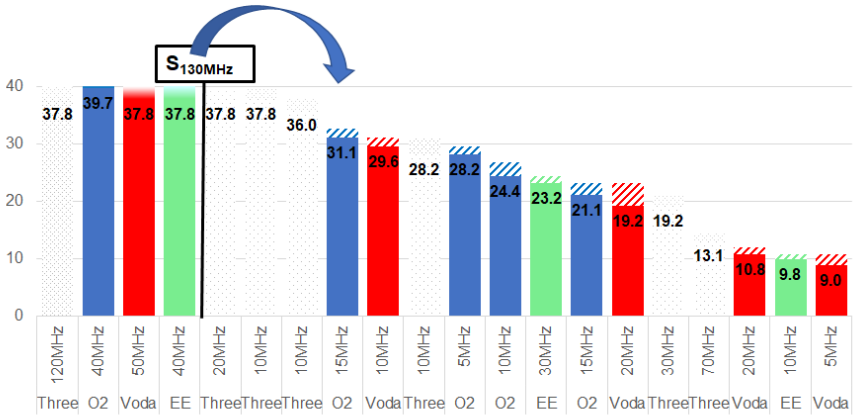
Ofcom's marginal opportunity cost is also inconsistent with the SRSP because it risks distorting bidding incentives

1.75. Ofcom's calculation of marginal opportunity cost appears to be based on the ASM method it developed to set 900MHz and 1800MHz ALFs without adversely affecting bidders' incentives. However, ASM

[25] Para 4.73, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.
[26] Para 4.6, https://www.ofcom.org.uk/__data/assets/pdf_file/0033/79764/statement.pdf.

systematically overestimates marginal opportunity cost and, in our view, is inconsistent with Principle 8 of the SRSP. Ofcom's calculation of marginal opportunity cost with Three as the "excluded bidder" is illustrated in Figure 5.

Figure 5: Ofcom's calculation of marginal opportunity cost with Three as the excluded bidder



Source: Three (based on PSSR auction data)

1.76. Ofcom looks at the last time a bidder other than Three bid for more spectrum than it won (round 48, when Telefónica bid £31.1m per 5MHz block for 55MHz, before dropping to the 40MHz it eventually won at a price of £32.7m per block). Ofcom takes £31.1m per 5MHz as the marginal opportunity cost of UKB's spectrum, or the amount that Three's rivals would be willing to pay for some of UKB's spectrum (on top of the 3.4GHz they won).

1.77. In effect, this is an abbreviated version of Ofcom's ASM method. The ASM would produce the same value in the following steps:[27]

- Identify 130MHz as the "baseline" spectrum, i.e. all 150MHz in the auction less the 20MHz won by Three. The baseline bid value for that spectrum is £999m, i.e. the total amount of the winning bids (£1,150m), less £151m in Three's winning bid for 20MHz;[28]
- Add a hypothetical block of UKB's spectrum to this baseline. Ofcom does not discuss the relevant marginal increment but it must be 15MHz or less. Absent Three, the winning bids if an extra 15MHz had been offered in the auction are the same as in the baseline, but with O2 winning 15MHz more (i.e. 55MHz rather than 40MHz). The total bid value includes the £999m in the baseline

[27] For Ofcom's original description of the ASM method, see para A13.70, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/63582/2nd_condoc_annexes_8-15.pdf.
[28] That is, eighteen 5MHz blocks from Vodafone and EE at £37.8m per block, plus eight 5MHz blocks from O2 at £39.7m per block

plus O2's bid for an extra 15MHz at £31.1m per 5MHz block, or £1,092m; and

- The marginal opportunity cost of UKB's 120MHz, proxied by the hypothetical addition of 15MHz to the auction, is then £93.3m (i.e. £31.1m per 5MHz block). This is the delta between the total bid value in the hypothetical scenario (£1,092m), and the baseline bid value (£999m).

1.78. Ofcom's ASM estimate of £31.1m per block is not an appropriate measure of the marginal opportunity cost of UKB's spectrum. Without Three, Telefónica's £31.1m bid for 15MHz would have been fulfilled without any of the UKB spectrum. Ofcom's value determines the marginal opportunity cost to other bidders of the 3.4GHz acquired in the PSSR auction, not the marginal opportunity cost of UKB's spectrum.

1.79. The problem with Ofcom's estimate is that, in reality, ASM does not *"exclude any bid that the ALF payer concerned may have made, in order to prevent* its *bids from influencing the estimate of full market value that results".*

1.80. ASM eliminates all bids from Three in its calculation of the marginal opportunity cost, but it simultaneously reduces the total supply available to other users by the 20MHz won by Three, so the baseline spectrum is 130MHz instead of 150MHz.

1.81. This is equivalent to putting Three's winning bid for 20MHz back into the opportunity cost calculation. In Figure 5, UKB's spectrum is hypothetically added to a hypothetical supply of 130MHz, not the actual 150MHz available in the auction. This prevents O2 from buying some of the 20MHz released by Three in the counterfactual with Three as the excluded bidder.

1.82. To explain this point another way, ASM implicitly assumes that Three would divest UKB's spectrum before the 20MHz Three won in the auction, but this is incorrect. The 20MHz is not in use, whereas UKB's spectrum is tied to frequency-specific equipment and is being used to serve UKB's customers.

1.83. The marginal opportunity cost that provides the right incentives at the margin is £29.6m per block, not £31.1m because Three has every incentive to sell its 20MHz first. The figure also has the advantage of being completely independent of Three's bids, so it does not distort bidding incentives.

Ofcom should send a clear message that it will not use market-clearing price or its marginal opportunity cost estimate to set UKB's ALFs

1.84. Regulatory certainty is important to us. Three did not expect that its bids for 3.4GHz in the PSSR auction would end up impacting the ALFs payable on its UKB spectrum.

1.85. ALFs will become payable on all MNOs' 2.1GHz spectrum from 1 Jan 2022, and subsequently on Vodafone and Three's 1400MHz spectrum from 16 May 2023. The most recent auction value estimates that

Ofcom will have available to set the ALFs will be those from the PSSR 2.3GHz and 3.4GHz award and those from the 700MHz and 3.6GHz auction scheduled for Spring 2020.

