Annex 1

Responding to this consultation

How to respond

A1.1 Ofcom invites written views and comments on the issues raised in this document, to be made **by 5pm on Fri 26 September 2014**.

A1.2 Ofcom strongly prefers to receive responses using the online web form at http://stakeholders.ofcom.org.uk/consultations/annual-licence-fees-900-MHz-1800-MHz/, as this helps us to process the responses quickly and efficiently. We would also be grateful if you could assist us by completing a response cover sheet (see Annex 3), to indicate whether or not there are confidentiality issues. This response coversheet is incorporated into the online web form questionnaire.

A1.3 For larger consultation responses - particularly those with supporting charts, tables or other data - please email ALF@ofcom.org.uk attaching your response in Microsoft Word format, together with a consultation response coversheet.

A1.4 Responses may alternatively be posted or faxed to the address below, marked with the title of the consultation.

Robert Emson
3rd Floor
Spectrum Policy Group
Riverside House
2A Southwark Bridge Road
London SE1 9HA

Note that we do not need a hard copy in addition to an electronic version. Ofcom will acknowledge receipt of responses if they are submitted using the online web form but not otherwise.

A1.5 It would be helpful if your response could include direct answers to the questions asked in this document, which are listed together at Annex 4. It would also help if you can explain why you hold your views and how Ofcom's proposals would impact on you.

Further information

A1.6 If you want to discuss the issues and questions raised in this consultation, or need advice on the appropriate form of response, please contact Alan McNaboe on 020 7783 4522.

Confidentiality

A1.7 We believe it is important for everyone interested in an issue to see the views expressed by consultation respondents. We will therefore usually publish all responses on our website, www.ofcom.org.uk, ideally on receipt. If you think your response should be kept confidential, can you please specify what part or whether all of your response should be kept confidential, and specify why. Please also place such parts in a separate annex.

A1.8 If someone asks us to keep part or all of a response confidential, we will treat this request seriously and will try to respect this. But sometimes we will need to publish all responses, including those that are marked as confidential, in order to meet legal obligations.

A1.9 Please also note that copyright and all other intellectual property in responses will be assumed to be licensed to Ofcom to use. Ofcom's approach on intellectual property rights is explained further on its website at http://www.ofcom.org.uk/terms-of-use/

Next steps

A1.10 Following the end of the consultation period, and depending on our consideration of the responses to this consultation, we expect to publish our decision around the end of the year.

A1.11 Please note that you can register to receive free mail Updates alerting you to the publications of relevant Ofcom documents. For more details please see: http://www.ofcom.org.uk/email-updates/

Ofcom's consultation processes

A1.12 Ofcom seeks to ensure that responding to a consultation is easy as possible. For more information please see our consultation principles in Annex 2.

A1.13 If you have any comments or suggestions on how Ofcom conducts its consultations, please call our consultation helpdesk on 020 7981 3003 or e-mail us at consult@ofcom.org.uk . We would particularly welcome thoughts on how Ofcom could more effectively seek the views of those groups or individuals, such as small businesses or particular types of residential consumers, who are less likely to give their opinions through a formal consultation.

A1.14 If you would like to discuss these issues or Ofcom's consultation processes more generally you can alternatively contact Graham Howell, Secretary to the Corporation, who is Ofcom's consultation champion:

Graham Howell
Ofcom
Riverside House
2a Southwark Bridge Road
London SE1 9HA

Tel: 020 7981 3601

Email Graham.Howell@ofcom.org.uk

Annex 2

Ofcom's consultation principles

A2.1 Ofcom has published the following seven principles that it will follow for each public written consultation:

Before the consultation

A2.2 Where possible, we will hold informal talks with people and organisations before announcing a big consultation to find out whether we are thinking in the right direction. If we do not have enough time to do this, we will hold an open meeting to explain our proposals shortly after announcing the consultation.

During the consultation

A2.3 We will be clear about who we are consulting, why, on what questions and for how long.

A2.4 We will make the consultation document as short and simple as possible with a summary of no more than two pages. We will try to make it as easy as possible to give us a written response. If the consultation is complicated, we may provide a shortened Plain English Guide for smaller organisations or individuals who would otherwise not be able to spare the time to share their views.

A2.5 We will consult for up to 10 weeks depending on the potential impact of our proposals.

A2.6 A person within Ofcom will be in charge of making sure we follow our own guidelines and reach out to the largest number of people and organisations interested in the outcome of our decisions. Ofcom's 'Consultation Champion' will also be the main person to contact with views on the way we run our consultations.

A2.7 If we are not able to follow one of these principles, we will explain why.

After the consultation

A2.8 We think it is important for everyone interested in an issue to see the views of others during a consultation. We would usually publish all the responses we have received on our website. In our statement, we will give reasons for our decisions and will give an account of how the views of those concerned helped shape those decisions.

Annex 3

Consultation response cover sheet

A3.1 In the interests of transparency and good regulatory practice, we will publish all consultation responses in full on our website, www.ofcom.org.uk.

A3.2 We have produced a coversheet for responses (see below) and would be very grateful if you could send one with your response (this is incorporated into the online web form if you respond in this way). This will speed up our processing of responses, and help to maintain confidentiality where appropriate.

A3.3 The quality of consultation can be enhanced by publishing responses before the consultation period closes. In particular, this can help those individuals and organisations with limited resources or familiarity with the issues to respond in a more informed way. Therefore Ofcom would encourage respondents to complete their coversheet in a way that allows Ofcom to publish their responses upon receipt, rather than waiting until the consultation period has ended.

A3.4 We strongly prefer to receive responses via the online web form which incorporates the coversheet. If you are responding via email, post or fax you can download an electronic copy of this coversheet in Word or RTF format from the 'Consultations' section of our website at http://stakeholders.ofcom.org.uk/consultations/consultation-response-coversheet/.

A3.5 Please put any parts of your response you consider should be kept confidential in a separate annex to your response and include your reasons why this part of your response should not be published. This can include information such as your personal background and experience. If you want your name, address, other contact details, or job title to remain confidential, please provide them in your cover sheet only, so that we don't have to edit your response.

Cover sheet for response to an Ofcom consultation

BASIC DETAILS

Consultation title:

To (Ofcom contact):

Name of respondent:

Representing (self or organisation/s):

Address (if not received by email):

CONFIDENTIALITY

Please tick below what part of your response you consider is confidential, giving your reasons why

Nothing	☐	Name/contact details/job title	☐
Whole response	☐	Organisation	☐
Part of the response	☐	If there is no separate annex, which parts?	

If you want part of your response, your name or your organisation not to be published, can Ofcom still publish a reference to the contents of your response (including, for any confidential parts, a general summary that does not disclose the specific information or enable you to be identified)?

DECLARATION

I confirm that the correspondence supplied with this cover sheet is a formal consultation response that Ofcom can publish. However, in supplying this response, I understand that Ofcom may need to publish all responses, including those which are marked as confidential, in order to meet legal obligations. If I have sent my response by email, Ofcom can disregard any standard e-mail text about not disclosing email contents and attachments.

Ofcom seeks to publish responses on receipt. If your response is non-confidential (in whole or in part), and you would prefer us to publish your response only once the consultation has ended, please tick here. ☐

Name   Signed (if hard copy)

Annex 4

Consultation questions

Question 1. Do you have any comments on our proposal to base our assessment of the market value of 800 MHz and 2.6 GHz spectrum in the UK on an analysis of bids by the marginal bidders in the UK 4G auction?

Question 2. Do you have any comments on our revised assessment of the lump sum values of 900 MHz spectrum and 1800 MHz spectrum?

Question 3. Do you have any comments on our revised approach to converting our estimate of the lump-sum value of the spectrum into annual fees using a discount rate based on the cost of debt?

Question 4. Do you have any further comments on our revised proposals?

Annex 5

Asymmetry of risks to efficient use of spectrum

Introduction

A5.1 In implementing the Government Direction to revise fees to reflect full market value, we have considered the impact in those areas where we are exercising discretion and are exercising regulatory judgement in light of the evidence available to us and our statutory duties. In particular, we have assessed whether there is an asymmetric risk of inefficient use of spectrum from inadvertently setting ALFs below or above market value. This annex sets out in further detail our revised assessment of the asymmetry of risks to spectrum efficiency and supports Section 1. First, it covers our position in the October 2013 consultation and stakeholder responses. Then, we discuss our assessment of the risks to efficiency, in particular the efficient use of spectrum from inadvertently setting ALFs below, or above, market value. This annex does not consider or apply to the question of whether to revise fees to reflect full market value, since (as set out in Section 1) that policy decision has already been taken by the Government in making the Government Direction.

October 2013 consultation and stakeholder responses

A5.2 Prior to our October 2013 consultation, some licence holders argued that setting ALFs above market value could lead to inefficient use of spectrum, and that this risk was greater than any risk of inefficiency from setting ALFs below market value. They argued that, in light of this asymmetry, and the uncertainty as to the true market value of the licences, we should set ALFs conservatively.

A5.3 We set out our provisional view of this matter in Annex 9 of the October 2013 consultation, which was that:

a) There were risks in either direction: on one hand that inadvertently setting ALFs above the market value could trigger an inefficient return of spectrum, and on the other that if ALFs were inadvertently set below market value, this could allow inefficient holding or use of spectrum to persist.

b) We recognised the greater risk might be in setting ALFs too high. However, in practice we considered this was substantially mitigated by the fact that our approach to setting ALFs was based on the opportunity cost of the licences, rather than their value to licensees. For this reason we expected that the value to licensees would typically be considerably higher than ALFs (suggesting that the circumstances which would give rise to a risk of inefficiency from ALFs being set too high – i.e. a return of spectrum – would be relatively rare).

c) We considered that there was some risk that setting ALFs below or above market value would distort efficient use of the spectrum and investment decisions, but that this risk did not appear to be asymmetric in either direction.

d) We provisionally concluded that, on balance, it was not appropriate to set ALFs either below or above the levels implied by our best estimates of market value for reasons of spectrum efficiency.

e) We also noted that:

i) To the extent that ALFs affected consumer prices, there was a risk in setting them too high or too low, but that this risk did not appear to be asymmetric in either direction.

ii) Likewise, it was not clear that there was material asymmetry, in the effects on licensees' choices between spectrum and network investment, in setting ALFs too low or too high.

iii) It was not appropriate to make a downward adjustment to allow for the possibility of falling spectrum values over time.

A5.4 In response to our consultation, licence-holders made a range of points relating to our position on asymmetry of risk. In particular they argued that:

a) Allocations of spectrum are likely to be optimal absent ALF;

b) Spectrum trading is likely to mitigate any inefficiencies associated with existing allocations;

c) The cost of spectrum lying fallow is high;

d) There are reasons to believe that the relative difference between private values and market values for incremental 900/1800 MHz spectrum will be much smaller than that observed between packages of 800 and 2.6 GHz spectrum in the auction;

e) ALFs risk having an undue effect on consumer prices; and

f) ALFs risk having an undue effect on investment.

A5.5 The following discussion sets out our current view, having regard to the arguments set out by stakeholders.

Risks to spectrum efficiency from setting ALFs below market value

A5.6 The risk from inadvertently setting ALFs too low is illustrated in Figure A5.1. The licence holder's marginal valuation is shown as first increasing (due to synergies) and then declining as its spectrum holdings increase.[1] The market value of spectrum is the highest value that an alternative user would have for the spectrum - for simplicity, this is shown as a single value for a marginal increment of spectrum. Four regions are denoted on the horizontal axis and labelled A, B, C and D:

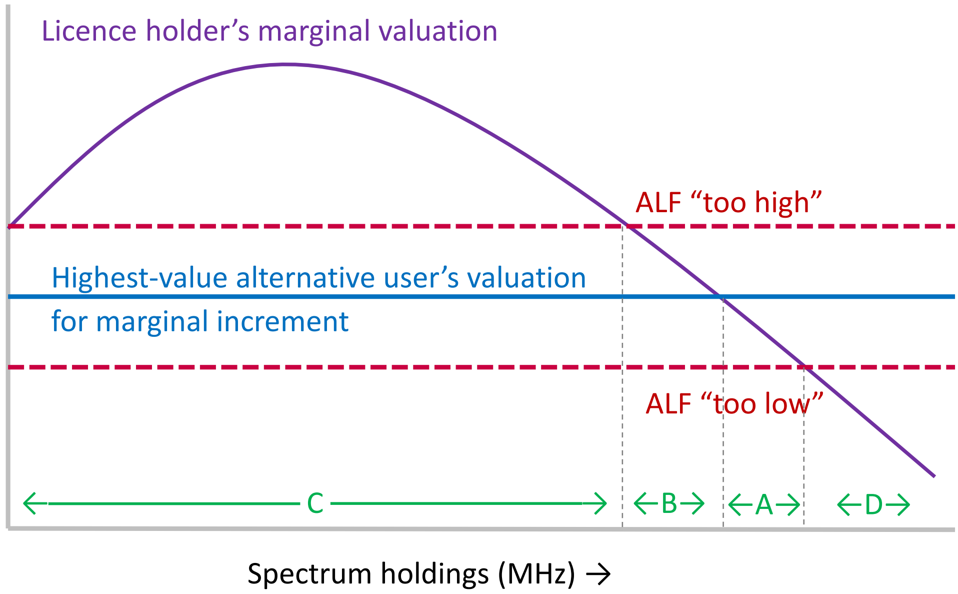
- A and D are ranges of spectrum over which the licence holder's marginal valuation is lower than market value, the value of the highest-value alternative user, and hence there would be an efficiency gain from a change of user.

[1] This is a simplified illustration as there could be multiple spectrum holdings that give rise to synergies (such as 2x20 MHz as well as 2x10 MHz), in which case the marginal valuation curve may have more than one upward-sloping portion.

- B and C are the ranges of spectrum over which the licence holder is the highest-value user and so a change of user would be inefficient.

A5.7 If the situation of ALF "too low" prevails, then the current licence holder may be willing to hold spectrum in the range A, even though its valuation of the spectrum is below the market value for this spectrum, which is an inefficient outcome.

Figure A5.1: Illustration of asymmetry of risk from setting ALF too low or too high



A5.8 Stakeholders raised arguments as to why setting ALFs below market value is unlikely to lead to substantial inefficiencies of the kind characterised above. They argued that:

- There is likely to be little scope for improvements in current allocations, as operators have an incentive to make efficient use of their spectrum holdings. In particular, they argued that operators have an incentive to use spectrum efficiently to minimise the amount of spectrum they need to acquire in future auctions.

- The ability to trade spectrum gives operators an incentive to hold spectrum efficiently.

A5.9 We consider each of these issues in turn.

Incentive to use spectrum holdings efficiently

A5.10 Stakeholders argued that current licence holders are likely to be the highest-value users of spectrum they hold, in particular because they have optimised their networks based on these spectrum holdings. We agree that this may be the case, but it may also be the case that some spectrum may be held by operators who are not the highest-value users of at least a proportion of their holdings in the 900 MHz or 1800 MHz bands. Furthermore, valuations of different operators can change over time in different ways.[2]

A5.11 Stakeholders also argued that operators have access only to a fixed amount of spectrum (at least in the short term) so they have an incentive to put spectrum to the most efficient use they can. Again, we agree this may be the case, but this does not rule out the possibility that another operator would be a higher-value user of the spectrum.

A5.12 Stakeholders argued that operators know that they will need more spectrum in future and so, even if ALF were zero, they would have a strong incentive to make efficient use of their existing spectrum to avoid increasing the amount of new spectrum they will need to acquire in expensive auctions. We recognise there are arguments as to why operators may be incentivised to make the most efficient use possible of spectrum they currently hold. However, this does not necessarily rule out the possibility that they may not be the highest-value users of spectrum that they hold (i.e. even if they are incentivised to maximise the value of their spectrum use).

A5.13 It could further be argued that as more spectrum becomes available, if some operators have a higher value for incremental spectrum than others, they will have an incentive to bid more aggressively for it in auctions. Other things equal this would tend to mitigate any inefficient allocation of spectrum. For example, if before an auction operator 1 holds spectrum for which it has a low marginal value, while operator 2 has a higher marginal value of spectrum, then 2 will be likely to bid more aggressively and acquire more spectrum in the auction. This effect could reduce the scope for ALF to lead to efficiency-improving reallocation of spectrum, suggesting we should pay more attention to the cost of fallow spectrum described below. We consider this argument has merit. However, there are some reasons why it may not lead to an efficient outcome:

- We consider that demand for mobile services is likely to grow, and we have identified spectrum bands which could be made available to help meet this demand. However, it is possible that demand growth may be slower than expected, which would reduce the prospect of more spectrum being made available to mobile operators (beyond the 2.3 GHz, 3.4 GHz and 700 MHz bands).[3] In this case the prospect for market growth to correct inefficient allocation would be more limited.

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[2] The value of a spectrum licence to an operator depends on a range of factors, including the portfolio of licences held by that operator, its network configuration (e.g. the relative density of high-power and small cells in urban, suburban and rural locations) and the ecosystem available for the spectrum licences it holds (such as the number of new devices that are LTE900 compatible). We recognise that operators will generally seek to configure their networks to exploit the spectrum licences they hold, and to bid for new licences which are more complementary to their networks and portfolios of licences. However, as the market, technology and regulatory environment evolves, it is possible that the current holder of a licence, even if incentivised to use that licence as efficiently as it can, will not be the most efficient user of the spectrum.