1.86. The 2.3GHz values provide a clear reference for the 2.1GHz ALF. Ofcom may also use the 700MHz and 3.4GHz and 3.6GHz values to inform the 1400MHz ALF, either directly (as it considers 1400MHz to be low-frequency spectrum in its 700MHz award consultation) or in combination with other values (in a distance method estimate similar to the one used for the 1800MHz ALF).

1.87. It is therefore very important that Ofcom sends a clear message to stakeholders in its Statement on UKB's 3.4GHz and 3.6GHz ALFs that it will not use bids mechanically to set ALFs. In practice, this means not using the market-clearing price or its marginal opportunity cost estimate to determine the level of UKB's ALFs.

5. ALFs based on opportunity cost raise the minimum revenue needed to ensure optimal use.

Executive Summary

1.88. This section discusses the role of ALFs in promoting the optimal use of spectrum, as envisaged by Principle 1 of the SRSP. Principle 1 states that Ofcom does not take revenue raising into consideration when setting fees. The role of ALF is instead to promote optimal use, by ensuring that users face a long-term signal of opportunity cost when spectrum markets do not exist, are immature or do not function well.

1.89. Since, as discussed in Section 1, Ofcom's sole rationale for imposing an ALF is to give Three incentives to trade or return spectrum if it is no longer the highest value user for some of UKB's spectrum in the future, Ofcom should be particularly sensitive to the level of the lump-sum value of 3.4 and 3.6GHz spectrum. This is for two reasons:

- Some candidate measures are clearly better than others at promoting the optimal use of UKB's spectrum; and
- Ofcom should not raise more revenue than needed to ensure the optimal use.

1.90. In our view, opportunity cost is the right measure for UKB's ALFs (if a case can be made to impose such an ALF). Such an ALF minimises the risk of leaving spectrum unused (if Three's value for UKB's spectrum decreased over time) and raises only the minimum amount of revenue (£458m) that is consistent with ensuring optimal use.

1.91. Opportunity cost, not marginal opportunity cost, is the measure advocated by Ofcom's SRSP. It is consistent with opportunity cost-pricing in Ofcom's auctions and a conservative approach to ALFs. Three could not possibly sell all of its spectrum for £29.6m per block (let alone £31.1m or £37.8m). Any other measure would grossly overstate the market value of UKB's spectrum.

1.92. In comparison, marginal opportunity cost is appropriate when pricing small increments of spectrum, not a 120MHz block. As rivals' values for additional spectrum decrease with the amount of spectrum, either version of marginal opportunity cost carries some risk of fallow spectrum and serves no other purpose than extracting revenue (contrary to Principle 1 of the SRSP).

1.93. The market-clearing price is clearly the worst option, as it carries the greatest risk to optimal use of all options and extracts an inordinate amount of revenue with no clear justification.

Principle 1 of the SRSP and the optimality of opportunity cost pricing

Ofcom's duty is to promote the optimal use of spectrum, not to raise revenue from ALFs

1.94. Principle 1 of the SRSP discusses the role of spectrum fees (AIP or ALF). It explains that Ofcom does not have a duty to generate revenue from spectrum. Ofcom passes receipts from spectrum fees to the Exchequer, but raising revenue is not a consideration that it takes into account when setting fees. Principle 1 stated that Ofcom does not aim to deliver a "*fair rate of return*" of a state resource.[29]

1.95. The SRSP states that Ofcom's main objective in exercising its power to set licence fees under section 12 of the WT Act is instead to promote the optimal use of spectrum. The role of spectrum fees is to *"mimic, broadly, the incentives for efficient use of spectrum that result from well-functioning markets*".[30]

> **AIP principle 1: role of AIP**
> AIP should continue to be used in combination with other spectrum management tools, in both the commercial and the public sectors, with the objective of securing optimal use of the radio spectrum in the long term. AIP's role in securing optimal use is in providing long-term signals of the opportunity cost of spectrum.

1.96. ALF acts as *"a proxy for market prices for scarce spectrum that has been assigned administratively…rather than auctioned"*.[31] It promotes optimal use by ensuring that users face a long-term signal of opportunity cost when spectrum markets do not exist, are immature or do not function well.[32]

1.97. Principle 1 discusses the role of spectrum fees as a surrogate for the prices that would emerge in a well-functioning market:[33]

"In general terms, benefits to society will be maximised over time if spectrum is priced to reflect opportunity cost. The opportunity cost is the price that would emerge in a well functioning market and reflects the value of spectrum to the best alternative use or user that is denied access to it.

When AIP fees are charged, users will hold scarce spectrum if they value it more than the AIP fee. If AIP fees reflect opportunity costs, users have an incentive to hold only the spectrum that they value as highly as the best alternative user or use. In this way, AIP fees have an effect similar to the prices that would emerge in a well functioning spectrum market…

[29] Ibid, paras 4.61-4.62.
[30] Ibid, pages 28-29.
[31] SRSP consultation, para. 1.12.
[32] Page 28, https://www.ofcom.org.uk/__data/assets/pdf_file/0024/42909/srsp-statement.pdf.
[33] Para. 3.41.

The SRSP advocates opportunity cost, not 'marginal opportunity cost'

1.98. The SRSP refers to 'opportunity cost' 138 times. Contrary to the suggestion in this Consultation, there is no reference to 'marginal opportunity cost'. Principle 1 refers explicitly to the role of fees "*in providing long-term signals of the value of spectrum which can be indicated by its opportunity cost"*. [Emphasis added]

1.99. The same is true of Ofcom's recent consultation on the award of 700MHz and 3.6GHz spectrum, which also aims to ensure optimal use. Ofcom's description of the pricing rule states: "*Base prices to be paid by winning bidders who are assigned a non-zero package are based on the concept of opportunity cost"*.[34] [Emphasis added]

1.100. Both the SRSP and Ofcom's pricing rule for the 2020 auction could have referred to 'marginal opportunity cost', but they do not. They say 'opportunity cost'. This is unsurprising since Ofcom must observe its duty to promote optimal use in all of its spectrum functions, whether by setting ALFs or awarding spectrum by auction.

1.101. Like the SRSP, Ofcom's first consultation on 900MHz and 1800MHz ALFs also speaks of opportunity cost (11 times).[35] 'Opportunity cost' morphed into 'marginal opportunity cost' for the first time in Ofcom's second ALF Consultation in 2014.

1.102. The 2014 ALF consultation refers for the first time to the price in a well-functioning market representing the 'marginal' opportunity cost, the highest losing bid for the 'marginal' increment of spectrum in a (competitive) auction, and the value denied to other operators 'at the margin'.[36]

1.103. The mutation of 'opportunity cost' into 'marginal opportunity cost' is an unfortunate one, because the optimality properties of opportunity cost-pricing do not extend to marginal cost pricing. Marginal cost pricing risks optimal use and would serve no other purpose than extracting revenue from Three, contrary to Principle 1 of the SRSP.

Optimal use requires pricing at opportunity cost, not marginal opportunity cost

1.104. The SRSP interprets 'optimal use' as synonymous with economic efficiency. Economic efficiency is obtained by charging for resources according to their opportunity cost, not marginal opportunity cost.

1.105. Marginal opportunity cost is appropriate when pricing a resource consumed by atomistic users consuming an infinitesimal part of the total supply. If a user cannot buy additional units at marginal cost, it cannot choose rationally (from society's point of view) between

[34] Ofcom (2018), "Award of the 700 MHz and 3.6-3.8 GHz spectrum bands," para A16.126.
[35] For instance, to estimate the market value of Telefónica's 900MHz Ofcom's ASM calculates "*the additional amount that bidders other than Telefónica would have been willing to pay if the total amount of spectrum on offer in the auction had included an additional 2x15 MHz of 800 MHz spectrum (as a proxy for the 2x17.4 MHz of 900 MHz spectrum retained by Telefónica*)". This estimates the opportunity cost to others of Telefónica's entire 2x17.4MHz of 900MHz (not the marginal opportunity cost).
[36] Paras 2.9-2.10, https://www.ofcom.org.uk/__data/assets/pdf_file/0025/74680/condoc.pdf.

purchasing extra units of the resource or spending money in other direction, since the amount it must pay would not reflect the value of the resource to another user.

1.106. However, Ofcom proposes to set ALFs for a large amount of spectrum (UKB's 120MHz holding). Charging at marginal opportunity cost breaks down entirely where there are only four MNOs vying for a large fraction (i.e. 120MHz out of 390MHz) of the total stock of 3.4-3.8GHz available. If the amount payable then reflects marginal opportunity cost times the large stock, the user faces a price which is much greater than the value of the resource to other users.

1.107. Ofcom's focus on providing incentives for Three to relinquish spectrum at the margin through an ALF is therefore misplaced. The following quote reflects the consensus of the economics profession:[37]

> "*Although we have argued that MOC [marginal opportunity cost] is generally the right measure of scarcity, there are situations where the appropriate concept is not a marginal one. In particular, this will be so when the policies being considered involve large changes to the stocks of natural resources. Then the value of a small change in the resource, suitably scaled up, will not be an accurate measure and what is required is a comparison between the value of the total stock before and after the change*".

1.108. The "*value of a small change in the resource, suitably scaled up*" is precisely the marginal cost of UKB's spectrum applied to the entire 120MHz in UKB's portfolio. But it *"will not be an accurate measure"* of value. What is required instead is a "*comparison between the value of the total stock before and after the change*" – i.e. the true opportunity cost, which is in fact the measure advocated by the SRSP.

<u>Charging at opportunity cost ensures that winning bidders pay no more than needed to win the spectrum</u>

1.109. ALF is meant to proxy for the prices that would emerge in a well-functioning market.[38] It is no coincidence that Ofcom adopts opportunity cost, not marginal opportunity cost, as its principle for determining payments by winning bidders in its CCA auctions. Opportunity cost-pricing is the gold standard of a well-functioning market.

1.110. Opportunity cost-pricing is the only pricing rule that attains full efficiency in all scenarios. On a per-unit basis, the bidders, as a group, pay the average opportunity cost. If instead base prices were based on marginal opportunity costs, the CCA would not attain efficient outcomes.

1.111. Because ALF is supposed to proxy for the price that would emerge in a well-functioning market, and because Ofcom has no duty to raise

[37] Pearce, D. & Markandya (1987), "Marginal opportunity cost as a planning concept in natural resource management," *Annals of Regional Science*, 21(3), pp 18–32, at p. 24.
[38] This is the Vickrey-Clarke-Groves (VCG) mechanism.

revenue from spectrum fees, lump-sum values for ALF purposes should never exceed opportunity cost. Ofcom's CCA auctions opportunity cost prices are as low as they can be, subject to the requirement that no other bidder (or group of bidders) is prepared to pay more for that spectrum.[39]

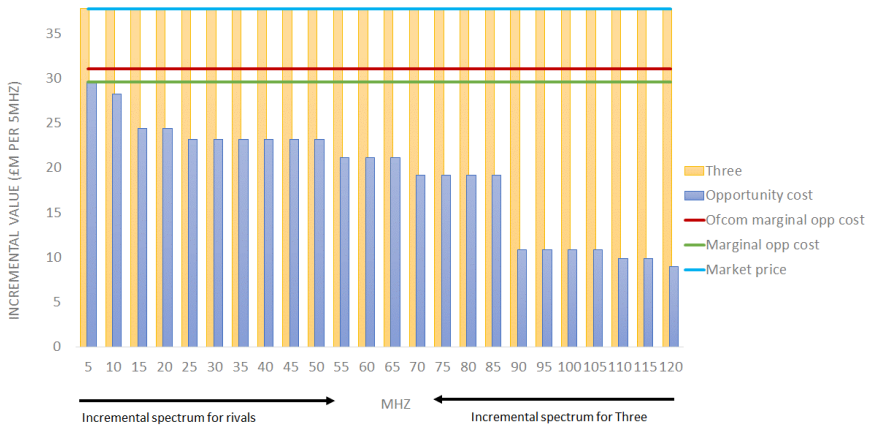
1.112. These are the opportunity cost prices in the "well-functioning" market that ALFs are meant to emulate. They reflect the value of the spectrum to the highest losing bidders. This is analogous to the outcome of a competitive process where prices continue to rise while there is competition, but only until demand from rival bidders is choked off.

ALFs based on the market-clearing price or marginal opportunity cost have a greater risk of unused spectrum

1.113. Since Ofcom's purpose in applying an ALF is to give Three incentives to return or trade some of UKB's spectrum it if it is no longer the highest-value user in the future, Ofcom should carefully consider the risks to optimal use from setting ALFs based on an excessive lump-sum value.