[3] In our Mobile Data Strategy Statement, 28 May 2014, (paragraphs 1.4 and 1.5) we note that: "We are already planning to award additional spectrum for mobile data services in the 2.3 GHz and 3.4 GHz bands and today (28 May 2014) set out our proposals for enabling the 700 MHz band to be used for mobile services. Beyond these bands, it is possible that there will be limited benefit in making more spectrum available for mobile data services if demand can be met at lower cost through technology and network improvements. However, if further major changes to spectrum use do turn

- The argument assumes that new spectrum which may become available is a close substitute for existing holdings, and ALF spectrum bands in particular. The next award is likely to be for spectrum in the 2.3 GHz and 3.4 GHz bands, and these are not expected to be a close substitute for ALF spectrum bands. The 700 MHz band may be a closer substitute especially for the 900 MHz band, but will not come available for another six to eight years. On the other hand it could be argued that the 4G auction will already have tended to mitigate any inefficiencies in spectrum holdings, to the extent that 800 MHz and 2.6 GHz are substitutes for the ALF bands.

- More generally, major spectrum awards are relatively infrequent, and following a 700 MHz award there may be little scope for further sub-1 GHz spectrum to be awarded, so there could still be scope for ALF to lead to efficiency-improving reallocation of spectrum by encouraging licence holders to review their spectrum holdings more regularly.

A5.14 Overall, we remain of the view that there is a risk that efficiency-improving changes of licensees will not occur if ALFs is inadvertently set too low. While licensees might have an incentive to use the spectrum they hold as efficiently as possible, this does not necessarily imply that they will be the most efficient users of that spectrum. However, we agree that at least in principle future spectrum releases will provide some opportunity for inefficient allocations of spectrum to be mitigated.[4]

Spectrum trading

A5.15 In principle, operators have an incentive to trade spectrum if there is a higher-value user. This will tend to reduce the risk that they will hold spectrum inefficiently (i.e. when they are not the highest-value user). However, we consider that operators may be less responsive to foregone receipts from trading spectrum than they would be if faced with a direct cost of ALF.

A5.16 Direct costs such as ALF are visible to shareholders in company accounts. In contrast, it is not clear that the opportunity cost of holding licences – in this context, the potential receipts that could be obtained by trading the spectrum - is visible to shareholders in the same way. While the business may be aware of the opportunity cost of holding spectrum rights which it could otherwise trade to rivals, it may be less responsive to these opportunity costs than to the direct cost of an ALF.

A5.17 The presence of this distinction between foregone receipts and direct costs appears to be borne out by MNOs' accounts of how the imposition of ALF will affect them. Consultation responses have set out in some detail the pressure that managers will be under to respond to an increase in ALFs. For example:

- [✂]

- [✂]

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out to be beneficial, they can require several years of preparation, for example to secure the necessary international agreements." http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/statement.pdf

[4] We have also considered whether the value of current spectrum holdings may have fallen recently due to the prospect of future spectrum awards – see Section 1 and Annex 9.

- [✂]

A5.18 While these responses have focused on pressures to increase prices or delay investment in response to ALF, rather than trading, such pressures would not arise if the opportunity cost of foregone receipts were already fully reflected in operators' decisions.

A5.19 We therefore consider that, even though ALF spectrum is tradable, operators may be less responsive to foregone receipts from trading spectrum than they would be if faced with a direct cost of ALF.

Risks to spectrum efficiency from setting ALFs above market value

A5.20 If ALFs are inadvertently set above market value:

a) Licence holders may have a private value for some spectrum which is sufficiently above market value also to be above the level of ALF. They will continue to hold this spectrum, which is the efficient outcome as they are the highest-value users. Returning to Figure A5.1, even if the ALF "too high" prevails, the current licence holder will be willing to hold spectrum in the range C, despite ALF being set above market value for this spectrum.

b) Licence holders may hold some spectrum for which the ALF exceeds their private value, represented by the ranges labelled A, D and B in Figure A5.1. There is an important difference between these two ranges:

   i) In range B the licence holder has an incentive to relinquish this spectrum even though it is the highest-value user. This spectrum should then be reassigned to the highest-value user, which would be the original licensee, at a lower price.

   ii) In ranges A and D the licence holder is not the highest-value user. Hence, relinquishment by the licence holder should lead to an efficiency gain.

A5.21 If there were no costs associated with changing licensee, there would not be any inefficiency from (initially) setting ALFs above market value. However, respondents argued that there is a substantial risk of inefficiency from valuable spectrum lying fallow before it is reassigned through a regulatory process. Spectrum might also be underused while the incumbent licensee migrated traffic to other bands, and then while the new licensee migrated traffic onto the band.

A5.22 We recognise this risk of inefficiency from spectrum lying fallow may be greater than the potential efficiency gain from reallocation. This is likely to be the case in range B in Figure A5.1 as there is no offsetting efficiency gain from relinquishment by the licence holder. However we consider this risk is potentially mitigated by a number of factors, in particular:

a) Our approach to setting ALFs is largely based on auction prices or highest losing bids, which reflect the opportunity cost of the licences, rather than their private value to licensees. The outcome of the 4G auction was that private values of spectrum greatly exceeded the auction price (determined by the highest losing bidder). For example, Telefónica acquired lot A2 (800 MHz with coverage obligation) for £550m, having bid £1.22bn. This suggests that a large proportion of operators' spectrum holdings may be "inframarginal" spectrum which they would not relinquish even at a relatively high ALF (i.e. in the range C in Figure A5.1 above), rather than “marginal” spectrum (in ranges A and B) which they might relinquish if ALF was at or above market value (illustrated by ranges A and B respectively). We therefore consider that the risk of inefficiency from inadvertently setting ALFs too high is mitigated by our approach to setting ALFs.

b) The cost of fallow spectrum only arises in circumstances where the current licence holder has responded to ALF by opting to relinquish spectrum. Where relinquishment occurs, while it is possible that the current licence holder is the highest-value user, it is also possible that it is not. In other words, if spectrum is relinquished (and a “fallow inefficiency” is incurred) this could be because it is in range A in Figure A5.1. If so, any inefficiency cost from spectrum lying fallow will need to be set against the efficiency gain from transferring spectrum to a higher-value user.

c) If the ALF is below market value but above the current licence holder’s value (this is the range D to the right of A in Figure A5.1, it may prefer to trade this spectrum (and obtain some receipts as well as avoiding ALF) rather than simply returning the spectrum to the regulator (and only avoiding ALF). This will tend to speed up the reallocation process.

A5.23 In summary, we recognise there is a risk of inefficiency arising from spectrum lying fallow if ALFs are inadvertently set too high. There are some factors which may reduce this risk: (a) our approach to setting ALF; (b) the fact that this risk only arises when spectrum is relinquished (giving rise to a potential efficiency gain in some circumstances); and (c) the scope for operators to trade spectrum.

A5.24 However, on balance we consider that the risk of inefficiency from spectrum lying fallow if ALF is set too high may be greater than the risk that efficiency-improving changes of licensees will not occur if ALF is set too low.

Risk to efficiency through effect of ALF on consumer prices if ALF is set above or below market value

A5.25 In an efficient market, consumer prices will reflect the resource costs of inputs to supply goods and services, and to the extent that consumer demand reflects those prices, it will appropriately reflect the cost of supply.

A5.26 The level of ALFs could have an effect on downstream consumer prices for mobile services, and there is a risk of inefficiency from setting ALFs either above or below market value.

- If ALFs were set above market value, and if operators could pass on this cost through inflated consumer prices, the result of these inflated prices could be to artificially depress the growth in mobile traffic.

- If, as described above, operators are not fully responsive to the opportunity cost of spectrum, then, with ALFs set below market value, operators may tend to set consumer prices which do not reflect the full resource cost of providing their services. If instead prices already reflected the opportunity cost of holding spectrum, then setting ALF below market value would not lead to inefficiency, and the only risk to inefficiency of this kind would be in setting ALFs above market value. However, the responses to the October 2013 consultation indicate that operators' prices are not independent of the level of ALF when fees are below market value (as they are currently).

A5.27 On balance, therefore, we consider the risk to efficiency through the effects on consumer prices if ALF is set too low or too high to be broadly symmetric.

Risk to efficiency through effect of ALF on investment if ALF is set above or below market value

A5.28 In general, investment decisions should be informed by the true cost of inputs. In their responses mobile operators (in particular EE) described how the increased costs associated with ALFs will reduce funds available for investment in the short term. It is possible that a firm which has to pay ALFs will have its capital budget reduced by its shareholders. In some cases, this may prevent the firm from making investments which would be economically worthwhile or, more likely, affect the timing of a profitable investment through deferring it. However, this does not necessarily give rise to longer-term inefficiency on which we focus in this annex.

A5.29 As regards specific arguments that there is a risk of inefficient under-investment in the longer term in response to ALFs, in the October 2013 consultation we addressed arguments about regulatory risk associated with perceived asset expropriation and incentives to innovate.[5] We do not consider that stakeholder responses provide a basis to change our views. Therefore, on balance, we consider the risk to efficiency in the longer term through the effect on investment if ALF is set too low or too high to be broadly symmetric.

Summary

A5.30 In summary, our revised analysis, in light of stakeholders' responses, is as follows:

a) If ALFs are inadvertently set below market value, we consider that there is a risk that efficiency-improving changes of licensees will not occur. In particular,

   i) while licensees might have an incentive to use the spectrum they hold as efficiently as possible, this does not necessarily imply that they will be the most efficient users of that spectrum; and

   ii) even though ALF spectrum is tradable, operators may be less responsive to foregone receipts from trading spectrum than they would be if faced with a direct cost of ALF.

b) However, we consider that, at least in principle, future spectrum releases will provide some opportunity for inefficient allocations of spectrum to be mitigated If ALFs are inadvertently set above market value, we recognise there is a risk of inefficiency arising from spectrum lying fallow. However, we consider that there are some factors which may reduce this risk: our approach to setting ALF; the fact that this risk only arises when spectrum is relinquished (giving rise to a potential efficiency gain in some circumstances); and the scope for operators to trade spectrum.

[5] See paragraphs A9.39 to A9.44 of the October 2013 consultation.

c) On balance we consider that the risk of inefficiency from spectrum lying fallow if ALF is set too high may be greater than the risk that efficiency-improving changes of licensees will not occur if ALF is set too low.

d) We consider, on balance, that the risk to efficiency through the effects on consumer prices if ALF is set too low or too high to be broadly symmetric.

e) We also consider, on balance, that the risk to efficiency in the longer term through the effect on investment if ALF is set too low or too high to be broadly symmetric.

Annex 6

UK market values of 800 MHz and 2.6 GHz spectrum for the purpose of ALF: supporting material

Introduction

A6.1 This annex provides supporting material for the analysis of UK market value of the 800 MHz and 2.6 GHz spectrum bands for the purpose of ALF, based on the 4G auction data. It supports Section 2.

A6.2 The annex covers:

- Decomposition of auction prices by band;
- Linear Reference Price (LRP) methodology;
- Additional Spectrum Methodology (ASM);
- Marginal bidder analysis for 800 MHz; and
- DTT co-existence costs.

Decomposition of UK 4G auction prices by band

A6.3 The auction prices in the UK 4G auction were determined for each winner on the basis of the highest losing bids (which could involve bids made by more than one bidder). This is the opportunity cost to other bidders based on the bids made in the auction for the particular package of spectrum acquired by that specific winner.[6] An implication of this approach to derive auction prices is that they can be: (a) non-linear; and (b) non-uniform. By non-linear we mean that, taking the example of a bidder winning a package of two lots of 800 MHz spectrum, the price for the second lot of 800 MHz may be different from the price for the first lot. By non-uniform we mean that for the same amount of spectrum in the same band, prices can be different across winners.

A6.4 In a combinatorial (or package) auction, such as the UK 4G auction, the identification of the highest losing bids may be complicated, because the removal of winning bidder 1 could lead to a significant rearrangement of the packages of the other bidders that would be highest value in the absence of winning bidder 1. A relatively simple case would be if (in the absence of bidder 1) the other winning bidders would just obtain more spectrum than in their winning packages (and/or the bidders who failed to win would obtain some spectrum). If so, the auction price for bidder 1 is the sum of the incremental bid values by those bidders for the larger packages compared to their winning packages. A more complex case would be if some aspects of the packages of the other bidders would be smaller as well as

[6] Also known as Vickrey prices.

others being larger, e.g. bidder 2 would win more spectrum in lot category A but less spectrum in lot category C (perhaps because bidder 2 made this bid, but did not make a bid for more spectrum in A and the same amount in C). As discussed below, in the 4G auction there were instances of both the relatively simple case (Niche) and of more complex cases (EE, Telefónica and Vodafone).

A6.5 We set out below a decomposition of the auction prices, based on the nature of the highest losing bids from which they were derived. Given the nature of the highest losing bids, this is well-defined for three of the five winning bidders. However, in the case of each of Niche's and Vodafone's auction price we have not identified a unique decomposition by band and instead we present alternatives. Table A6.1 sets out the auction prices for the winning packages in the 4G auction (these are the base prices from the principal stage of the auction and do not include the prices of £15.1m for Niche and £12.1m for Vodafone in the assignment stage).

Table A6.1: 4G auction prices for winning packages

Band / Lot category	800 MHz A1	800 MHz A2	2.6 GHz paired C	2.6 GHz unpaired E	Reserve price	Base price
Lot size	2x5 MHz	2x10 MHz	2x5 MHz	5 MHz		
EE	2x5 MHz 1xA1		2x35 MHz 7xC		£330m	£588.876m
H3G	2x5 MHz 1xA1				£225m	£225m
Niche			2x15 MHz 3xC	20 MHz 4xE	£45.4m	£186.476m
Telefónica		2x10 MHz 1xA2			£250m	£550m
Vodafone	2x10 MHz 2xA1		2x20 MHz 4xC	25 MHz 5xE	£510.5m	£790.761m
Total	2x20 MHz 4xA1	2x10 MHz 1xA2	2x70 MHz 14xC	45 MHz 9xE	£1,360.9m	£2,341.113m

Source: Ofcom

A6.6 We now consider the derivation of these auction prices in turn for each of the five winning bidders. We start with the two winning packages that were band-specific, won by H3G and Telefónica, and we then consider the prices for the winning packages of EE, Niche and Vodafone.

H3G

A6.7 H3G's auction price is the reserve price for 2x5 MHz in the 800 MHz band (1xA1). H3G won reserved spectrum and a different pricing rule applied in the auction to this spectrum compared to unreserved spectrum. Given this different pricing rule and the way H3G bid, it won this reserved 800 MHz spectrum at the reserve price of £225m.[7]

[7] For further details, see Myers (2013), "The innovative use of spectrum floors in the UK 4G auction to promote competition", Centre for the Analysis of Risk and Regulation, London School of Economics,

Telefónica

A6.8 Telefónica won 2x10 MHz in the 800 MHz band (with coverage obligation, 1xA2). The entirety of this auction price is therefore attributable to the 800 MHz band. The derivation of this auction price from the highest losing bids is shown in Table A6.2.

Table A6.2: Telefónica's auction price – highest losing bids

	Packages				Changes from winning packages				
Bidder	A1	A2	C	E	A1	A2	C	E	£m
Vodafone		1	4	4	-2	+1		-1	-£33m
EE	2		6		+1		-1		+£310.5m
Unsold	1				+1				+£225m
Niche			2	5			-1	+1	-£52.5m
H3G	1		2				+2		+£100m
Telefónica's winning package					0	1	0	0	£550m

Source: Ofcom

A6.9 We can see that, even though Telefónica's winning package is only in the 800 MHz band, the set of bids that constitutes the highest losing bids for Telefónica's package includes rearrangements of packages for other bidders in other bands. The reasons are as follows:

- the highest losing bid for the A2 lot won by Telefónica is Vodafone's bid for a package which, compared to its own winning package, involves substituting the A2 lot for 2xA1 (i.e. an equivalent 2x10 MHz of 800 MHz) but also one fewer lot of E, unpaired 2.6 GHz; and

- the highest losing bidder for one of the 2xA1 freed up by Vodafone switching from its winning package to the A2 lot is EE, but changing EE's package also involves a reduction of spectrum in EE's package (compared to its winning package) of 1xC (and there are further rearrangements in lot categories C and E involving Niche and H3G).

EE

A6.10 EE won 2x5 MHz in the 800 MHz band (1xA1) and 2x35 MHz in the 2.6 GHz band (7xC). The derivation of this auction price from the highest losing bids is shown in Table A6.3.

A6.11 The amount of this auction price attributable to 1xA1 is £225m (the reserve price). The remaining amount of the auction price of £363.876m is attributable to 7xC.

DP 74, November 2013, ISSN 2049-2718, http://www.lse.ac.uk/researchAndExpertise/units/CARR/pdf/DPs/DP74-Geoffrey-Myers.pdf.