1.114. Figure 6 is the same as Figure 5 but focuses on the first 120MHz (i.e. UKB's holding). Rivals' values are now shown left to right (and Three's right to left). The first value is Vodafone's £29.6m for 5MHz, the last is Vodafone's value of £9.0m per block for an extra 5MHz. Figure 6 also shows the candidate lump-sum values. The opportunity cost of UKB's spectrum is represented by rivals' decreasing values for additional spectrum (on top of the 130MHz they won in aggregate, and after removing Three's bids).

Figure 6: The different candidate measures are not all equally effective at promoting optimal use



[39] Ofcom accounts for collective (through a core adjustment) as well as for individual opportunity costs

Source: Three (based on bid data)

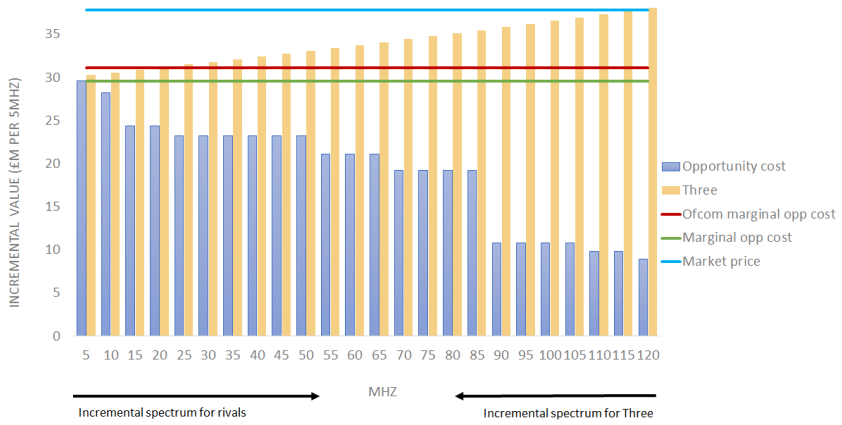
1.115. It seems clear that the candidate measures are not all equally effective at promoting optimal use of UKB's spectrum. We do not therefore agree with Ofcom's view that the market clearing price and marginal opportunity cost are both capable of securing optimal use.

1.116. Ofcom is right to remark that Three may be a "*particularly high-value user of the UKB 3.4 GHz and 3.6 GHz spectrum*". It is also true that Three was willing to purchase additional 3.4GHz at the clearing price of £37.8m per block, so its value for UKB's spectrum can be expected to be higher than that.[40]

1.117. But this does not eliminate the risk that Three may return some or all of UKB's spectrum if the ALF is set at £37.8m per block. Ofcom's purpose in proposing an ALF in the first place is precisely to address the risk that Three may become a lower value user for some of UKB's spectrum in the future. As discussed in Section 1, if there is no such risk ALF can play no useful role in promoting optimal use.

1.118. Marginal opportunity cost is clearly better at promoting optimal use than the market clearing price. Figure 7 shows that an ALF set at market price could lead to large inefficiency if Three's valuation for some of UKB's spectrum fell below the £37.8m mark but remained above marginal opportunity cost. Three would then return those blocks to Ofcom (even though it is still the highest-value user), and there would be no willing buyer at that price. This inefficiency would not arise if the ALF is based instead on the marginal opportunity cost to others.

Figure 7: an ALF set at the market clearing price could lead to large inefficiency



Source: Three (based on bid data)

[40] Consultation, para. 3.34

1.119. Although clearly preferable to the market clearing price, both measures of marginal opportunity cost also risk inefficiency. If Three's valuation for some of UKB's spectrum fell further and the ALF is set uniformly at £31.1m per block, Three could be forced to relinquish spectrum to Ofcom for which it was still the highest value user.

1.120. The best option to promote optimal use is to set UKB's ALF based on opportunity cost – i.e. the value denied to other MNOs. In principle, an ALF that mirrors the decreasing valuations for more 3.4GHz expressed by Three's rivals in Figure 7 would avoid these inefficiencies. It would ensure that Three only retains blocks for which it is the highest-value user, and remove the risk that Three could remain the highest-value user but nonetheless return some spectrum to Ofcom.

1.121. This is consistent with Ofcom's opportunity cost-pricing in spectrum auctions. In a CCA, an MNO can pay different amounts for different blocks of spectrum in the same band, reflecting the differential opportunity cost of each block. For instance, in the 4G auction EE paid £128m for the first 2x10MHz 2.6GHz it won (reflecting Telefónica's incremental bid value) but only £100m for the second 2x10MHz won (reflecting Three's incremental bid value).

1.122. If a non-linear ALF (i.e. not £ per MHz) is not practical to implement, the next best option to promote optimal use of UKB's spectrum is to implement a linear ALF at a level determined by the weighted average opportunity cost. We discuss this in Section 6.

ALFs based on market-clearing price or marginal opportunity cost would serve no other purpose than raising revenue from Three

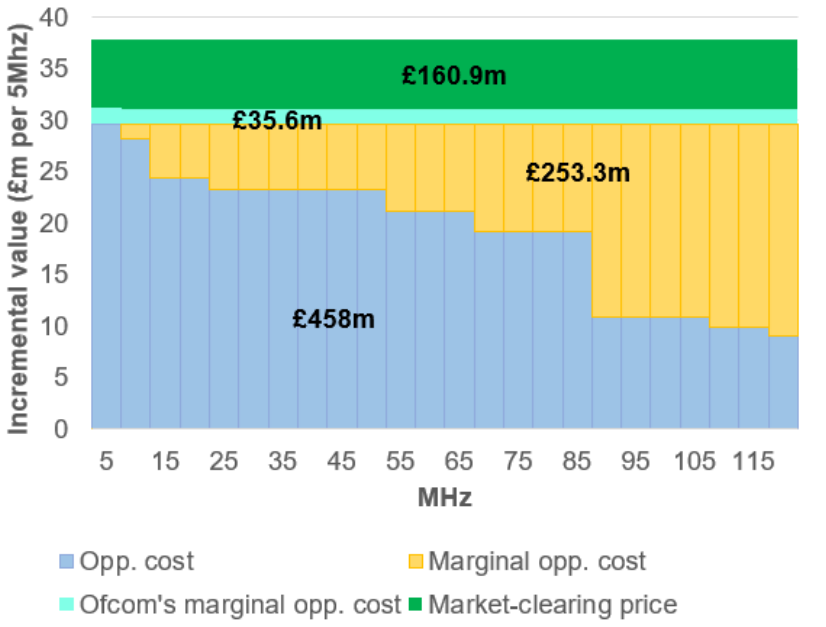
1.123. Ofcom considers that, in principle, both the market clearing price of £37.8m and the marginal opportunity cost to other users of £31.1m per 5MHz block provide a measure of the market value of UKB's spectrum. Three's view is that, on the contrary, both measures grossly overestimate the market value of UKB's 120MHz holding.