Table A6.3: EE's auction price – highest losing bids

	Packages				Changes from winning packages				
Bidder	A1	A2	C	E	A1	A2	C	E	£m
Unsold	1				+1				+£225m
Telefónica		1	2				+2		+£128m
H3G	1		2				+2		+£100m
Vodafone	2		7	9			+3	+4	+£165.876m
Niche			3					-4	-£30m
EE's winning package					1	0	7	0	£588.876m

Source: Ofcom

Niche

A6.12 Niche won 2x15 MHz in the paired 2.6 GHz band (3xC) and 20 MHz in the unpaired 2.6 GHz band (4xE). The derivation of this auction price from the highest losing bids is shown in Table A6.4.

Table A6.4: Niche's auction price – highest losing bids

	Packages				Changes from winning packages				
Bidder	A1	A2	C	E	A1	A2	C	E	£m
Telefónica		1	2				+2		+£128m
Vodafone	2		5	9			+1	+4	+£58.476m
Niche's winning package					0	0	3	4	£186.476m

Source: Ofcom

A6.13 The highest losing bid by Telefónica of £128m is attributable to 2xC.

A6.14 We can decompose Vodafone's highest losing bid for 1xC and 4xE more than its winning package at an incremental bid value of £58.476m as follows (using additional package bids by Vodafone):

- £25.226m for 1xC (as the difference between Vodafone's winning bid and its bid for the package with an additional 1xC, i.e. 2xA1 + 5xC + 5xE);
- £4.776m for 4xE (as the difference between Vodafone's winning bid and its bid for the package with an additional 4xE, i.e. 2xA1 + 4xC + 9xE); and
- residual amount of £28.474m – one interpretation of this is a synergy value for Vodafone to win an additional 1xC and 4xE together (not separately as in the previous calculations).

A6.15 We are not aware of a uniquely correct way to attribute this synergy between 1xC and 4xE. The maximum of Niche's auction price attributable to C would include all of the synergy and the minimum would include none of it (in addition to the £128m from Telefónica's highest losing bid for 2xC). The maximum and minimum attributable to 4xE can similarly be identified by attributing all or none of the synergy to 4xE.

Vodafone

A6.16 Vodafone's winning package included spectrum in all three bands in the 4G auction: 2x10 MHz of 800 MHz (2xA1), 2x20 MHz of paired 2.6 GHz (4xC) and 25 MHz of unpaired 2.6 GHz (5xE). The derivation of this auction price from the highest losing bids is shown in Table A6.5 below.

Table A6.5: Vodafone's auction price – highest losing bids

	Packages				Changes from winning packages				
Bidder	A1	A2	C	E	A1	A2	C	E	£m
Unsold A1	1				+1				+£225m
EE	2		6		+1		-1		+£310.5m
Telefónica		1	2				+2		+£128m
H3G	1		2				+2		+£100m
Unsold C			1				+1		+£15m
Niche			3	5				+1	+£1m
HKT				2				+2	+£10.25m
MLL				2				+2	+£1.011m
Vodafone's winning package					2	0	4	5	£790.761m

Source: Ofcom

A6.17 The unsold 1xA1 in the highest losing bids is attributable to the 800 MHz band. Similarly the unsold 1xC is attributable to the paired 2.6 GHz band.

A6.18 There is a complication in attributing the incremental bid values of EE, Telefónica and H3G (£538.5m in total) between the 800 MHz and paired 2.6 GHz bands. The reason is that, if Vodafone had only won 2xA1 and no C, there would still have been package rearrangements in C for the highest losing bidders – see, for example, the package rearrangements for Telefónica's auction price in Table A6.2.[8] Some of these same bids would also be included in Vodafone's auction price if it had won 4xC and no A1. This means that there is an overlap between the highest losing bids for C shown in Table A6.5 as between the amounts of the auction price attributable to A1 and C.

A6.19 The value of the highest losing bids for 1xA1 in Vodafone's winning package including all package rearrangements is, in effect, the same question as is addressed by ASM for 2x5 MHz of 800 MHz with Vodafone as the excluded bidder - this value is £383.5m (see Table A6.11 below). Under this method, the amount

[8] Note, however, that the precise package rearrangements would be different as between Vodafone and Telefónica. This is because Telefónica's highest losing bid for 2xC would be included in the package rearrangements for Vodafone's auction price. But it could not be included in the derivation of Telefónica's own price, because that excludes the winner's own bids.

attributable to 4xC would be the residual of £155m plus the reserve price of the unsold 1xC of £15m, i.e. £170m.

A6.20 Alternatively, we could identify the amount attributable to 4xC by looking at the highest losing bids for 4xC by Telefónica and H3G at £228m. Under this method, the amount attributable to 1xA1 would be the residual of £310.5m plus the reserve price of the unsold 1xC and 1xA1 of £15m and £225m respectively, i.e. £550.5m.

A6.21 The amount of Vodafone's auction price attributable to 5xE is the sum of the incremental bid values in the highest losing bids for E in Table A6.5 by Niche, HKT and MLL at £12.261m.

Summary of decomposition of auction prices by band

A6.22 The decomposition of the auction prices by band described above is summarised in Table A6.6. For Niche the table shows the maximum and minimum for each of C and E. For Vodafone the table shows the alternative methods to decompose the prices between A1 and C.

Table A6.6: Decomposition of auction prices, including alternatives for Niche and Vodafone (in £m per MHz)

	A1	A2	C	E
EE	£22.5m		£5.198m	
H3G	£22.5m			
Telefónica		£27.5m		
Niche (1)			£6.057m	£0.239m
Niche (2)			£5.108m	£1.663m
Vodafone (1)	£27.525m		£5.700m	£0.490m
Vodafone (2)	£30.425m		£4.25m	£0.490m

Source: Ofcom

Linear Reference Price (LRP) methodology

Revenue-constrained LRPs

A6.23 The LRP methodology is a mathematical algorithm which takes account of both winning and losing bids in an auction to generate linear and uniform prices (i.e. a single price per MHz for each band that is the same for each bidder) that best support the auction outcome. This means that, at these prices, the incentives for bidders to prefer a different outcome are minimised. In this sense the LRP methodology identifies the linear and uniform prices that are closest to market clearing. However, the 4G auction prices were non-linear and non-uniform which means that if those LRPs were implemented, the market would not clear in the sense that not all winning bidders would have preferred their winning packages to any other packages at those prices.

A6.24 Applying the revenue constraint requires the sum of the LRPs (applied to the winning packages) to be the same as the total auction revenue. The method of revenue-constrained LRPs is thus a revenue attribution approach, i.e. it takes the total auction revenue as given and attributes it to the three different bands taking into account all the bids made, including losing bids as well as the winning bids.

LRPs without revenue constraint

A6.25 The LRPs *without* revenue constraint derive the linear prices that are closest to market clearing, i.e. that minimise the sum of excursions[9] or yield the linear and uniform prices that are as close as possible to separating the winning and losing bids, allowing the sum of the LRPs to differ from the auction revenue. A necessary feature of this method is that it provides a better fit with the bids than when the revenue constraint is imposed (i.e. it involves significantly lower excursions), and there is therefore an argument that it provides a better measure of market-clearing prices and market value.

A6.26 In neither of the LRP methodologies above is there a perfect fit, i.e. there are no LRPs that incentivise all bidders to choose their respective winning packages in the 4G auction. Thus, the aggregate of the excursions across bidders will be strictly positive. This reflects the feature of the 4G auction noted above that auction prices were non-linear and non-uniform (and at those prices, unlike the LRPs, each bidder preferred the package it won amongst the bids it made).

A6.27 In the remainder of this section, for the LRPs without revenue constraint we discuss:

- our preference to exclude the bids for packages with D1 or D2 lots when deriving LRPs; and

- the constraints which determine the LRPs and price differentials.

Reasons to exclude the bids for packages with D1 or D2 lots

A6.28 The LRPs (both with and without revenue constraint) in our analysis in the October 2013 consultation were based on the original set of bids submitted to the 4G auction without any changes. The LRPs without revenue constraint were £30.93m/MHz for 800 MHz (without coverage obligation, lot category A1) and £5.43m/MHz for 2.6 GHz (paired, lot category C). Since the October 2013 consultation, we noticed that some bidders, when faced with the linear prices, are modelled in the LRP calculations to choose packages with D1 and/or D2 spectrum (concurrent, low-power licences offered in competition against individual, standard-power licences in lot category C). This is related to the assumption that in the LRP determination, the prices for both D1 and D2 lots were held at zero. In particular, under the LRP methodology bidders are assumed to be payoff-maximisers, thus, they have an incentive to choose packages with D1 and D2 lots because, by assumption, this spectrum was available free of charge. We think that the free D1/D2 spectrum assumption has the potential to create an undue bias in bidders' choices towards packages with these lot categories in the LRP modelling.

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[9] The excursion for a bidder is the maximum amount by which the payoff of any of its bids (difference between amount bid and the price of bid at the LRP) exceeds the payoff of its winning bid, for the particular set of linear lot prices being considered. Note that the excursion for a bidder will be zero if the payoff for its winning bid is at least as great as the payoff for all of their losing bids. In other words, the excursion for a bidder is the maximum extent to which the proposed linear prices are unable to explain the auction outcome for that bidder. Thus, the lower the excursions, the better the fit.

A6.29 We also note that no D1 or D2 lots were won in the 4G auction. In our view, for the purpose of ALF, it is better to exclude the bids for packages containing D1 or D2 spectrum to run the LRPs. This exclusion is equivalent to setting a sufficiently high price (rather than zero) for D1 and D2 spectrum such that it is never preferred by bidders.

Constraints which determine LRPs and price differentials

Base case: LRPs without revenue constraint and excluding bids for D1/D2

A6.30 The new base case LRP scenario excludes bids for packages including D1/D2. This involves the LRPs shown in Table A6.7. The excursions are £77.5m in aggregate, with the majority accounted for by the excursion for EE of £55.5m. The other excursions by bidder are £14m for Telefónica, £6m for Vodafone, £2m for Niche and zero for H3G, HKT and MLL.

Table A6.7: LRPs excluding bids for packages with D1 or D2 lots (£m per lot)

Lot category	Lot size	LRPs
A1	2x5 MHz	£312m
A2	2x10 MHz	£593m
C	2x5 MHz	£57m
E	5 MHz	£8m
Revenue		£2,711m
Excursions		£77.5m

Source: Ofcom, Price Point Calculator (PPC) software

A6.31 This compares as follows to the aggregate excursions in other scenarios:

- Revenue-constrained LRPs (excluding bids for packages with D1/D2 lots): £124.5m, with the majority accounted for by the excursion for EE of £91.5m; and
- LRPs *without* revenue constraint including all bids (i.e. as published in the October 2013 consultation): £104m, with the majority accounted for by the excursions for EE and Telefónica of £55.5m and £43.8m respectively.

Constraining bids for LRPs in the base case

A6.32 The allocations at the LRPs are shown in Table A6.8 below, i.e. the packages that are most profitable for the bidders (based on the bids made). These packages are the constraining bids for this set of LRPs, i.e. the losing bids which impose the relevant constraints.

A6.33 The constraining bids for HKT, H3G and MLL in rows (iv) to (vi) in Table A6.8 are in fact their respective winning bids. This indicates that these bidders do not provide the relevant constraints to determine this set of LRPs.

A6.34 The price differential in the LRPs **between A1 and A2**, 800 MHz without and with the coverage obligation is determined by Vodafone's constraining bids (and this is also the case in other LRP scenarios). We can see this by comparing the price differential in the LRPs with the incremental bid value between Vodafone's two constraining bids:

- price differential in LRPs (given difference in lot size) is £312m x 2 - £593m = £31m; and
- incremental bid value between Vodafone's two constraining bids, rows (x) and (xi) in Table A6.8, is £2,073.044m - £2,042.044m = £31m. This is the discount required by Vodafone (the highest losing bidder for A2) for it to substitute A2 for 2xA1 (which it won[10]).

Table A6.8: Constraining bids for LRPs without revenue constraint (excluding bids for packages including D1 or D2)

Bidder	A1	A2	C	E	Row	Comment
EE (1)	0	0	8	0	(i)	Constraint on price differential between A1 and C
EE (2)	2	0	6	0	(ii)	
EE (3)	2	0	0	9	(iii)	Constraint on price differential between C and E along with (vii) and (viii)
HKT	0	0	0	0	(iv)	Winning bid
H3G	1	0	0	0	(v)	Winning bid
MLL	0	0	0	0	(vi)	Winning bid
Niche (1)	0	0	2	4	(vii)	Constraint on price differential between C and E
Niche (2)	0	0	3	0	(viii)	
Telefónica	0	1	2	0	(ix)	Highest losing bid for C (but not binding constraint on price of C)
Vodafone (1)	2	0	4	4	(x)	Constraint on price differential between A1 and A2
Vodafone (2)	0	1	4	4	(xi)	

Source: Ofcom

A6.35 Telefónica's constraining bid in row (ix) is the highest losing bid in the auction for additional C (paired 2.6 GHz). But this is not the binding constraint on the LRP of C – otherwise the LRP would be £64m.

A6.36 Niche's constraining bids in rows (vii) and (viii) involve substitution between lot categories C and E, 1xC for 4xE. This constrains the price differential in the LRPs **between C and E**:

- price differential in LRPs between 1xC and 4xE is £57m – (£8m x 4) = £25m; and

[10] The packages between which this discount is bid by Vodafone are close to Vodafone's winning bid – the only small difference is that they contain 4xE whereas Vodafone's winning package included 5xE.

- incremental bid value between Niche's two constraining bids in rows (vii) and (viii) is £310.431m - £285.431m = £25m.

A6.37 EE's constraining bids in rows (i) to (iii) constrain the price differentials in the LRPs between both A1 and C and between C and E.

A6.38 EE's constraining bids in rows (ii) and (iii) involve substitution between C and E, 6xC for 9xE, which constrains the price differential in the LRPs **between C and E** (alongside Niche's constraining bids):

- price differential in LRPs between 6xC and 9xE is £57m x 6 – £8m x 9 = £270m; and

- incremental bid value between EE's two constraining bids in rows (ii) and (iii) is £1,360m - £1,090m = £270m.

A6.39 EE's constraining bids in rows (i) and (ii) involve substitution between lot categories A1 and C, 2xA1 for 2xC, which constrains the price differential in the LRPs **between A1 and C**:

- price differential in LRPs between 2xA1 and 2xC is £312m x 2 - £57m x 2 = £510m; and

- incremental bid value between EE's two constraining bids in rows (ii) and (i) is £1,360m - £850m = £510m.

A6.40 The discussion above shows that information on the rate of substitution between bands in auction bids is relevant when determining the relative LRPs of those bands. Vodafone's rate of substitution between A1 and A2, noted above, is one example. Niche's rate of substitution between C and E is another example. However, it is less clear that, for the purpose of ALF, EE's rate of substitution between bands is appropriate information to derive market-clearing prices. The difference from other bidders is that only for EE was the overall spectrum cap a binding constraint in the auction. Where the overall spectrum cap was binding, EE's rate of substitution between bands may not, therefore, reflect its intrinsic relative values for the bands. For example, this is the case for the two packages in rows (i) and (ii) which constrain the price differential between A1 and C.

A6.41 This suggests that, if we consider that we should not treat the overall spectrum cap in the 4G auction as a binding constraint on a forward-looking basis, the prices of A1 and C in this LRP scenario may be below the relevant market-clearing prices. We explore this issue below by adding hypothetical bids for EE that breach the overall spectrum cap in the 4G auction to see the impact they have on the LRPs.

A6.42 The binding constraints on the price differential in the LRPs for A1 and C relate to EE's incremental bid values between packages which both include 2xA1 (2x10 MHz of 800 MHz). In contrast, the auction price of A1 is determined (along with the value of rearrangements and the reserve price of A1) by EE's incremental bid value between its winning package of 1xA1 + 7xC and the package of 2xA1 + 6xC. This involves substitution of 1xA1 for 1xC at an incremental bid value of £310.5m, which is larger than the corresponding differential in the LRPs and the relevant constraining bids of £510m for 2xA1 versus 2xC or an average of £255m per 1xA1 versus 1xC.

A6.43 On the one hand, this derivation of LRPs is consistent with the use of a 2x10 MHz increment. On the other hand, the LRP of A1 is constrained (as were auction bids) by the overall spectrum cap – without this cap, EE could have bid for larger packages of A1 without being forced only to substitute more A1 for less C (compared to its winning package). It is therefore informative to consider how the LRPs change if we add hypothetical bids for EE that breach the overall spectrum cap which applied in the 4G auction.

Hypothetical bid case: LRPs with hypothetical bid added for EE

A6.44 The hypothetical bid case is designed to test the potential impact of the overall spectrum cap on LRPs as compared to the base case. As explained below, we find that relaxing the overall spectrum cap (by adding in a hypothetical bid for EE) promotes a degree of convergence between LRPs and the marginal bidder analysis.[11]

A6.45 This LRP scenario involves adding a hypothetical bid by EE for the package of 2xA1 + 7xC at an incremental bid value for an additional 1xA1 (compared to its winning package) of £383m.[12] Under the overall spectrum cap in place in the 4G auction, EE was not permitted to make this bid.

Table A6.9: LRPs excluding bids for packages with D1 or D2 lots with hypothetical bid added for EE (£m per lot).