1.124. Bid data shows that rivals' incremental values for additional 3.4GHz (over and above the 130MHz they won) decrease markedly with the amount of 3.4GHz added to their holdings. Taking the highest losing bid from a bidder other than Three in the 3.4GHz auction (O2's) and applying that across UKB's 120MHz results in a figure that cannot reasonably be said to represent market value.

1.125. It should be clear from looking at Figure 7 that Three could not possibly sell UKB's spectrum for £37.8m or even £31.1m per block. Basing lump-sum values on the market clearing price or either measure of marginal opportunity cost produces a lump-sum value that is much greater than the true opportunity cost of UKB's 120MHz (i.e. the value to the highest value users other than Three which are denied access to it).

1.126. This is shown in Figure 7, which is the same as Figure 6 but with overlapping bars representing the different estimates of the market value of UKB's spectrum derived from each candidate measure.

Figure 7: Opportunity cost extracts the minimum revenue consistent with optimal use



Source: Three (based on bid data).

1.127. The market value of UKB's spectrum estimated by opportunity cost is only a fraction of the values generated by the other measures:

- **The opportunity cost of UKB's spectrum to others** is the sum of the purple columns. The value denied to others by Three continuing to hold UKB's spectrum is £458m, representing the incremental values for additional 3.4GHz that Three's rivals expressed in the auction (on top of the 130MHz they won, and excluding Three's winning bid for 20MHz from the calculation);
- **Marginal opportunity cost** (i.e. Vodafone's £29.6m per 5MHz applied across to UKB's 120MHz holding) – i.e. the sum of the purple and orange areas, up to the height set by Vodafone's £29.6m per 5MHz figure. This extracts £253.3m more than opportunity cost without justification, since it carries a higher risk of unused spectrum;
- **Ofcom's marginal opportunity cost** (i.e. O2's £31.1m per 5MHz for an extra 15MHz, applied to UKB's 120MHz) – i.e. the sum of the purple, orange and blue areas, which are limited by O2's £31.1m per 5MHz value. This extracts a further £35.6m from Three;

- **Market clearing price** (i.e. £37.8m per 5MHz applied to UKB's 120MHz – i.e. the sum of all areas, limited only by £37.8m per 5MHz (Three's highest losing bid for extra 10MHz in the auction). This would add a further £160.9m to Three's ALF bill despite being the worst option in terms of efficiency. It can serve no other purpose than revenue extraction.

Ofcom should not be concerned about unfair outcomes, competitive distortions or administrative burdens if the market price is not used

1.128. The consultation discusses certain risks that might arise if UKB's ALF did not reflect the market clearing price for 3.4GHz. These include the risks of an unfair outcome (as different operators would be paying different amounts for equivalent spectrum), potential competitive distortions (as Three could be seen to receive a discount or "subsidy" compared to the other MNOs) and an administrative burden if this led to an increased frequency of ALF changes.[41]

1.129. As shown in Figure 3, in the PSSR auction O2 paid £39.7m per block, more than the £37.8m paid by all other bidders for spectrum which is otherwise equivalent. This is a feature of the SMRA auction format chosen by Ofcom. O2 was unlucky to be the first MNO randomly asked to bid for 3.4GHz at the next price increment, before the auction closed in the next round (when Three was asked to do the same). There is no suggestion that this was unfair, created a competitive distortion or an administrative burden for Ofcom.

1.130. Moreover, when Ofcom uses opportunity cost to set auction prices in its CCA auctions, it sets a price for each winning bid, not a linear (i.e. uniform) price for each type of lot. This means that MNOs can pay different prices for the same amount of spectrum if the underlying opportunity costs (or "*value to the best alternative user that is denied access to the spectrum*") are different.

1.131. We agree with Ofcom's provisional view that there is little reason to be concerned about these risks, in the same way that the prices Ofcom sets in its CCA auctions cannot be said to be unfair or create competitive distortions. They simply reflect the fact that the value denied to others may differ as between uses and blocks of spectrum.

[41] Para 3.41

6. Ofcom can practically implement ALFs based on opportunity cost.

Executive Summary

1.132. In this section, we explain how opportunity cost-based ALFs can be practically implemented. As Ofcom recognised in its 2014 Consultation on 900MHz and 1800MHz ALFs, in principle a non-linear ALF would be optimal from an efficiency point of view.

1.133. In the case of UKB's ALFs, Ofcom has direct evidence on the valuations of non-holders of the 3.4GHz and 3.6GHz spectrum. In principle, it should be possible to implement a non-linear ALF which mirrors these valuations. To preserve efficiency incentives, if UKB returned some spectrum back to Ofcom or traded it to another user, the highest ALF would have to go first.

1.134. However, we discuss below that a non-linear ALF may not be practical in this case, due to the industry's desire to defragment the 3.4-3.8GHz band. As Ofcom is aware, Three has engaged a specialist consultancy to design a trading process and act as intermediary, with a view to completing potential trades as soon as practicable.

1.135. Although we obviously do not know the preferences of other MNOs, we can see that the optimal outcome of this process may require a number of trades in the 3.4-3.6GHz band. This could make a non-linear ALF difficult to implement in practice.

1.136. If a non-linear ALF cannot be implemented, Ofcom should set instead a uniform ALF based on £19.1m per 5MHz block, reflecting the average rather than the marginal opportunity cost to other users. This would be consistent with the SRSP, would extract no more revenue than needed and would better promote optimal use of UKB's spectrum than the alternative of a linear ALF based on marginal opportunity cost.

Ofcom has previously accepted that the ALF which ensures optimal use in principle is non-linear

1.137. In its 2014 Consultation for ALFs for 900MHz and 1800MHz spectrum, Ofcom explained that the incremental valuations from non-holders of 800MHz and 2.6GHz spectrum were non-linear (i.e. varied with the amount of spectrum).