Lot category	Lot size	LRPs
A1	2x5 MHz	£321.381m
A2	2x10 MHz	£611.763m
C	2x5 MHz	£60.263m
E	5 MHz	£8.815m
Revenue		£2,820.315m
Excursions		£81.171m

Source: Ofcom, PPC software

[11] Although both LRPs and the marginal bidder analysis are seeking to derive market-clearing prices, we do not necessarily expect full convergence between them. This is because there are some differences in the methodologies to do so. The LRP methodology considers all bands in the auction simultaneously, whilst the marginal bidder analysis is conducted using a band-by-band analysis. In the LRP methodology any losing bid can be the constraining bid (for which the bidder's excursion is minimised), even for a package very different from the bidder's winning package. In contrast, the marginal bidder analysis focuses on bids for increments of additional spectrum compared to the bidder's winning package.

[12] The incremental bid value of £383m for an additional 1xA1 is for consistency with the marginal bidder analysis as set out in Section 2 and later in this annex. Adding this hypothetical bid for EE does not change the optimal spectrum allocation as compared to the 4G auction (even if it would change the base prices for Telefónica and Vodafone). This can be shown by running the Winner Determination Problem software available at http://stakeholders.ofcom.org.uk/spectrum/spectrum-awards/awards-archive/completed-awards/800mhz-2.6ghz/keydocuments/winner/.

A6.46 When this hypothetical bid is added, the LRPs are obtained as shown in Table A6.9. Compared to the base case, all the LRPs of A1, A2, C and E are higher. The excursions are larger in aggregate at more than £81m.

Constraining bids for LRPs in the hypothetical bid case

A6.47 The constraining bids for this scenario are set out in Table A6.10. The changes in LRPs compared to the base case can be explained as follows.

A6.48 Adding the hypothetical bid for EE relaxes the constraint in the base case on the price differential between A1 and C. The hypothetical bid by EE compared to its actual (losing) bid for 8xC sets the constraint on the price differential between A1 and C:

- price differential in LRPs of 2 x £321.381m - £60.263m = £582.5m; and
- incremental bid value between EE's two constraining bids in rows (i) and (ii) to substitute 2xA1 for 1xC of £1,432.5m - £850m = £582.5m.

A6.49 The remaining constraints are as discussed in the base case.

Table A6.10: Constraining bids for LRPs in hypothetical bid case without revenue constraint (excluding bids for packages including D1 or D2)

Bidder	A1	A2	C	E	Row	Comment
EE (1)	0	0	8	0	(i)	Constraint on price differential between A1 and C
EE (2)	2	0	7	0	(ii)	
EE (3)	2	0	0	9	(iii)	Constraint on price differential between C and E along with (vii) and (viii)
HKT	0	0	0	0	(iv)	Winning bid
H3G	1	0	0	0	(v)	Winning bid
MLL	0	0	0	0	(vi)	Winning bid
Niche (1)	0	0	2	4	(vii)	Constraint on price differential between C and E
Niche (2)	0	0	3	0	(viii)	
Telefónica	0	1	2	0	(ix)	Highest losing bid for C (but not binding constraint on price of C)
Vodafone (1)	2	0	4	4	(x)	Constraint on price differential between A1 and A2
Vodafone (2)	0	1	4	4	(xi)	

Source: Ofcom

A6.50 Whilst the LRP of A1 at £321.381m is higher than in the base case, it is still significantly below the corresponding market value that would be derived, for consistent assumptions, in the marginal bidder analysis. That would be the market value for 1xA1 implicit in the hypothetical bid added for EE of £383m, i.e. the assumed incremental bid value of the highest losing bidder for an additional 1xA1 compared to its winning package.

A6.51 This exercise illustrates that treating the overall spectrum cap in the 4G auction as non-binding on a forward-looking basis is likely to have a material effect in increasing the LRPs. In this exercise we have only added one hypothetical bid for EE but relaxation of the overall cap would imply various further bids might be added. We do not, therefore, regard £32.1m/MHz, the LRP with the single hypothetical bid added, as an upper bound.

Additional Spectrum Methodology (ASM)

A6.52 The ASM considers hypothetical additional spectrum in the auction. For example, in computing the ASM with Telefónica as the "excluded bidder", we exclude Telefónica's auction bids from the analysis and consider the value of additional 800 MHz to the other bidders. In this way the ASM estimates a value that the other three bidders (but not Telefónica) would place on additional 800 MHz (as a proxy for the same amount of 900 MHz spectrum from Telefónica's holdings).

A6.53 The ASM method yields different results for each band depending on:

- the increment of additional spectrum that is added; and
- the identity of the excluded bidder.

A6.54 The size of the spectrum increment affects the results because the highest losing bids were different for different amounts. They were generally smaller for larger quantities of additional spectrum, but there are exceptions arising from synergies.

A6.55 The identity of the excluded bidder affects the results because the ASM figures are derived as the sum of two components:

- highest losing bid for the spectrum in question; and
- package rearrangements.

A6.56 For example, the ASM figure of £38.35m/MHz for 2x5 MHz of 800 MHz with Vodafone as the excluded bidder is composed of:

- EE's incremental bid value (IBV), compared to its winning package, of £31.05m/MHz for an additional 2x5 MHz of 800 MHz and 2x5 MHz less of 2.6 GHz. This reduction in the amount of 2.6 GHz spectrum was necessary for EE to remain within the overall spectrum cap; and
- IBV of that 2x5 MHz of 2.6 GHz to other bidders of £7.3m/MHz, including the effect of package rearrangements, i.e. rearranging 2x5 MHz of 2.6 GHz each from EE and Niche to Telefónica.

A6.57 So the value of the package rearrangements includes Telefónica in working out the highest losing bids when Vodafone is the excluded bidder. But rearrangements involving Telefónica are not included when deriving the ASM value with Telefónica as the excluded bidder (as all of Telefónica's bids are excluded in this case). Hence the ASM results can differ as between different excluded bidders.

A6.58 The value of package rearrangements can be realised in the context of a multi-band (package) auction by shifting bidders from one package to a different winning package. However, outside of such an auction, realising a similar value would require a co-ordinated set of spectrum trades between, in this example, three operators (EE, Niche and Telefónica).

800 MHz as a proxy for 900 MHz

A6.59 The ASM results are shown in Table A6.11 for different increments of 800 MHz as a proxy for 900 MHz, and for different excluded bidders. The results are shown from right to left, as for the highest losing bids in Table 2.2 in Section 2. For example, the final column in Table A6.11 with Telefónica as the excluded bidder has the same value of £35.6m/MHz as the penultimate column in Table 2.2 in the row for IBVs of EE (as the highest losing bidder).

Table A6.11: ASM results (incremental values) for additional 800 MHz spectrum as a proxy for 900 MHz (in £m per MHz)

Additional spectrum ←	2x15 MHz	2x10 MHz	2x5 MHz
ASM results for excluded bidder:			
Telefónica	£35.5376m	£17.3m	£35.6m
Vodafone	£39.3m	£14.5m	£38.35m

Source: Ofcom

A6.60 The ASM results for 2x10 MHz are lower than for 2x5 MHz. This is affected by the packing issue described in Section 2, i.e. the absence of a losing bid by EE for an additional 2x10 MHz of 800 MHz. This is also why the ASM results for 2x15 MHz of about £30m/MHz are higher than for 2x10 MHz, by reflecting EE's losing bid for an additional 2x15 MHz.

2.6 GHz as a proxy for 1800 MHz

A6.61 The ASM results are shown in Table A6.12 for different increments of 2.6 GHz as a proxy for 1800 MHz, and for different excluded bidders.[13]

Table A6.12: ASM results (incremental values) for additional 2.6 GHz spectrum as a proxy for 1800 MHz (in £m per MHz)

Additional spectrum ←	2x45 MHz	2x40 MHz	2x35 MHz	2x30 MHz	2x25 MHz	2x20 MHz	2x15 MHz	2x10 MHz	2x5 MHz
ASM results for excluded bidder:									
EE	£0.805m	£2.628m	£5.37m	£4.63m	£3.588m	£5.45m	£4.55m	£5.45m	£7.35m
H3G							£2.848m	£5.45m	£7.35m
Telefónica									£4.55m
Vodafone									£7.3m

Source: Ofcom

[13] In the October 2013 consultation we also considered 800 MHz spectrum, and combinations of 800 MHz and 2.6 GHz spectrum, as proxies for 1800 MHz spectrum.

Marginal bidder analysis for 800 MHz spectrum

A6.62 EE was the marginal bidder for 800 MHz spectrum. Table A6.13 shows EE's demand (or IBVs) for the 800 MHz band. The IBVs in this table are derived from the relevant part of EE's bid map, which is shown in Table A6.22 in the Appendix to this annex. In Section 2 we use the information on EE's IBVs to consider both 2x5 MHz and 2x10 MHz increments of additional 800 MHz spectrum compared to its winning package. In this annex we provide a more detailed discussion of the estimates in Section 2.

Table A6.13: EE's demand (IBVs) for 800 MHz (lot category A1)

Packages with:	First A1	Second A1	Third A1	Fourth A1
0xC	£230m	£420m	£263.3m[14]	
1xC	dnb	dnb	dnb	dnb
2xC	£230m	£605m	£290.2m	
3xC	£230m	£555.9m	£266.5m	
4xC	£230m	£505.5m	£326.3m	
5xC	£230m	£491.2m	dnb	np
6xC	£275m	£461m	np	np
7xC	£353m*	np	np	np
Ranking of IBVs in each row	third	first	fourth[15]	second
Contiguity premium		Likely for 2x10 MHz block		Likely for 2x20 MHz block
Coverage premium / underlying IBVs for sub-1 GHz	Assumed to decline with larger quantities of sub-1 GHz spectrum			
Other relevant drivers of IBVs, e.g. cross-band effects or financial constraints	Unknown impact on IBVs			

Source: Ofcom

dnb EE did not bid for this package

np EE was not permitted to bid for this package by the overall spectrum cap

* EE's winning package

A6.63 For both 2x5 MHz and 2x10 MHz increments of additional 800 MHz spectrum we cannot directly observe EE's IBV, because EE was not permitted by the overall spectrum cap to bid in the 4G auction for a second lot of A1, or for its second and third lots of A1, in addition to its winning package of 1xA1 + 7xC. These are the highlighted cells in Table A6.13 in bordered cells in the row for packages with 7xC. However, using the IBVs that we can directly observe, we consider proxy estimates of EE's IBVs for these increments.

[14] This is the average value for EE's third and fourth lots of A1 (since EE did not bid separately for a third lot of A1).

[15] This is on the basis that EE chose not to bid for a third lot of A1 (without also bidding for a fourth lot of A1), suggesting that its IBVs were less than the reserve price.

A6.64 In doing so, we are in effect treating the overall spectrum cap which applied in the 4G auction as not being binding on a forward-looking basis, i.e. not preventing EE from acquiring either an additional 2x5 MHz or 2x10 MHz of spectrum.

A6.65 There is a risk that these different estimates may understate or overstate the market value we are seeking to derive. Using a similar framework as we apply to the benchmarking evidence, we consider:

- whether the IBV examined reflects the relevant IBV which is not directly observed; and
- whether the IBV for 800 MHz reflects the market value relevant to the ALF bands, 900 MHz and 1800 MHz.

A6.66 For each category, we consider the following risk factors:

- direction of the potential understatement or overstatement, if known;
- risk that the potential understatement or overstatement is present: smaller, larger or an "unknown" risk if we consider that we cannot sensibly judge whether the risk is smaller or larger; and
- scale of the potential understatement or overstatement: smaller, larger or "unknown" if we consider that cannot sensibly judge whether the scale is smaller or larger.

A6.67 In making this assessment, we take into account the known or expected features of IBVs shown in the lower rows of Table A6.13. First, we observe the ranking of EE's IBVs for 800 MHz (lot category A1) in packages with a given amount of 2.6 GHz (lot category C), i.e. how the IBVs evolve across the columns in a given row. The highest observed IBV in each row is for EE's second lot of A1. By making a reasonable inference (that EE's IBV for its third lot of A1 is below the reserve price, given that it chose not to make any bids for packages with 3xA1), we infer that the next highest IBV is for its fourth lot of A1. Then its IBV for its first lot of A1 is ranked third and the IBV for its third lot of A1 is ranked last.

A6.68 Second, it is likely that an important contributory factor to this ranking of IBVs is the synergies available in larger block sizes. This suggests that the IBVs of EE's second and fourth lots of A1 are likely to include a "contiguity premium" for acquiring these block sizes with contiguous spectrum.

A6.69 Third, the underlying IBV may decline with larger quantities of spectrum (abstracting from synergies and other factors). For sub-1 GHz spectrum such as 800 MHz this can be characterised as a declining "coverage premium". For the first 2x5 MHz of sub-1 GHz acquired by EE, it may have a relatively high value for the coverage advantages associated with such low-frequency spectrum. As it acquires larger quantities of sub-1 GHz spectrum, this premium is likely to reduce in size. However, there is still likely to be a premium present - acquiring sub-1 GHz spectrum still provides advantages over acquiring higher-frequency spectrum, because the signals travel further outdoors and generally deeper into buildings. This means that more customers can be served in locations that are harder to reach, or the customers can be served at higher speeds. For this reason we consider together the coverage premium and the underlying IBV of sub-1 GHz spectrum.[16]

A6.70 Fourth, there may well be a range of other considerations which affect EE's IBVs. For a high-stakes auction such as the 4G auction we expect that bidders would have prepared a detailed spectrum valuation model to inform their bids. The value of spectrum to an operator may involve a large number of different drivers of value, reflecting the range and complexity of the use of different combinations of spectrum in its business and how that might affect its commercial strategy. Examples of possible additional drivers of IBVs include cross-band effects and financial constraints:

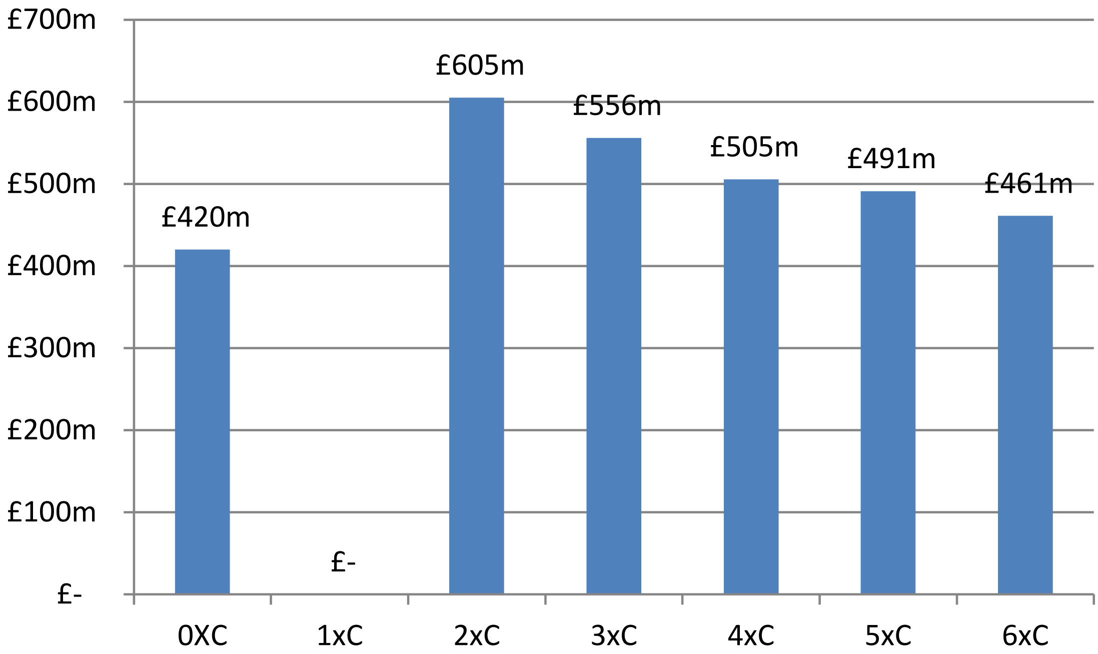
- **Cross-band effects.** The pattern of EE's IBVs suggests cross-band effects are relevant and potentially material. For example, see EE's (generally) increasing IBVs of its third and fourth 2x5 MHz of A1 with larger quantities of C (2.6 GHz), i.e. comparing the rows in Table A6.13 - see also Figure A6.4 below. This might suggest the presence of cross-band synergies in EE's bids. However, we note that, in contrast, EE's IBVs of its second 2x5 MHz of A1 are (generally) declining with larger quantities of C, which might indicate some degree of substitutability between the bands (see Figure A6.1 below).

- **Financial constraints.** Bidders may have financial constraints which are below their intrinsic values for the spectrum. In a CCA a bidder can respond to such a situation in different ways. One way is to reduce the number of packages it bids for. Another is to include bids for all packages in which it is interested, avoid any bid that exceeds its financial constraint, but express IBVs which differ from its true incremental values for the spectrum (either by compressing all IBVs below true value or reducing IBVs for some packages by more than others).

A6.71 In our view, whilst important insights can be obtained by considering known or likely drivers of spectrum value, it is unrealistic and potentially misleading to believe that the entirety of EE's bids can be explained by considering a small number of such drivers. For this reason in our marginal bidder analysis we focus on directly observed IBVs based on bids actually made by EE.

[16] In contrast, Frontier Economics (January 2014, on behalf of Vodafone) sought to distinguish between a declining underlying marginal value of spectrum and a coverage premium which applied only to the first 2x5 MHz lot of 800 MHz spectrum.

Figure A6.1: EE's IBV for its second 2x5 MHz of A1 in packages with different amounts of C



Source: Ofcom

2x5 MHz increment

A6.72 The closest package to EE's winning package with more 800 MHz for which EE placed a bid is 2xA1 + 6xC. This package includes an additional 2x5 MHz of 800 MHz, but also 2x5 MHz less of 2.6 GHz as compared to the winning package. EE's IBV between these two packages is derived as: £1,360m for 2xA1 + 6xC less £1,049.5m for 1xA1 + 7xC (i.e. EE's winning package). Therefore, EE's bid is £310.5m more for the package with additional 800 MHz.

A6.73 Given that the package with additional 800 MHz also includes less 2.6 GHz for which EE had a value, we know that EE's IBV for an additional 2x5 MHz of 800 MHz alone would have been larger than £310.5m. To estimate how much larger we need an estimate of the lost value to EE from the reduction of 2x5 MHz of 2.6 GHz, which should then be added on to £310.5m.

A6.74 We illustrate the possibilities by considering one specific estimate (and we note that there could be further candidate values). For example, we consider EE's IBVs for 2x5 MHz of 2.6 GHz (especially for its seventh lot of C). When this is added to £310.5m, in effect, this approach seeks to derive an estimate of EE's incremental value between its winning package and the "missing" bid for the package of 2xA1 + 7xC (which it was not permitted to make by the overall spectrum cap). This approach does not treat the overall spectrum cap imposed in the 4G auction as providing a binding constraint for the purpose of estimating market value on a forward-looking basis, because it envisages spectrum holdings for EE larger than the overall cap amount of 2x105 MHz.

A6.75 With this approach we can obtain an estimate of EE's IBV for an additional 2x5 MHz of 800 MHz of £383m (or £38.3m per MHz). EE's IBV for its seventh lot of C is only observed in packages with 1xA1 or 0xA1. The former IBV is £150.5m, whereas the latter is only £72.5m. Using the latter, lower estimate would yield an estimate of EE's incremental value for 2x5 MHz of 800 MHz of £383m (i.e. £310.5m + £72.5m).

Whether estimate reflects relevant IBV which is not directly observed

A6.76 There is a risk that £383m may understate the relevant IBV because £72.5m seems to be a conservative estimate of the value of the lost seventh lot of C.

A6.77 The estimate of £383m is for a bid by EE that is not directly observed (and indeed it was not permitted to make because of the overall spectrum cap which applied in the 4G auction). As a point of reference, we can compare the estimate to EE's bids which are directly observed for an additional 2x5 MHz of 800 MHz in smaller packages than its winning package as shown in Table A6.14.

Table A6.14: EE's directly observed bids for an additional 2x5 MHz of 800 MHz (lot of A1) in £m

	IBV of additional lot of A1 less lot of C	IBV of lost lot of C	IBV of additional lot of A1
3xC	£385.442m	£170.478m	£555.92m
4xC	£395.478m	£110m	£505.478m
5xC	£403.178m	£88m	£491.178m
6xC	£334.478m	£126.522m	£461m
7xC	£310.5m	[£72.5m]	[£383m]

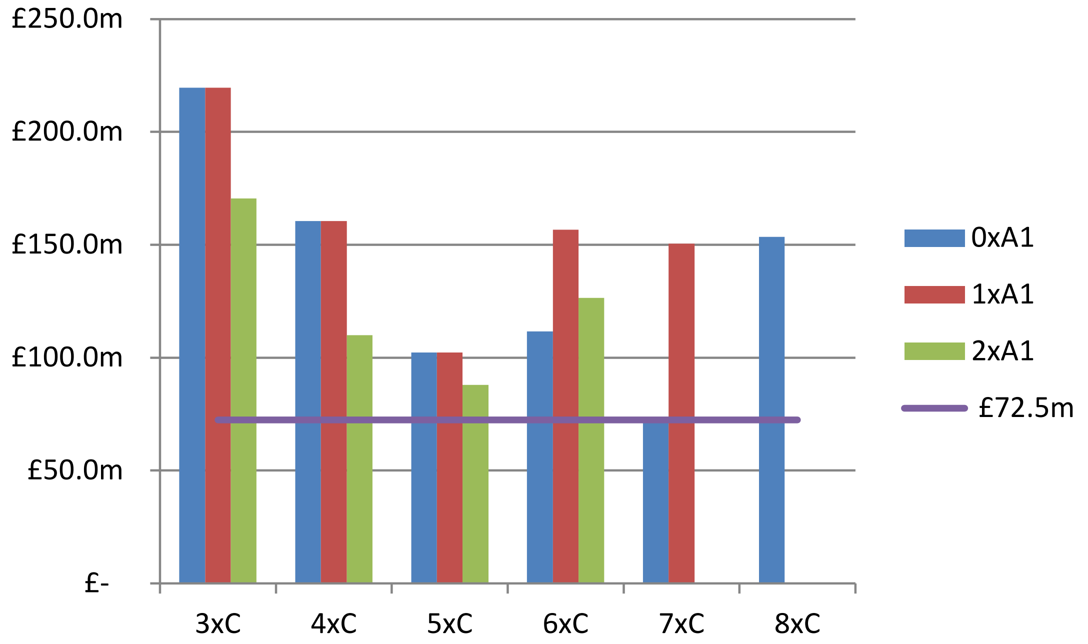
Source: Ofcom

A6.78 Our estimates are shown in the final row in Table A6.14 in square brackets. On this basis, EE's value for additional 800 MHz (as the marginal bidder) could be larger than £383m and potentially materially larger, such as in excess of £40m/MHz.[17]

A6.79 Similarly, as shown in Figure A6.2 below, all other IBVs by EE for one lot of C are larger than £72.5m.

[17] One possible complication is that, by acquiring 2x5 MHz of additional spectrum, EE could in future be constrained by any future spectrum caps which Ofcom might set in future spectrum awards. EE would be constrained if any such future caps proved to be a binding constraint on EE. If this were the case, then there might be an opportunity cost to EE of acquiring the 2x5 MHz of additional spectrum. In the limit, for example, it could mean that EE would only be able to acquire 2x5 MHz (or 10 MHz) less of spectrum in the future award than it wished. In such circumstances, there could be a case to reduce the estimate of EE's value of the 2x5 MHz of additional 800 MHz spectrum by the potentially lost value to EE of an equivalent amount of spectrum in the future award. However, first, it is not clear to us that the relevant circumstances necessarily apply for such a reduction in the estimate. Second, we do not consider that we have evidence to usefully quantify the size of any reduction.

Figure A6.2: EE's IBVs for one lot of C in packages with different amounts of A1 (in £m per 2x5 MHz lot)



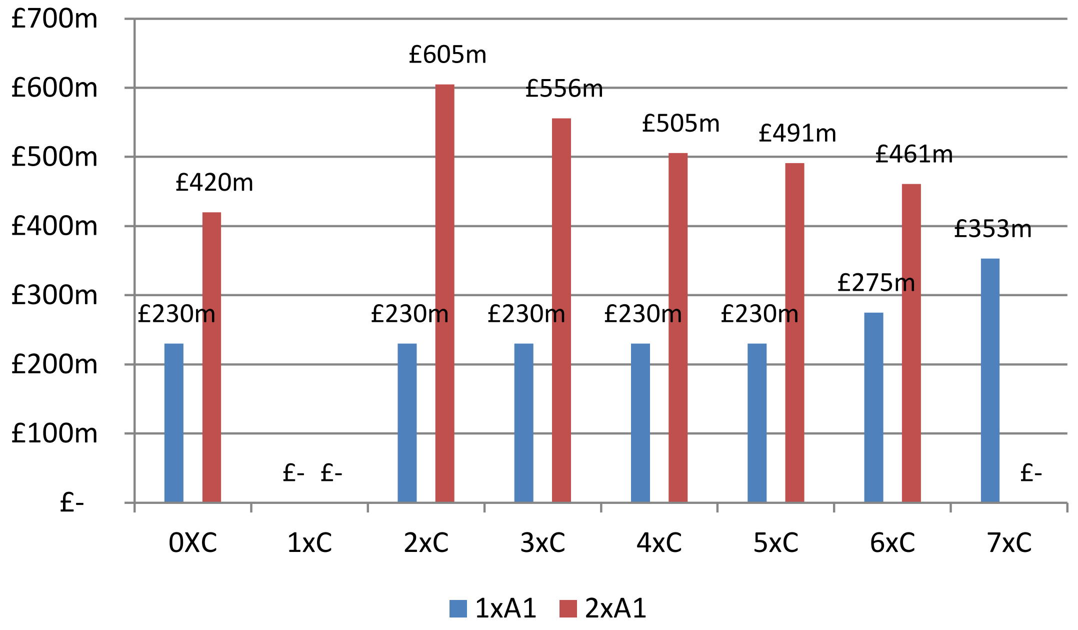
Source: Ofcom

<u>Relevance to ALF bands</u>

A6.80 There is a risk that £383m may overstate the relevant market value for the ALF bands, because it is likely to include a contiguity premium for a 2x10 MHz block of 800 MHz. If an additional 2x5 MHz of spectrum were acquired by EE in the 900 MHz band, it would be EE's first spectrum in that band and so would not form a contiguous 2x10 MHz block. EE might, therefore, be unable to realise any contiguity premium. We note the possibility that carrier aggregation between different bands with LTE Advanced might enable EE in future to realise at least some of the contiguity premium. However, for the purposes of the discussion below we abstract from this possibility.

A6.81 The evidence in Table A6.13 tends to suggest that the contiguity premium may generally be significant – see the much larger IBVs in the second column headed "2nd A1" compared to the first column headed "1st A1", as also shown in Figure A6.3. For example, a simple way of estimating a contiguity premium is as the excess in the IBV for its second lot of A1 compared to the first lot (although this may understate the premium as it implicitly assumes a constant underlying IBV of spectrum / constant coverage premium whereas it may be declining). On this simplified basis, £383m only implies a modest contiguity premium of £30m, i.e. compared to the IBV for the first lot of A1 with 7xC of £353m (since £383m is being used here as a proxy for the IBV of the second lot of A1 with 7xC). The modest implied contiguity premium seems to reflect our view that £383m may be a conservative estimate of EE's IBV for its second 2x5 MHz of A1 in packages with 7xC, as set out above.

Figure A6.3: EE's IBVs for its first and second lots of A1 in packages with different amounts of C (in £m per 2x5 MHz lot)



Source: Ofcom

A6.82 EE's IBV for its first 2x5 MHz of A1 in its winning package with 7xC is £353m, which excludes a contiguity premium. However, £353m for EE's first 2x5 MHz of A1 may include a larger coverage premium than is relevant to the estimate for its second 2x5 MHz of A1.

Reconciliation between estimate for 2x5 MHz increment and estimates derived using different methods

A6.83 We can reconcile the estimate of £383m (or £38.3m/MHz) set out above for the marginal bidder analysis for a 2x5 MHz increment with each of the following: the ASM results for 2x5 MHz for each of Telefónica and Vodafone as the excluded bidder; the relevant components of Telefónica's and Vodafone's auction prices; and H3G's auction price if it were at full opportunity cost. The reconciliation is as follows.

A6.84 EE's directly observed incremental bid value of £31.05m/MHz for an additional 2x5 MHz of 800 MHz and 2x5 MHz less of 2.6 GHz is a common starting point for the marginal bidder analysis, ASM, the relevant component of the auction prices for both Telefónica and Vodafone, and H3G's auction price if it were at full opportunity cost. The differences between these various values derive only from differences in the amounts that are 'added back' to account for the 'lost' 2x5 MHz of 2.6 GHz.

A6.85 In the marginal bidder analysis for a 2x5 MHz increment, we add back £7.25m/MHz as a proxy for EE's incremental value of 2x5 MHz of 2.6 GHz, giving an estimate of £38.3m/MHz.

A6.86 In Telefónica's auction price and in ASM with Telefónica as the excluded bidder, £4.55m/MHz is added back giving a value of £35.6m/MHz. This reflects package rearrangements for Vodafone, Niche and H3G as well as EE - see Table A6.2.

A6.87 In Vodafone's auction price and in ASM with Vodafone as the excluded bidder, £7.3m/MHz is added back giving a value of £38.35m/MHz.[18]

A6.88 Similarly, in H3G's price if it were at full opportunity cost, the same £7.3m/MHz would be added back, again giving a value of £38.35m.

2x10 MHz increment

A6.89 We consider two candidate IBVs as proxies for EE's average IBV for its second and third lots of A1 in a package with 7xC:

- £368m on average per 2x5 MHz: the average IBV for EE's first and second lots of A1 in packages with 6xC (i.e. the average of £275m and £461m, as indicated by the dotted line around the relevant cells in Table A6.13). The same average can also be obtained as the average of £353m for EE's first lot of A1 with 7xC (i.e. in its winning package) and our conservative estimate of EE's IBV for its second lot of A1 with 7xC of £383m.

- £326.3m on average per 2x5 MHz: the average IBV for EE's third and fourth lots of A1 in packages with 4xC (i.e. the IBV indicated by the relevant dotted box in Table A6.13).

Whether estimate reflects relevant IBV which is not directly observed

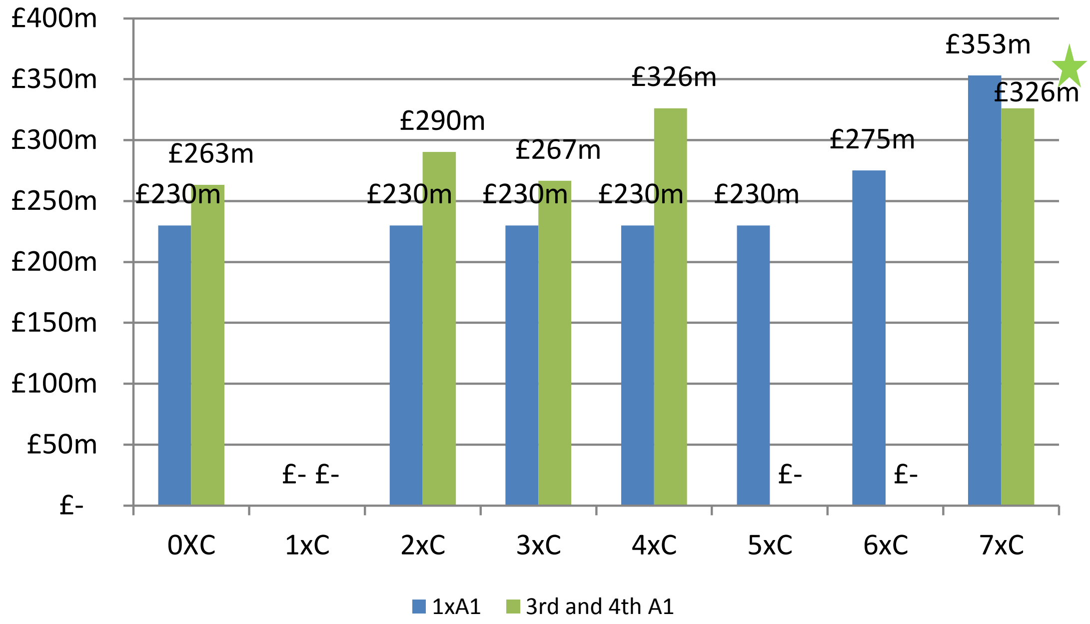
A6.90 The first estimate of £368m could understate the relevant IBV because £383m used in one of the methods to derive this average may be a conservative estimate. However, on the other hand, the average IBV of EE's first 2x10 MHz (i.e. first and second lots of A1) is similar for packages with 4, 5 or 6xC (at £367.75m, £361m and £368m respectively), which tends to suggest it may not understate.

A6.91 There is a risk that the second estimate of £326.3m may understate the relevant IBV because it reflects the IBV with 2x20 MHz of 2.6 GHz spectrum, not the relevant larger package of 2x35 MHz which EE won in the auction. EE's IBV is generally higher in packages with more 2.6 GHz spectrum (compare the £326.3m with the lower figures in the previous rows in Table A6.13 of £263.3m, £290.2m and £26.62m).

A6.92 In addition, for all observed IBVs EE's average IBV for its third and fourth lots of A1 is higher than the IBV for its first lot of A1 (in packages with a given number of lots of C), whereas £326.3m is lower than the observed IBV for its first lot of A1 with 7xC of £353m (compare the last and first columns in Table A6.13, as also shown in Figure A6.4).

[18] This reflects package rearrangements which are £28m higher in value than for Telefónica's auction price. This is because they include Telefónica's value for additional 2.6 GHz (instead of H3G's). Telefónica was the highest losing bidder for 2.6 GHz (whereas H3G was the second-highest losing bidder), but its bid values are irrelevant to its own auction price under the second price rule. £28m is the difference between Telefónica's incremental bid value for 2x10 MHz of 2.6 GHz of £128m and H3G's value of £100m.