1.138. Ofcom said that, if the structure of the demand of the highest-value non-holders for 900MHz and 1800MHz spectrum followed a similar

pattern, the optimal ALF would also be non-linear.[42] Ofcom declined to set non-linear ALFs for two reasons:

- Ofcom did not have direct evidence on non-holders' marginal valuations for 900MHz and 1800MHz spectrum; and
- Ofcom considered that it would be more complicated to implement non-linear ALFs and would break with previous practice for spectrum fees, which have always been set in a linear way (i.e. £/MHz).

1.139. In the case of UKB's ALFs, these difficulties do not arise. The 2018 PSSR auction provides direct evidence on the decreasing values that MNOs placed on additional spectrum in the 3.4-3.6GHz band (over and above the 3.4GHz they won).

1.140. We explain below that, in principle, it should be possible to implement a non-linear ALF which mirrors these valuations. We discuss how this could work in practice if Three returned some spectrum back to Ofcom or traded it to another user. We go on to explain that, in this case, a non-linear ALF may not be practical due to the industry's desire to defragment the 3.4-3.8GHz band.

A non-linear ALF could be implemented in principle, but defragmentation of the 3.4-3.8GHz band may make it impractical

1.141. In practice, a non-linear ALF for UKB based on opportunity cost could work as follows:

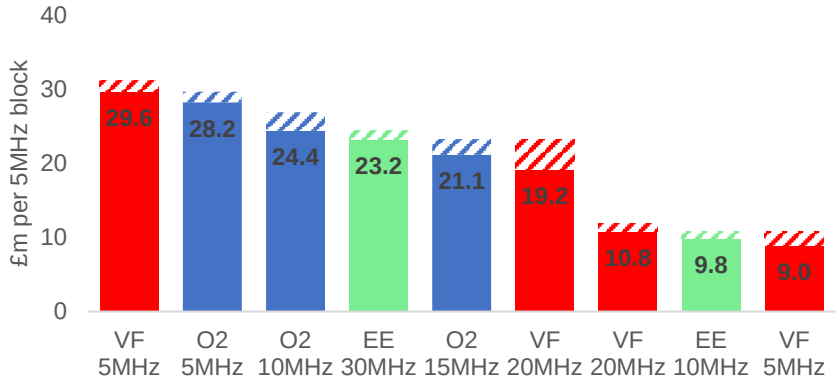
- The ALF function would mirror rivals' highest losing bids for an additional 120MHz of 3.4GHz in the PSSR auction and would not be frequency-specific;
- If Three wanted to trade or return some of its UKB's spectrum, the highest value ALF should be applied first.

<u>The ALF would mirror the excluded bids for additional 3.4GHz from rivals and would not be frequency-specific</u>

1.142. The ALF function could have nine rungs, mirroring the highest losing bids from Three's rivals for an additional 120MHz of 3.4GHz in the 2018 auction (after removing Telefonica's highest bid). The steps of the ALF function are shown in Figure 8.

[42] Para A6.98, https://www.ofcom.org.uk/__data/assets/pdf_file/0030/76926/annexes_1-7.pdf.

Figure 8: The ALF function could mirror rivals' losing bids for additional 3.4GHz



Source: Three's analysis of PSSR bid data.

1.143. UKB's 120MHz holding in the 3.4GHz to 3.6GHz band is held in two separate licences.[43] Given that Ofcom has now aligned the technical conditions for UKB's 3.4GHz and 3.6GHz licences, it would be possible to consolidate them into a single 120MHz licence.

1.144. The UKB licence would then stipulate the total amount of ALF payable for the right to use 120MHz (representing the sum of the diminishing valuations above), converted into an annual payment. There would be no need to map the different levels of the ALF function to specific frequencies within the licence. If Three wanted to trade or return some of its spectrum, it should be able to choose which specific blocks it wanted to release.

<u>If Three wanted to trade or return some of UKB's spectrum to Ofcom, the highest value ALF should be applied first</u>

1.145. If Three were to return some of UKB's spectrum to Ofcom or trade it with some to another user, Ofcom would issue a new licence to Three (and to the other operator in the latter case).

1.146. In both cases, the highest ALFs would be removed or transferred first to preserve the correct efficiency incentives. For instance, assume that Three's marginal value for the last 5MHz block falls to £29m, i.e. just below the highest rung of the ALF function of £29.6m (representing Vodafone's highest losing bid for extra 3.4GHz).

1.147. In this example, Three would only be willing to return 5MHz to Ofcom if doing so reduced its total ALF bill by £29.6m. If instead Three's ALF bill was reduced by a smaller amount, Three would inefficiently retain the 5MHz block despite there being a higher-value user for it.

1.148. Therefore, to ensure Three faces the correct incentives to only hold spectrum blocks for which it is the highest-value user, Three's ALF bill

[43] https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/mobile-wireless-broadband/below-5ghz

must reduce starting with the highest ALFs. For example, if UKB were to return 10MHz back to Ofcom, it ALF bill would be reduced by the annual equivalent of £57.8m (the two highest marginal valuations of £29.6m for the first 5MHz and £28.2m for the second 5MHz).

Defragmentation of the 3.4-3.8GHz band could make a non-linear ALF impractical

1.149. As Ofcom is aware, there is a common desire in the industry to defragment the 3.4-3.8 GHz band. Ofcom has suggested in its recent consultation on the 3.6GHz auction that this objective might be achieved through spectrum trading during or after the auction.

1.150. Three has previously indicated to Ofcom that we are open to the idea of trading. We believe, however, that there may be significant benefits if trades were concluded earlier. In particular, it may allow earlier deployment of frequency-specific 5G equipment and/or may avoid wasting costs required in changing equipment.

1.151. We have therefore discussed with Ofcom the possibility of engaging in a trading process before the auction. Three has engaged a specialist consultancy to design and implement a trading process and to act as intermediary, with a view to completing trades as soon as practicable.

1.152. Although we obviously do not know the preferences of other MNOs, we can see that the optimal outcome may require several trades in the 3.4-3.6GHz band. ✂

Figure 9: ✂

✂

Source: Three.

1.153. ✂ it is not clear that the mechanism described above (whereby Three's ALF bill would be reduced when trading, starting with the highest ALF) would be practical.