Figure A6.4: EE's average IBVs for its third and fourth lots of A1 compared to its IBV for its first lot of A1 in packages with different amounts of C (in £m per 2x5 MHz lot)



Source: Ofcom

★ Our proxy estimate for third and fourth lots of A1 with 7xC

Relevance to ALF bands

A6.93 The first estimate of £368m may overstate the relevant market value as a basis for ALF. This is because it represents an estimate of EE's value for its first 2x10 MHz of sub-1 GHz spectrum, whereas if EE were to acquire a 2x10 MHz block of 900 MHz, it would be additional to the 2x5 MHz of sub-1 GHz spectrum at 800 MHz which EE also holds (having won it in the 4G auction). If there is a declining coverage premium for sub-1 GHz spectrum, in principle a downward adjustment could be made to account for this.

A6.94 However, in our view there is not a reliable basis to make such an adjustment. We could base an adjustment on differences in EE's average IBVs between its first and second 2x10 MHz blocks for packages with different amounts of 2.6 GHz spectrum (specifically, there are such directly observed IBVs with 0xC, 2xC, 3xC and 4xC). However, there are the following issues in deriving an adjustment in this way:

- In practice, whilst the average value of the second 2x10 MHz block is less than the value of the first 2x10 MHz block, the difference in value varies between these different packages. The smallest observed difference is £4.148m/MHz for packages with 4xC, the largest packages for which we can observe the difference and so the closest to the relevant packages (although still materially smaller packages than the relevant packages with 7xC). The other observed differences for even smaller packages are £6.169m/MHz with 0xC and about £12.7m/MHz for packages with 2xC and 3xC.

- These observed differences are only an accurate measure of the declining coverage premium if we make the assumption that the contiguity premium is the same in the first 2x10 MHz block as in the second 2x10 MHz block.

- These differences are between holdings of 2x10 MHz and 2x20 MHz, not the relevant comparison between 2x5 MHz and 2x15 MHz (if a constant £m decline in coverage premium is assumed, the adjustment could be one-half of the differences set out above).

A6.95 There is a risk that the second estimate of £326.3m may understate the relevant market value for the ALF bands, because the estimate reflects the smaller coverage premium / underlying IBV of sub-1 GHz spectrum of EE's third and fourth lots of sub-1 GHz spectrum, instead of its second and third lots.

Summary of risk factors: 2x5 MHz vs 2x10 MHz

A6.96 A summary of our views on the risk factors is set out in Table A6.15 below.

Table A6.15: Summary of risk factors for estimates of market value of 2x5 MHz and 2x10 MHz increments for the purpose of ALF (in £m per MHz)

Increment:	2x5 MHz	2x10 MHz	2x10 MHz
	£38.3m	£36.8m	£32.63m
Direction	Overstate	Overstate	Understate
Risk	Larger	Unknown	Larger
Scale	Larger	Unknown	Larger

Source: Ofcom

Price signals provided by values of 2x5 MHz and 2x10 MHz increments

A6.97 The question we address in this sub-section is whether a price signal for an increment of 2x5 MHz or 2x10 MHz is more likely to provide an efficient price signal.

A6.98 The values for 800 MHz and 2.6 GHz of the marginal bidder, or non-holder (NH) of the licences for ALF spectrum, are non-linear. This suggests that, in theory, if the structure of demand of the highest-value NHs for 900 MHz and 1800 MHz follows a similar pattern, the optimal ALF would also be non-linear. However, we do not propose to set a non-linear ALF for practical reasons. First, we do not consider that the evidence available to us would enable us to derive a sufficiently reliable set of non-linear ALFs. This is because we do not have direct evidence on the pattern of NH's values for 900 MHz and the available evidence for the highest-value NH's values for 800 MHz do not provide a robust basis to infer them. Second, it would involve a more complicated implementation than linear ALFs and a break with past practice for spectrum fees for 900 MHz and 1800 MHz which have always been set at a specified (linear) £/MHz.

A6.99 Given that we are setting linear ALFs, the efficiency of the price signals depends not only on the values of the highest-value NH, but also the structure of incremental values (IVs) of the licence holder (LH). It is the LH that we wish to respond to the ALF price signal, such as by trading or relinquishing spectrum if it is efficient to do so (and we assume in the discussion below that any such release of spectrum by the LH is in 2x5 MHz lots). We do not have direct evidence on the IVs of the LH for 900 MHz. Therefore, instead we work through a number of illustrative examples to bring out the issues at stake.

Assumptions for illustrative examples: available supply of 2x20 MHz

A6.100 For this purpose we assume, purely for illustration, that the LH's structure of values for 900 MHz is represented by EE's IBVs for packages with 2xC (see Table A6.13) up to an available supply of 2x20 MHz (i.e. assuming the LH holds this much 900 MHz spectrum). To decompose the average value for the third and fourth lots of £29.02m/MHz we make the further assumption that the IV of the third lot is £22.5m/MHz (the reserve price of 800 MHz spectrum in the 4G auction), and hence the IV of the fourth lot is £35.54m/MHz.

A6.101 We also assume for illustration that the highest-value NH of 900 MHz has value for a 2x10 MHz increment of 900 MHz of £32.63m/MHz. For the examples we need to decompose this average value for a 2x10 MHz increment into values for the first and second 2x5 MHz lots. We consider two cases (in both of which we assume a contiguity premium for the second lot but of differing sizes):

a) £25m/MHz for first 2x5 MHz and £40.26m/MHz for second 2x5 MHz.

b) £20m/MHz for first 2x5 MHz and £45.26m/MHz for second 2x5 MHz.

A6.102 The assumed values of the LH and the NH are set out in Table A6.16. The IVs of the LH are shown from left to right. For simplicity, we are assuming only one LH and one NH and so any acquisition of 900 MHz spectrum by the NH would only arise through a reduction in the holding of the LH. Therefore, the assumed IVs of the NH for its first 2x10 MHz are shown in Table A6.16 from right to left – as explained above, we assume two different cases which are labelled (a) and (b).

Table A6.16: Illustrative assumptions for values of LH and NH of 900 MHz with available supply of 2x20 MHz (in £m per MHz)

Holding of LH ⟶ Holding of NH ⟵	2x5 MHz 2x20 MHz	2x10 MHz 2x15 MHz	2x15 MHz 2x10 MHz	2x20 MHz 2x5 MHz
IVs of LH				
For each 2x5 MHz	£23m	£60.5m	£22.5m	£35.54m
Average for last 2x10 MHz			£29.02m	
Average for last 2x15 MHz		£39.51m		
Average for 2x20 MHz	£35.385m			
IVs of NH				
Case (a)			£40.26m	£25m
Case (b)			£45.26m	£20m
Average for first 2x10 MHz			£32.63m	

Source: Ofcom

Implications of case (a)

A6.103 Case (a) implies the following linear ALFs[19] depending on whether we are deriving the level of the ALF from the value of a 2x5 MHz or 2x10 MHz increment:

- £25m/MHz for the value of a 2x5 MHz increment; and
- £32.63m/MHz for the value of a 2x10 MHz increment.

A6.104 In case (a), it is efficient for the LH to relinquish 2x10 MHz or trade it to the NH (hereafter, for simplicity we just refer to relinquishment, not trading). This is because the IV of the LH for its last 2x10 MHz is £29.02m/MHz (i.e. the average of £22.5m and £35.54m), which is below the IV of the NH's first 2x10 MHz of £32.63m/ MHz.

A6.105 The linear ALF based on the value of a 2x5 MHz increment of £25m/MHz does not provide an incentive for the LH to relinquish, because its IV for its last 2x5 MHz at £35.54m/MHz exceeds the ALF, and so does its average IV for any larger possible relinquishment, e.g. £29.02m/MHz for its last 2x10 MHz. Therefore, the efficient outcome of a relinquishment of 2x10 MHz does not occur.

A6.106 The linear ALF based on the value of a 2x10 MHz increment of £32.63m/MHz does not provide an incentive for the LH to relinquish its marginal 2x5 MHz alone, because its IV at £35.54m/MHz exceeds the ALF. However, its average IV of £29.02m/MHz for its last 2x10 MHz is lower than the ALF, so it has an incentive to make the efficient relinquishment of 2x10 MHz.

Implications of case (b)

A6.107 Case (b) implies the following linear ALFs:

- £20m/MHz for the value of a 2x5 MHz increment; and
- £32.63m/MHz for the value of a 2x10 MHz increment.

A6.108 In case (b), it is again efficient for the LH to relinquish 2x10 MHz.

A6.109 The linear ALF based on the value of a 2x5 MHz increment of £20m/MHz does not provide an incentive for the LH to relinquish.

A6.110 The linear ALF based on the value of a 2x10 MHz increment of £32.63m/MHz provides an incentive to make the efficient relinquishment of 2x10 MHz.

A6.111 In summary, in both cases (a) and (b) it is efficient for the LH to relinquish 2x10 MHz. A linear ALF based on the value of a 2x10 MHz increment (which is the same in both cases) achieves this. However, a linear ALF based on the value of a 2x5 MHz increment (which is different between the two cases) does not, because in either case it is below £29.02m/MHz (LH's average value for its last 2x10 MHz).

[19] All the figures shown are lump-sum values, not annualised fees, but we use the term ALFs for convenience.

Assumptions for illustrative examples: available supply of 2x15 MHz

A6.112 Each current licensee of 900 MHz holds 2x17.4 MHz. It may therefore also be relevant to consider values up to an available supply of 2x15 MHz. In doing so, we are effectively assuming that none of the contiguity premium for a 2x20 MHz block over a 2x15 MHz block is achievable. The assumed values of the LH and the NH are set out in Table A6.17.

Table A6.17: Illustrative assumptions for values of LH and NH of 900 MHz with available supply of 2x15 MHz (in £m per MHz)

Holding of LH → Holding of NH ←	2x5 MHz 2x15 MHz	2x10 MHz 2x10 MHz	2x15 MHz 2x5 MHz
IVs of LH			
For each 2x5 MHz	£23m	£60.5m	£22.5m
Average for last 2x10 MHz		£41.5m	
Average for last 2x15 MHz	£35.33m		
IVs of NH			
Case (a)		£40.26m	£25m
Case (b)		£45.26m	£20m
Average for first 2x10 MHz		£32.63m	

Source: Ofcom

Implications of case (a)

A6.113 Case (a) with available supply of 2x15 MHz implies the following linear ALFs:

- £25m/MHz for the value of a 2x5 MHz increment; and
- £32.63m/MHz for the value of a 2x10 MHz increment.

A6.114 In case (a), it is efficient for the LH to relinquish 2x5 MHz because the IV of the LH for its last 2x5 MHz at £22.5m/MHz is less than the IV of the NH's first 2x5 MHz at £25m/MHz.

A6.115 The linear ALF based on the value of a 2x5 MHz increment of £25m/MHz provides an incentive for the LH to make the efficient relinquishment of 2x5 MHz.

A6.116 The linear ALF based on the value of a 2x10 MHz increment of £32.63m/MHz also provides an incentive to make the efficient relinquishment of 2x5 MHz.

Implications of case (b)

A6.117 Case (b) with available supply of 2x15 MHz implies the following linear ALFs:

- £20m/MHz for the value of a 2x5 MHz increment; and
- £32.63m/MHz for the value of a 2x10 MHz increment.

A6.118 In case (b), the efficient outcome is no relinquishment by the LH, because its IV for its last 2x5 MHz at £22.5m/MHz is greater than the IV of the NH for its first 2x5 MHz at £20m/MHz.

A6.119 The linear ALF based on the value of a 2x5 MHz increment of £20m/MHz does not provide an incentive for the LH to relinquish and so is consistent with the efficient outcome.

A6.120 The linear ALF based on the value of a 2x10 MHz increment of £32.63m/MHz provides an incentive for the LH to relinquish its marginal 2x5 MHz. Such relinquishment would, however, be inefficient.[20] In summary, setting ALFs based on the value of a 2x10 MHz increment to the NH could potentially lead to spectrum being relinquished (2x5 MHz in our example), even if the incremental value of this spectrum is higher to the licensee than to the highest-value alternative user.

Further illustrative example: 2x15 MHz

A6.121 We now make further assumptions on the structure of values of the LH and NH to illustrate another possibility. The further illustrative assumptions are set out in Table A6.18.

Table A6.18: Further illustrative assumptions for values of LH and NH of 900 MHz (in £m per MHz)

Holding of LH → Holding of NH ←	2x5 MHz 2x15 MHz	2x10 MHz 2x10 MHz	2x15 MHz 2x5 MHz
IVs of LH			
For each 2x5 MHz	£30m	£32m	£30m
Average for last 2x10 MHz		£31m	
Average for last 2x15 MHz	£30.67m		
IVs of NH			
For each 2x5 MHz	£20m	£40.26m	£25m
Average for first 2x10 MHz		£32.63m	
Average for first 2x15 MHz	£28.42m		

Source: Ofcom

A6.122 As for case (a) above, there would be the following linear ALFs:

- £25m/MHz for the value of a 2x5 MHz increment; and
- £32.63m/MHz for the value of a 2x10 MHz increment.

A6.123 With these further illustrative assumptions, the efficient outcome is relinquishment of 2x10 MHz by the LH, because its average IV for its last 2x10 MHz at £31m/MHz is less than the IV of the NH's first 2x10 MHz at £32.63m/MHz. It is not efficient for

[20] This inefficiency would be avoided if an efficient non-linear ALF were set, e.g. £20m/MHz for the last 2x5 MHz and £32.63m/MHz for the last 2x10 MHz held by the LH.

the LH to relinquish 2x5 MHz because its IV at £30m/MHz exceeds the IV of the NH at £25m/MHz. It is also not efficient to relinquish 2x15 MHz because the LH's average IV across 2x15 MHz at £30.67m/MHz exceeds that of the NH at £28.42m/MHz.

A6.124 The linear ALF based on the value of a 2x5 MHz increment of £25m/MHz does not provide an incentive for the LH to relinquish and so it does not achieve the efficient outcome.

A6.125 The linear ALF based on the value of a 2x10 MHz increment of £32.63m/MHz provides an incentive for the LH to relinquish all of its holding of 2x15 MHz, because this exceeds the LH's average IV across its 2x15 MHz holding of £30.67m/MHz. Such relinquishment would, however, be inefficient.[21]

A6.126 In this example, if the ALF were set conservatively at 6% below the true value to the NH of £32.63m/MHz, the inefficient outcome of excessive relinquishment would be avoided. The required linear ALF would be just below £30.67m/MHz – however, at that ALF there would only be relinquishment of 2x5 MHz and not the efficient amount of 2x10 MHz.

A6.127 In this further illustrative example, the values of the LH and NH are fairly similar, which tends to limit the scale of the efficiency losses, if the efficient relinquishment is not achieved.

Summary of illustrative examples

A6.128 Table A6.19 provides a summary of the illustrative examples set out above. If the ALF results in the efficient outcome, this is indicated by a relinquishment amount in bold (and if it is inefficient, it is shown in italics).

Table A6.19: Summary of relinquishment incentives on licence holder in illustrative examples compared to efficient outcome

	2x20 MHz supply: Case (a)	2x20 MHz supply: Case (b)	2x15 MHz supply: Case (a)	2x15 MHz supply: Case (b)	2x15 MHz supply: Further example
Efficient relinquishment by LH	2x10 MHz	2x10 MHz	2x5 MHz	None	2x10 MHz
Relinquishment with linear ALF based on the value of NH's increment of:					
2x5 MHz	*None*	*None*	**2x5 MHz**	**None**	*None*
2x10 MHz	**2x10 MHz**	**2x10 MHz**	**2x5 MHz**	*2x5 MHz*	*2x15 MHz*

Source: Ofcom

A6.129 The table shows two examples of a potentially problematic set of circumstances of excessive relinquishment if a linear ALF is based on based on the value of a 2x10 MHz increment. However:

[21] This inefficiency would be avoided if an efficient non-linear ALF were set, e.g. £25m/MHz for the last 2x5 MHz held by the NH, £32.63m/MHz for the last 2x10 MHz and £28.42m/MHz for 2x15 MHz.

- There are three other problematic examples of insufficient relinquishment in the illustrative examples above in the alternative of a linear ALF based on based on the value of a 2x5 MHz increment.

- The likelihood of excessive relinquishment is mitigated if there is a risk that our estimate of the value of a 2x10 MHz increment may understate market value for the purpose of ALF (see Table A6.15).

DTT co-existence costs

A6.130 We requested information (under Section 32A of the Wireless Telegraphy Act 2006) regarding the assumptions made about DTT co-existence costs in deciding the level of the bids for packages that included 800 MHz lots in the 4G auction. We received the following four responses.

A6.131 EE[22] said that it [✂].

A6.132 Vodafone[23] [✂].

A6.133 In Telefónica's[24] response [✂]

A6.134 H3G[25] said that [✂].

LRPs gross of expected DTT co-existence costs

A6.135 In order to derive the LRPs gross of expected DTT co-existence cost we take into account adjustments to the bids of all the bidders for 800 MHz (EE, Vodafone, Telefónica and H3G).[26] We consider what the bids gross of DTT co-existence costs would have been, based on stakeholder responses to the information request on DTT co-existence costs.

A6.136 In particular, we:

- increase [✂] bids for all relevant packages by [✂] for 800 MHz;

- make no change to [✂], which seems to suggest that its bids gross of DTT co-existence costs would have been the same as its actual bids;

- calculate first the LRPs without any change to [✂] bids, and then we re-run the calculation by adding £3m/MHz to all of its bids for 800 MHz to see what difference it makes to the resulting LRPs[27]; and

[22] See EE's response (7 May 2014) to our Section 32A letter dated 24 April 2014.
[23] See Vodafone's response (7 May 2014) to our Section 32A letter dated 24 April 2014.
[24] See Telefónica's response (8 May 2014) to our Section 32A letter dated 24 April 2014.
[25] See H3G's response (8 May 2014) to our Section 32A letter dated 24 April 2014.
[26] All calculations were done with the PPC software provided by DotEcon.
[27] We decided to take this approach with [✂] bids given that its response to the information request [✂].

- calculate first the LRPs without any change to [✂] bids; second, we re-run the calculations by changing [✂][28]; and third we re-run the calculations amending [✂].

Table A6.20: LRPs gross of expected DTT co-existence cost

LRPs	No change to [✂] bids	Changing [✂]	Amending [✂]
No change to [✂] bids	Scenario 1 A1: £342m A2: £653m C: £57m E: £8m	Scenario 2 A1: £342m A2: £653m C: £57m E: £8m	Scenario 3 A1: £342m A2: £653m C: £57m E: £8m
Add £3m/MHz to all of [✂bids for 800 MHz	Scenario 4 A1: £342m A2: £653m C: £57m E: £8m	Scenario 5 A1: £342m A2: £653m C: £57m E: £8m	Scenario 6 A1: £342m A2: £653m C: £57m E: £8m

Source: Ofcom

A6.137 In Table A6.20 we set out the scenarios and results for LRPs without revenue constraint, excluding bids for packages with D1/D2 lots, and gross of expected DTT co-existence cost.[29] As set out above, all scenarios assume:

- an increase of [✂] bids for all relevant packages by [✂] for 800 MHz; and
- no changes to [✂]'s bids.

A6.138 We find that the LRPs gross of expected DTT co-existence cost are identical under all the scenarios reported above. When compared to the base case (i.e. the LRPs without revenue constraint, excluding the bids for packages with D1/D2 lots and net of DTT co-existence costs reported in Table A6.7), the LRPs are higher by £3m/MHz for 800 MHz spectrum.

Estimates from marginal bidder analysis gross of expected DTT co-existence costs

A6.139 The marginal bidder for 800 MHz was EE. Its response to the information request was that it [✂] because of the DTT co-existence costs.

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28 [✂]

29 In all the six scenarios in Table A6.20 the optimal spectrum allocation remains the same as in the actual 4G auction (even if it would change the base prices for some bidders). This can be shown by running the Winner Determination Problem software available at http://stakeholders.ofcom.org.uk/spectrum/spectrum-awards/awards-archive/completed-awards/800mhz-2.6ghz/keydocuments/winner/.

A6.140 Therefore, the value of 800 MHz gross of expected DTT co-existence costs under the marginal bidder analysis is £3m/MHz higher than the value net of such costs.

A6.141 In Table A6.21 we provide a summary of the estimates from the marginal bidder analysis for the 800 MHz band both gross / net of expected DTT co-existence costs and with / without the coverage obligation.

Table A6.21: Estimates from marginal bidder analysis, gross/net of expected DTT co-existence costs and with/without coverage obligation (in £m per MHz)

	Without coverage obligation	With coverage obligation
Net of expected DTT co-existence costs	£32.63m	£31.08m
Gross of expected DTT co-existence costs	£35.63m	£34.08m

Source: Ofcom

A6.142 The discount for the coverage obligation spectrum is £31m for the 2x10 MHz lot of A2, or £1.55m/MHz. This is the discount of the marginal bidder for A2, Vodafone, and it is also reflected in the LRP results, e.g. see paragraph A6.34 above.

Appendix: EE's bid map

A6.143 The extract from EE's bid map in Table A6.22 below shows EE's bid values and the IBVs that can be derived from them. Some of these IBVs are shown, for example, in Table A6.13 as EE's demand for 800 MHz spectrum.

A6.144 EE's bid values for specified packages of spectrum are shown in the boxes, with the amount of 800 MHz spectrum in the columns and the amount of 2.6 GHz spectrum in the rows, in both cases in increments of 2x5 MHz. For example, EE's winning bid is £1,049.5m for a package of 1xA1 + 7xC (2x5 MHz of 800 MHz plus 2x35 MHz of 2.6 GHz).

A6.145 The IBVs are the figures between the boxes. For example, EE's IBV for its seventh lot of 2.6 GHz spectrum in packages with no 800 MHz is £72.5m; and the incremental value of its second lot of 800 MHz in packages including 6xC (2x30 MHz of 2.6 GHz) is £461m.

A6.146 IBVs on a diagonal are shown in italics – they relate to both an increment of additional spectrum in one lot category and a reduction in the other. For example, the IBV for an increment of 1xA1 and a reduction of 1xC compared to EE's winning package is £310.5m.

A6.147 A cell shows as "N/A" if EE did not make a bid for the specific package it represents.

A6.148 The average IBVs for a 2x10 MHz increment shown for the third and fourth lots of A1 in Table A6.13 above are derived as the difference between the bid values in the final column in the bid map (headed "2x20 MHz, 4xA1") and the bid values in the column headed "2x10 MHz, 2xA1", divided by 20 (to express in terms of £m per MHz). For example, £32.63m/MHz is derived as £1,798m for 4xA1 + 4xC less £1,145.478m for 2xA1 + 4xC divided by 20 (2x10) MHz (giving a figure of £32.6261m/MHz before rounding to two decimal places).

Table A6.22: EE's bid map for packages including only lot categories A1 (800 MHz without coverage obligation) and C (paired 2.6GHz)

			800 MHz included in package (A1 only)								
			0 MHz		2x5 MHz		2x10 MHz		2x15 MHz		2x20 MHz
			0xA1		1xA1		2xA1		3xA1		4xA1
2.6 GHz included in packages (C)	0 MHz	0xC	£ -	£ 230.000m	£ 230.000m	£ 420.001m	£ 650.001m	-	N/A	-	£ 1,176.622m
			-		-		-		-		-
	2x5 MHz	1xC	N/A	-	N/A	-	N/A	-	N/A	-	N/A
			-		-		-		-		-
	2x10 MHz	2xC	£ 30.000m	£ 230.000m	£ 260.000m	£ 605.000m	£ 865.000m	-	N/A	-	£ 1,445.478m
			£ 219.558m		£ 219.558m	*£ 385.442m*	£ 170.478m		-		£ 123.000m
	2x15 MHz	3xC	£ 249.558m	£ 230.000m	£ 479.558m	£ 555.920m	£ 1,035.478m	-	N/A	-	£ 1,568.478m
			£ 160.442m		£ 160.442m	*£ 395.478m*	£ 110.000m		-		£ 229.522m
	2x20 MHz	4xC	£ 410.000m	£ 230.000m	£ 640.000m	£ 505.478m	£ 1,145.478m	-	N/A	-	£ 1,798.000m
			£ 102.300m		£ 102.300m	*£ 403.178m*	£ 88.000m		-		-
	2x25 MHz	5xC	£ 512.300m	£ 230.000m	£ 742.300m	£ 491.178m	£ 1,233.478m	-	N/A	-	N/A
			£ 111.700m		£ 156.700m	*£ 334.478m*	£ 126.522m		-		-
	2x30 MHz	6xC	£ 624.000m	£ 275.000m	£ 899.000m	£ 461.000m	£ 1,360.000m	-	N/A	-	N/A
			£ 72.500m		£ 150.500m	*£ 310.500m*	-		-		-
	2x35 MHz	7xC	£ 696.500m	£ 353.000m	£ 1,049.500m	-	N/A	-	N/A	-	N/A
			£ 153.500m	*£ 199.500m*	-		-		-		-
	2x40 MHz	8xC	£ 850.000m	-	N/A	-	N/A	-	N/A	-	N/A

Source: Ofcom

Annex 7

Assessment of lump-sum values - supporting material

Introduction

A7.1 This annex provides additional material on the assessment of lump-sum values and supports Section 3. It covers:

- Identification of international auction prices from combinatorial auctions;
- Derivation of UK-equivalent prices;
- Role of absolute and relative benchmarks;
- The distance method; and
- Interpretation of benchmarks.

Identification of international auction prices from combinatorial auctions

A7.2 Our benchmarks are, whenever possible, based on information about the market value of specific lots awarded in European auctions. However, some of the awards included in our benchmarking work were combinatorial clock auctions (CCAs), in which the published prices are for winning packages which often include spectrum in more than one band. Unlike simultaneous multiple-round auctions (SMRAs), it is not possible to observe band-specific prices from these awards. However, with knowledge of the bids made it is possible to estimate band-specific prices (such as Linear Reference Prices, or LRPs).

A7.3 None of the other national regulatory authorities (NRAs) who conducted a combinatorial auction published bid data. However, we have approached these NRAs to request information which might allow us to estimate band-specific prices. This process and its outcome are described below.

Approach to other NRAs

A7.4 In January 2013 we contacted the six NRAs which had held CCAs from the beginning of 2010 in the relevant bands (the awards were of 2.6 GHz in Austria; 800 MHz in Denmark and multiple bands in Switzerland, Romania, the Netherlands and Ireland). We requested the disclosure of the full set of bids to us or, if this was not possible, to DotEcon, an independent consultancy which has advised us on this project, on the basis that DotEcon would then calculate LRPs from the bid data, without sharing the bid data with us.

A7.5 None of the NRAs we contacted were willing to disclose their bid data to us or DotEcon at that time. However, we engaged further with Ireland's Comreg after Vodafone submitted a confidential note to us which included a bar chart showing its best estimate of the price ratios for 800MHz, 900MHz and 1800MHz spectrum in the Irish CCA, based on the prices in the clock rounds of the auction in which supply matched demand for each frequency band. Comreg confirmed that the estimated price ratios (that we put to Comreg on the basis of Vodafone's bar chart) were reasonable indications of the ratios of, respectively, the final clock price for 900MHz relative to 800MHz spectrum and of the final clock price of 1800 MHz relative to 800MHz spectrum ("within a couple of percentage points").

A7.6 After the publication of the October 2013 consultation, further combinatorial awards took place in Austria, Norway, the Slovak Republic and Slovenia. In November 2013 we wrote to Austria's NRA, RTR, suggesting alternative approaches through which we might obtain band-specific price information from the Austrian CCA. RTR agreed to calculate LRPs using software developed by DotEcon. RTR provided us with results in April 2014 and we published this new evidence in our May 2014 update.

A7.7 In May 2014 we wrote to two other NRAs who had concluded a multiband CCA since our October 2013 consultation (the Slovak Republic and Slovenia), requesting information on similar terms to those we proposed to Austria.[30] Slovenia's NRA, AKOS, told us that it would not be able to do so at the present time. We did not receive a response from the Slovakian NRA.

A7.8 We also re-contacted the Swiss, Dutch and Irish NRAs asking if they would be willing to calculate LRPs using software to be developed by DotEcon.[31] Each of them replied that this approach raised confidentiality issues, and that they were unable to comply with our request.

Available evidence from combinatorial awards

A7.9 As a result of this engagement with other European NRAs our benchmarking sample now includes the following[32]:

[30] We did not request bid data from the Norwegian Post and Telecommunications Authority (NPTA). We considered that its auction was unlikely to be informative of market value, due to the significant risk of bid shading in this first-price sealed bid auction. We asked NPTA to comment on the relative price of different bands, but it declined to do so due to confidentiality.

[31] As regards the three other CCAs which took place before our October 2013 consultation: we have derived a 2.6 GHz price for Austria from winning packages which only included paired lots; for Denmark our estimated 800 MHz price is based on the larger package won by TDC; Romania is discussed in paragraph A7.10.

[32] AM&A (June 2014 response, p. 11) said that in the absence of additional information on CCAs from all regulators, the inputs to the UK 1800MHz lump-sum value should be restricted to data that is available in the public domain for all countries. We consider that it is appropriate to use all relevant information where it is available to us, and we see no reason to exclude potentially useful auction benchmarks on the basis of the unavailability of band-specific prices in other auctions.

i) For the 2012 Irish CCA, we estimated band-specific information on the basis of publicly available information and further evidence submitted by Vodafone and confirmed by Comreg (in the manner explained above). This methodology is detailed in Annex 7 (pages 98-99) of the October 2013 consultation.

ii) For the 2013 Austrian CCA, we obtained LRPs from RTR, as detailed in the May 2014 Update on European auctions.

A7.10 In addition, we use publicly available information about two further CCAs:

iii) For the 2012 Romanian award, we use reserve prices (and the present value of future spectrum fees) as an approximation of band prices, since the total revenue raised by the auction was only slightly above the sum of reserve prices.

iv) For the 2014 Slovakian CCA, we use reserve prices as an approximation of band prices, since the total revenue raised by the auction in the primary stage was not much higher than the sum of reserve prices (the package price of the new entrant and two incumbents was at reserve price, with only Slovak Telekom paying a price above reserve from the primary rounds).

A7.11 Our view is that we do not have sufficient information from the Dutch, Swiss, or Slovenian auctions to estimate band-specific prices accurately. This is because we cannot infer prices with sufficient accuracy from publicly available information, and we have been unable to obtain additional information from the relevant NRA to inform the analysis in this document.

Alternative methodologies

A7.12 Stakeholders proposed alternative methodologies to estimate band-specific prices from CCAs in the absence of access to the underlying bids data. We discuss the merits of these methodologies below.

Decomposition method

A7.13 Frontier, on behalf of Vodafone (Annex 1 to Annex 4), proposed a decomposition method to calculate band-specific prices for CCAs where necessary information is otherwise unavailable.[✂]

A7.14 [✂]

A7.15 [✂]

A7.16 [✂]. In light of our revised approach, which focuses on relative values and uses absolute values only as a high-level cross check, we do not consider that the output of this approach (in the form of estimated absolute values) provides significant additional information of relevance to our proposals.

Telefónica method

A7.17 Telefónica provided indicative band-specific prices for CCAs in the Slovak Republic, Slovenia and Switzerland. It calculated these prices by establishing as far as possible which bands sold for reserve price, and then estimated prices of other bands based on overall package prices. Telefónica said that limited weight should be applied to these numbers as benchmarks in isolation, but that they might be relevant as a sanity check of Ofcom's conclusions.

A7.18 This approach necessarily makes a number of assumptions. For example, in the case of Slovenia and Switzerland the results depend on an initial assumption about certain bands selling at reserve price as well as the order in which inferences are made about a band and the choice of bidder's package. There is also a risk that the band-specific price estimates will not be accurate, potentially by a large margin, if operators paid different prices (i.e. non-uniform prices, whether linear or not) for lots of spectrum in the same band (as can occur in CCAs). These risks are more material when the extent to which total revenues exceed the level implied by reserve prices is large.

A7.19 Given the number of assumptions that this method invokes, we consider that the resulting estimates carry a high degree of uncertainty when revenues imply band specific prices substantially above reserve prices. We have not adopted this method where this is the case (although we think an approximation can be used in the case of the Slovak Republic where revenues imply band specific prices that are at, or close to, reserve prices – see Annex 8).

Estimates by Analysys Mason and Aetha (AM&A)

A7.20 AM&A, on behalf of EE and H3G, consider evidence from CCAs as follows:

v) Where band-specific price information is available (e.g. clock prices in Ireland and LRP in Austria), they use this information in the distance method. We agree that this information can provide reasonable proxies of band-specific prices.

- For CCAs with total revenues close to the level implied by reserve prices, such as Romania, they consider that using reserve prices as a proxy for band-specific prices is reasonable. We agree that in these circumstances reserve prices are a reasonable proxy of band-specific prices, and we use them as such for Romania and the Slovak Republic.

- For CCAs with revenues substantially above reserve prices, they consider whether differences across bidders in the composition and price of packages, alongside assumptions on which bands likely sold at reserve price, allow inferences on the value of individual bands. They argue that band-specific prices can be reliably inferred for Switzerland and the Slovak Republic but not for the Netherlands, Norway and Slovenia. This is similar to Telefónica's proposed method above, where we noted its limitations. We have not adopted this method and we consider AM&A's treatment of specific countries in Annex 8.

Derivation of UK-equivalent prices

A7.21 This section sets out the sources and calculation method we have adopted in deriving UK-equivalent values by band from the auction prices in the benchmark countries.

Sources of information

A7.22 We have used the following sources of information about lot-specific auction prices and licence fees:

- The main source of information is DotEcon's database of spectrum auctions. This includes award-level information (such as date of the award) as well as lot-specific information. At lot level, the dataset reports both price information (such as reserve price, upfront fee and the future payments (by year) of fees levied on the licence) as well as other non-price information (such as lot size, licence duration, population covered).

- For CCAs, DotEcon's dataset generally only includes data about lot-specific reserve prices rather than realised lot prices.[33] Where total package prices were close to the sum of reserve prices (in Romania and the Slovak Republic) we used reserve prices as an approximation of band-specific prices.

- LRP information for CCAs where bidding data was available (UK) or we secured the NRA's co-operation to calculate LRPs without disclosure of bids data (Austria).