The next best option is to implement a linear ALF based on £19.1m per block.

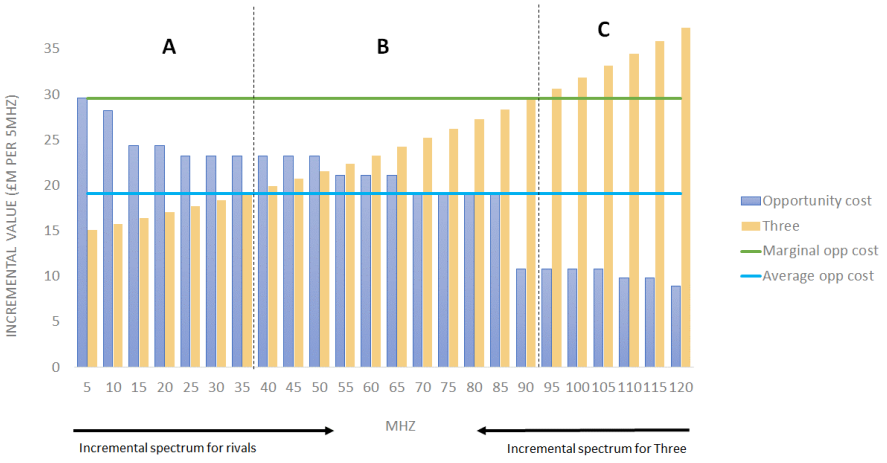
1.154. If a non-linear ALF cannot be made to work for practical reasons, the correct level of a uniform ALF would be £19.1m per block, reflecting the (weighted) average opportunity cost of UKB's spectrum, not marginal opportunity cost.

1.155. It is straightforward to show that a linear ALF set at £19.1m per block would be better at promoting optimal use than a linear ALF based on marginal opportunity cost (e.g. £29.6m per block).

A linear ALF based on average opportunity cost is better at promoting optimal use than a linear ALF based on marginal opportunity cost

1.156. Assume that Three's incremental values for UKB's spectrum decreased over time as shown in Figure 10, such that Three was no longer the highest value user for 50MHz of its spectrum.

Figure 10: Efficiency of average vs marginal opportunity cost



1.157. Figure 8 is divided in three sections. In Sections A and B, the higher ALF (based on marginal opportunity cost) leads to Three returning most of UKB's spectrum to Ofcom. The ALF exceeds Three's values and, because it is set at the level of the highest losing bid absent Three, there is no willing buyer for that spectrum (except perhaps the first block) at that level.

1.158. By contrast, if the ALF is set at the lower level determined by average opportunity cost, in Section A Three has an incentive to efficiently trade 35MHz with higher value users (who are willing buyers at that level of ALF). In Section B Three trades a further 15MHz with higher value

users and efficiently retains 40MHz for which it remains the highest value user.

1.159. In Section C, Three's values for 30MHz are above both ALFs, so Three has the correct incentive to retain the 30MHz (for which it is the highest value user) with either ALF.

1.160. This result can be generalised to show that average opportunity cost dominates marginal opportunity cost, for any assumed drop in Three's values from their current level. Ofcom should therefore set a uniform ALF based on £19.1m per 5MHz block, reflecting the average (rather than the marginal) opportunity cost of UKB's spectrum to other users.

1.161. As discussed in Section 5, an opportunity-cost based ALF would be fully consistent with economic theory and the principles of the SRSP, and would replicate the value that UKB's spectrum would achieve in a competitive auction. It would extract the minimum amount of revenue from Three (£458m in total) consistent with achieving optimal use of UKB's spectrum.

7. Ofcom should account for a 5G premium to properly estimate the opportunity cost of UKB's spectrum.

Executive Summary

1.162. The previous sections argue that Ofcom should produce the best estimate that can be determined of the opportunity cost of UKB's 120 MHz of spectrum. There is, however, one complication in that Ofcom is offering 3.4GHz and 3.6GHz in two sequential auctions, so bidders may have taken the possibility of buying additional 3.6GHz into account when bidding for 3.4GHz.

1.163. The Power Auctions report considers how best to measure opportunity cost based on the PSSR data in this case. Consistent with the approach taken in previous sections, the report shows that, if the 3.6GHz auction happened immediately after the 3.4GHz one, the sum of the highest losing bids for 120MHz in the PSSR auction (starting from the 20MHz won by Three) would give the best measure of the opportunity cost of UKB's spectrum.

1.164. However, because the auctions are being held two years apart, bidders will have a temporal preference for winning spectrum in the first auction, to gain a first-mover advantage (or not being left behind) in 5G. All else the same, a bidder's valuation in the second auction would be reduced by a discount factor.

1.165. Based on modelling from Frontier Economics, Power Auctions have conservatively applied a discount factor of between 0.9 and 0.93 to the lump-sum value derived from the PSSR auction. This reduces the lump-sum value of UKB's spectrum from £19.1m to a range of £17.2 – £17.8m per 5MHz block.

The sum of the highest losing bids for 120MHz in the 3.4GHz auction provides the best measure of the opportunity cost of UKB's spectrum

1.166. Ofcom is offering 3.4GHz and 3.6GHz in two sequential auctions. This means that bidders' valuations for spectrum in either auction may be inter-related. For instance, bidders may have taken the possibility of buying additional 3.6GHz into account when bidding for 3.4GHz. A bidders' valuation for 3.6GHz could depend on the amount of 3.4GHz won in the first auction. Because 3.4GHz and 3.6GHz are substitutes,

the value of 3.6GHz to an MNO may fall the more 3.4GHz it wins in the first auction.

1.167. This raises the question of how best to estimate the opportunity cost of UKB's spectrum based on the bid data from the PSSR auction. In principle, the correct approach to replicate would be to:

- Run a single CCA auction for the total supply of 390MHz of 3.4 GHz and 3.6 GHz spectrum, with Three only allowed to bid on packages including at least 120 MHz and all other bidders allowed to bid for the remaining 270MHz;
- Determine the winning bids (Winner Determination Problem, WDP) by calculating the value-maximizing combination of bids subject to the constraint that Three must win at least 120 MHz;
- The opportunity cost of each bidder would be determined by: (a) solving a second WDP in which the bidder is "absent" (and, in Three's case, the constraint on minimum winnings is removed); and b) calculating the value difference between the WDP with the given bidder present and the given bidder absent.

1.168. If Three won 120MHz in this hypothetical auction, its opportunity costs would be the lump-sum value of UKB's spectrum. If Three won more spectrum, its auction price would include the opportunity cost of both UKB's 120MHz and the newly-acquired spectrum. The lump-sum value for 120MHz of UKB spectrum could be found by subtracting Three's payment for the newly-acquired blocks from its overall opportunity costs.

1.169. This approach would determine the true opportunity cost of UKB's spectrum, and would ensure that the determined lump-sum value replicates what Three would pay in a competitive auction—and not a greater amount. However, in the present case the situation differs from this idealized exercise in four key respects:

- The 3.4GHz auction did not include UKB's 120MHz holding - this can be accounted for by taking the sum of the highest losing bids for 3.4GHz from Three's rivals (starting after the highest losing bids for 20MHz and continuing for the next 120MHz);
- Second, the actual auction was an SMRA, not a CCA. To account for this, Power Auctions have developed an equilibrium model that compares the opportunity cost based on bidders' equilibrium bids with the true opportunity cost based on the bidders' real values;
- Third, as discussed above, the 3.4GHz and 3.6GHz is being awarded sequentially. Power Auctions have developed the model to compare the payment in the single combined auction with the sum of the payments in two sequential auctions. This establishes that each of the individual payments is greater than the clearing price in the combined auction;
- Fourth, the 3.6GHz auction will occur a full two years after the 3.4GHz auction. Bidders will have a temporal preference for winning spectrum in the first auction, to gain a first-mover

advantage (or not being left behind) in 5G. This can be accounted for by applying a discount factor to the lump-sum value derived solely from the first auction.

1.170. Based on this analysis, the Power Auctions report proposes the methodology outlined in previous sections to calculate the opportunity cost to other users of UKB's spectrum, namely:

- Remove first all of Three's bids from the PSSR auction (thereby converting the highest 20MHz of other users' losing bids into winning bids);
- Second, sum the highest 120MHz of other bidders' losing bids in the PSSR auction.

1.171. The Power Auctions model confirms that this is a sound methodology. When applied to the model, it replicates the exact opportunity cost that calculated, based on bidders' true demand curves. The sum of the highest losing bids of rivals in the first sequential auction coincides exactly with the true opportunity cost of the prior holdings to the other users in the model.

The value of 3.6GHz spectrum should be discounted

1.172. Ofcom proposes to set the same level of ALFs across all of UKB's 120MHz holding, based on the highest losing bid from a bidder other than Three in the PSSR auction.

1.173. Ofcom has implicitly assumed that the 3.4GHz and 3.6GHz auction prices will be the same. However, the 3.6GHz auction will occur around two years after the 3.4GHz spectrum was auctioned. There is a strong argument that the 3.6GHz auction prices will be materially lower than those for 3.4GHz due to the "5G premium".

1.174. The other MNOs all won 3.4GHz spectrum in the 2018 PSSR auction, and have referenced this as part of their marketing. All MNOs have now publicly announced their 5G launch plans in 2019. 5G launch would not have been possible without 3.4GHz.

1.175. Although 3.4GHz and 3.6GHz have the same long-term value, Three's rivals will not be indifferent between winning 3.4GHz in 2018 and winning 3.6GHz in 2020 at the same auction price. The long-term market value of 3.4 and 3.6GHz spectrum, evaluated at mid-year 2020, is the same. However, the value of 3.4GHz evaluated at mid-year 2018 exceeds the value of 3.6GHz evaluated at mid-year 2020.

1.176. In short, auction prices for the 3.4GHz can be expected to be higher than auction prices for the 3.6GHz because of the existence of the 5G premium for being the first-mover in offering 5G services. All MNOs will have reasonably priced in their 3.4GHz bids the ability to attract and retain more customers.

1.177. These effects are highly material, as the effects are not only short-term, but also have a long-term effect.

Frontier Economics estimates that 3.4GHz auction prices could have been inflated by 10-15% compared to those in the upcoming 3.6GHz auction

1.178. Frontier Economics has modelled the total value to an MNO of holding 5G under two scenarios to estimate the portion of the value that depends on when the 5G spectrum was acquired. The two scenarios are:

- Scenario 1: The MNO was able to acquire 3.4GHz spectrum in 2018; and
- Scenario 2: The MNO was not able to acquire 5G spectrum until 2020 (as Ofcom has indicated that the auction will not be before Spring 2020).

1.179. Frontier Economics has assumed that an MNO would not be able to offer 5G services (before the 3.6GHz auction) without 3.4GHz spectrum. Therefore, the premium that an MNO was willing to pay for 3.4GHz spectrum in 2018, compared to waiting until 2020 for the 3.6GHz auction, can be estimated by the incremental profits the MNO would earn by having the 3.4GHz spectrum from 2018.

1.180. It models these higher incremental profits by assuming that MNOs can earn higher margins on 5G services than from 4G services because:

- MNOs could charge a higher price for 5G services (or MNOs would not be able to price 4G services at current levels as 5G would become the new normal); and/or
- 5G technologies are more efficient and so capacity can be offered at a lower incremental cost.

1.181. Frontier Economics assumes that this premium disappears over time. It assumes that potential customers first decide whether they will take up a 5G service and then choose which MNO to purchase the service from.

1.182. In scenario 1 above, the model assumes that all MNOs attain the same market share for 5G customers and non-5G customers. However, scenario 2 assumes that any operators that face a delay in acquiring 5G spectrum achieve a lower market share (below its current overall level), following a path of several years to reach this point. This reflects the first-mover advantage of offering 5G services.

1.183. An operator without 5G spectrum in the period between the 3.4GHz and 3.6GHz spectrum auctions has a lower market share and a lower variable margin per customer, on average. Frontier Economics uses a 15-year NPV (net present value) calculation on the variable margins under scenarios 1 and 2 to estimate the extent to which 3.6GHz auction prices will be lower than 3.4GHz prices.

1.184. Ofcom should account for the fact that 3.6GHz auction prices are likely to be lower. Setting ALFs based purely on bid data from the PSSR auction will overestimate the opportunity cost of UKB's prior 120MHz holding.

Ofcom should account for a 5G premium to properly estimate the opportunity cost of UKB's spectrum. continued