- Other evidence submitted by stakeholders about price levels in relevant auctions (e.g. Vodafone's submission about the Irish CCA).

- Publicly available information about lot characteristics (such as size, length of the licence term, any applicable coverage obligations or liability to mitigate DTT interference issues), reserve prices, auction prices (at package or lot level) and future fees levied on spectrum licences.

A7.23 In deriving UK-equivalent prices from this information, we have used the following information sources:

vi) Time series of the "CPI All Items Index" and the UK population from the 2011 Censuses, from the UK Office for National Statistics.[34]

vii) Time series of the "PPP conversion factor, GDP (local currency unit per international $)" from the World Bank as our measure of purchasing-power parity.[35]

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[33] There are some limited exceptions, for example when a winning package contains only lots from one band.

[34] Available at http://www.ons.gov.uk/

[35] Available at http://data.worldbank.org/indicator/PA.NUS.PPP

viii) Figures for the post-tax real weighted average cost of capital and cost of debt from the 2011 Review of Mobile Call Termination Charges, updated for the lower corporation tax rate (respectively equal to 4.7% and 2.4%), as explained in Section 4.

Derivation of spectrum values in benchmark countries

A7.24 The following paragraphs describe the steps for adjusting the value of spectrum bands in the benchmark dataset so that they are placed on a consistent basis.

Future licence fees

A7.25 To calculate the overall value of spectrum, we add upfront prices resulting from bids in the auction and the present value of future licence fees discounted at the rate of 2.4% (post-tax, real cost of debt).[36] These values are all expressed in local currency at this stage.

Licence duration

A7.26 To account for different lengths in the licence term, we adjust the value to represent a 20-year (240-month) period, comparable to the initial term of UK licences awarded in the 4G auction. We do so by applying the following adjustment factor, assuming the benchmark licence has a duration of *T* months and using a post-tax real WACC of 4.7%:[37]

$$\sum_{t=0}^{239}\left(\frac{1}{(1+WACC)}\right)^t \Big/ \sum_{t=0}^{T-1}\left(\frac{1}{(1+WACC}\right)^t$$

Delayed availability of spectrum

A7.27 We are aware of two instances where there was a substantial period of time between the auction and the date the spectrum became available to winning bidders:

ix) In the case of 800 MHz in Spain awarded in July 2011, the spectrum could only be used after the completion of the Digital Switchover in 2015.

x) In the case of 900 MHz and 1800 MHz in Austria, the spectrum would become (totally or partially) available to winners only from 2016.

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[36] Please note that this is different from the post-tax real cost of debt of 2.6% which we propose using to convert lump sum values into ALF (see Section 4, paragraph 4.25). The reason for using the 2.4% rate in the present context is explained in Section 4, paragraph 4.29.

[37] Please note that we propose using a WACC in this context, whereas we propose using a cost of debt rate to convert lump sum values into ALF, for reasons explained in Section 4, paragraph 4.26

A7.28 For these benchmarks we have calculated a "gestation adjustment" to allow for the fact that observed auction prices likely reflect the value of the licence at the date the spectrum becomes available for use, discounted back to the date of the auction.

Conversion to UK equivalents

A7.29 The next step in our calculation relates to the conversion from local currency prices (in most cases, euros) to pounds sterling. We use PPP conversion factors from the World Bank,[38] taking the ratio of the PPP factor for the UK and the PPP factor for the benchmark country, both in the year when the auction took place. When PPP factors were unavailable (that is, 2013 and 2014), we used linear extrapolation from the two nearest available data points.[39]

A7.30 We then adjust for inflation between the date of the auction in the benchmark country and the start date of licences awarded in the UK 4G auction (that is, 1 March 2013). The adjustment factor is the ratio between the value of the monthly CPI index for March 2013 and the value at the time of the benchmark auction.

A7.31 For comparability, we calculate benchmarks expressed as £ per MHz per head of population. We calculate UK-equivalent values by multiplying benchmarks by the ratio of the benchmark country population to the UK population recorded in the 2011 Census, expressed as "£m per MHz".

Coverage and co-existence

A7.32 To ensure that our benchmarking captures the market value of spectrum licences in the UK, it is necessary to consider whether lots awarded in benchmark countries have characteristics comparable to the UK 4G auction licences. In the rest of this section, we set out how we approached:

a) Differences in coverage obligations for lots in each band; and

b) Issues related to DTT co-existence (for 800 MHz only).

Coverage obligations

A7.33 The UK licences for 900 MHz, 1800 MHz and 2.6 GHz spectrum do not have coverage obligations attached to them. The extent to which a coverage requirement is onerous in a benchmark country depends on the level of coverage an operator would have sought to achieve for commercial reasons in the absence of such an obligation.

A7.34 We have included all available lots of 900 MHz, 1800 MHz and 2.6 GHz, irrespective of their coverage obligations in our dataset, and consider the

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[38] http://data.worldbank.org/indicator/PA.NUS.PPP

[39] As noted in Section 3, paragraph 3.12, the focus of our revised approach on relative values makes the issue of currency conversion less relevant to the result.

implications of the coverage obligations qualitatively if and when necessary. As part of our analysis of individual awards in Annex 8 we set out coverage obligations by band. In principle, were we to consider that such obligations are likely to require deployments significantly in excess of commercial levels then we would consider that the auction price could risk understating the value of that band in the UK in our assessment. In the event, we do not consider that this is the case in these bands for any of the countries in the dataset.[40]

A7.35 For 800 MHz, the UK 4G auction includes one lot subject to coverage obligation (A2 lot category) and four generic lots without coverage obligations (A1 lot category, which attracted a small but material price premium over A2). For consistency of treatment in deriving relative benchmarks, we therefore consider the basis of the 800 MHz price in the benchmark country (as regards coverage obligations) and identify the most closely corresponding 800 MHz lot category in the UK to enable a like-for-like comparison. In particular we adopt the following approach:

a) When price differentials between specific 800 MHz lots in the benchmark country can be ascribed to differences in coverage obligations over and above commercial levels, we include only blocks without, or with less onerous, coverage obligations in the calculation of an average price of 800 MHz for the benchmark country, .[41] We then use the nearest equivalent lots for 800 MHz in the UK (i.e. A1, without coverage obligation) when deriving the relative benchmark.

b) When there are no differences in coverage obligations across 800 MHz lots in the benchmark country, we calculate the value of 800 MHz as the average of all available lots. We then consider whether or not the obligation (on all 800 MHz lots) was likely to be onerous (i.e. requiring substantially more coverage than would be provided otherwise). Where there is a basis for believing coverage obligations to be onerous, then we use the UK A2 value in the derivation of relative benchmark; otherwise we use the UK A1 value.

DTT co-existence costs

A7.36 When deriving relative benchmarks we also consider whether some (or all) 800 MHz lots are affected by DTT co-existence costs.

a) In some benchmark countries we observe price differentials between different 800 MHz lots that are likely related to DTT co-existence costs (this is sometimes the case for one or two lots at the bottom of the 800 MHz band). In these cases, we take the average price of the 800 MHz lots which are less likely to be subject

[40] For example, a coverage obligation applied to 900 MHz in Ireland, Romania, Slovenia and Switzerland; to 1800 MHz in Czech Republic, Ireland, Romania, Slovenia and Switzerland; and in the 2.6 GHz band in Czech Republic, Italy and Romania. We consider that none of these obligations are likely to require coverage substantially in excess of the commercial level.

[41] The only exception to this is Denmark, where we use the larger 2x20 MHz lot which was subject to a coverage obligation. This is because the other 800 MHz lot, which did not include a coverage obligation, was affected by DTT co-existence costs (as we discuss in the next section).

to DTT co-existence costs. We then calculate relative benchmarks (that is, the 900 MHz / 800 MHz paired ratio and the distance method benchmark for 1800 MHz) using the UK market value of 800 MHz gross of DTT co-existence costs.

b) In other benchmark countries, we do not observe differentials in auction prices across the 800 MHz lots that are likely related to DTT co-existence costs. In these cases, we assume that DTT co-existence costs were positive and that all 800 MHz lots were equally affected so that all bids were reduced by the expected amount of DTT co-existence costs. Accordingly, we take the average of all lots to derive the value of 800 MHz in the benchmark country. We then apply the relevant paired ratio or Y/X ratio to the UK market value of 800 MHz net of DTT co-existence costs.[42]

Role of absolute and relative benchmarks

A7.37 As explained in paragraphs A7.24-A7.31, the derivation of absolute values expressed in UK terms requires us to make a number of adjustments to international benchmarks. We have essentially made four such adjustments, for: (a) differences in licence duration and start date; (b) differences based on purchasing power parity; (c) inflation rates between the auction in the benchmark country and 1 March 2013; and (d) differences in population.

A7.38 More generally, we consider that there are a number of country-specific factors which have the potential to affect auction prices in comparator countries relative to the UK. Licence holders argued to varying degrees that, for this reason, absolute auction prices may not provide reliable indicators of the value of spectrum in the UK.

A7.39 Some of the factors identified by licence holders, such as income levels and willingness to pay for mobile services, will be reflected in the PPP estimates which we have used to derive absolute benchmarks. However, there are other country-specific factors that may drive differences in auction values that are not (and cannot easily be) accounted for in our analysis. We accept that the presence of such country-specific factors tends to increase the uncertainty of absolute values in other countries as benchmarks for the UK.

A7.40 Some of the factors identified by licence holders could potentially affect some spectrum bands more than others. For example lower frequency bands have better propagation characteristics, and may tend to be more valuable in countries which are less urbanised or which have lower population density. For this reason, we have considered in paragraphs A7.58 to A7.85 whether specific factors mean that

[42] The level of DTT co-existence cost expected by bidders is not observable and may vary substantially across countries. We do not have a basis for adjusting the 800 MHz prices in the benchmark countries. We recognise that our approach may not be accurate where DTT co-existence costs in the benchmark country are significantly different from the UK (as a proportion of the value of 800 MHz. We note that our approach generates lower benchmarks than using UK market value of 800 MHz gross of co-existence costs.

benchmarks based on *relative* values will tend to overstate or understate values in the UK.

A7.41 However, in general we expect that relative values are less likely to be affected by country-specific factors than absolute values.

The distance method

A7.42 We have adopted the distance method proposed by AM&A as our preferred method for deriving benchmark values of 1800 MHz spectrum. Benchmark values of 1800 MHz generated by the distance method reflect the UK auction values of both 800 MHz and 2.6 GHz spectrum in the UK auction. We consider that, in principle, this is an advantage over the paired ratios of 1800 MHz to 800 MHz and 2.6 GHz spectrum.

Derivation

A7.43 The distance method can be seen as reflecting the proposition that the relative distance between the values of the 1800 MHz band and the 800 MHz and 2.6 GHz bands should be consistent between countries, and in particular that:

$$\frac{1800_{UK} - 2.6_{UK}}{800_{UK} - 2.6_{UK}} = \frac{1800_{BC} - 2.6_{BC}}{800_{BC} - 2.6_{BC}}$$

where 1800_{UK} is the value of 1800 MHz in the UK, 1800_{BC} is its value in the benchmark country, etc. This implies in turn that an estimate of the value of 1800 MHz in the UK can be calculated as:

$$1800_{UK} = \frac{1800_{BC} - 2.6_{BC}}{800_{BC} - 2.6_{BC}} \, x \, (800_{UK} - 2.6_{UK}) + 2.6_{UK}$$

(a) (b) (c)

A7.44 This equation can be seen as having three components, labelled (a) to (c) above. Component (a) is the ratio between the price premium commanded by 1800 MHz over 2.6 GHz spectrum and the price premium commanded by 800 MHz over 2.6 GHz in the benchmark country. Component (b) is the price premium commanded by 800 MHz over 2.6 GHz spectrum in the UK. Component (c) is the UK value of 2.6 GHz spectrum. Only the first of these components, which we refer to as the Y/X ratio, is affected by the values of spectrum in the benchmark country.

A7.45 In a benchmark country for which the equivalent UK 800 MHz value is £32.63m/MHz[43] (and taking the value of 2.6 GHz in UK as £5.5m/MHz), the distance method value is:

[43] This is our estimate net of coexistence costs and with no coverage obligation.

$$1800_{UK} = \frac{1800_{BC} - 2.6_{BC}}{800_{BC} - 2.6_{BC}} x\ (£27.13) + £5.5m$$

Proxies for the value of 2.6 GHz and 900 MHz

A7.46 AM&A suggested applying the distance method in countries where 2.6 GHz spectrum had not been auctioned by using zero as a proxy for the 2.6 GHz value. They note that this provides an upper bound for the value of 1800 MHz in the UK under the distance method, as the true value of 2.6 GHz spectrum could not be below zero.

A7.47 We consider it would be more appropriate to use a non-zero proxy for the value of 2.6 GHz spectrum in countries where this band has not been auctioned since the start of 2010, namely Ireland and Sweden. This will result in a lower distance method estimate for 1800 MHz in UK by comparison with AM&A's proposed proxy of zero.

A7.48 The table below shows UK and international results where both 800 MHz and 2.6 GHz spectrum was auctioned, together with the resulting ratio of 2.6 GHz to 800 MHz.

Table A7.1: Ratios of 2.6 MHz to 800 MHz values

£m/MHz (UK equivalent)	800 MHz	2.6 GHz	2.6 GHz / 800 MHz ratio
Austria (2010; 2013)	72.2	1.9	3%
Belgium (2011; 2013)	30.0	5.0	17%
Czech Republic (2013)	44.1	3.0	7%
Denmark (2010; 2012)	16.2	10.3	64%
Germany (2010)	52.9	1.6	3%
Italy (2011)	52.1	3.8	7%
Portugal (2011)	37.3	2.5	7%
Romania (2012)	43.9	10.6	24%
Slovak Republic (2013)	38.5	4.6	12%
Spain (2011)	40.4	3.3	8%
UK (2013)	32.6	5.5	17%

A7.49 The average (geometric mean) of the ratio in the ten countries is between 9.6% and 10.7%, according to whether this is calculated using values of 800 MHz spectrum gross of co-existence DTT costs (as shown) or net of DTT co-existence costs respectively.[44] Using this ratio we can derive proxy values of 2.6 GHz in Ireland and Sweden (respectively on a net (10.7%) and gross (9.6%) basis) for use in deriving the distance method benchmarks. The results are shown in the table below.

Table A7.2: Proxy values of 2.6 GHz spectrum for distance method

£m/MHz (UK equivalent)	800 MHz	1800 MHz	Proxy 2.6 GHz	Distance method
Ireland (2012)	63.5	25.2	6.8	14.3
Sweden (2011)	21.2	9.7	2.0	17.5

A7.50 In Greece, where neither 800 MHz nor 2.6 GHz was awarded, AM&A proposed to use the value of 900 MHz as a proxy for the value of 800 MHz (as well as using a proxy of zero for 2.6 GHz). However, as explained in Annex 8, our preference is to use Greece as an additional evidence point for the 1800 MHz / 900 MHz ratio cross-check, rather than to use it to derive a distance method benchmark based on two proxies.

Effect of risk of overstatement or understatement of UK market value in band-specific prices

A7.51 The effect of a risk that a benchmark overstates or understates UK market value in the price of a spectrum band in a benchmark country band will be to change the Y/X ratio set out above, which is:

$$\frac{1800_{BC} - 2.6_{BC}}{800_{BC} - 2.6_{BC}}$$

A7.52 The effect on the Y/X ratio depends on the band:

- An overstated 1800 MHz value will increase the ratio, leading to an overstated distance method benchmark;
- An overstated 800 MHz value will reduce the ratio, leading to an understated distance method benchmark;

[44] For countries where it was not possible to identify two 800 MHz benchmarks (one net of DTT co-existence costs, and one gross of these), we have estimated the missing benchmark on the basis of the observed 800 MHz benchmark in the country, adjusted for DTT co-existence cost by a multiplicative factor equal to the ratio of estimated DTT co-existence cost in the UK (that is, £3m per MHz) and the value of 800 MHz in the UK (with or without coverage obligation, in line with the available 800 MHz benchmark in the country).

- If 800 MHz is greater than 1800 MHz in the benchmark country, an overstated 2.6 GHz value will reduce the ratio, leading to an understated distance method benchmark.[45]

A7.53 The effect of an understated or overstated Y/X ratio on the distance method benchmark depends on the relative distance between bands in the benchmark country:

- In countries where the Y/X ratio is low (such as Germany, Portugal and the Czech and Slovak Republics) the distance method benchmark largely reflects the UK value of 2.6 GHz, so a moderate understatement or overstatement in the prices of bands in the benchmark country's auctions will tend to have a limited effect.

- In countries where there is a higher Y/X ratio, such as Austria, Italy and Romania the potential effect of an understatement or overstatement in band prices on the distance method benchmark will tend to be greater.

- In countries where the observed 2.6 GHz value is relatively low (compared to both 800 MHz and 1800 MHz), such as Austria and Italy, even a large percentage increase or decrease in the value of 2.6 GHz spectrum has little effect on the distance method benchmark.

Comparison with paired ratios

A7.54 The following table compares distance method benchmarks for 1800 MHz with the paired ratio to 800 MHz.

Table A7.3: Paired ratios of 1800 MHz to 800 MHz

	Austria	Ireland	Italy	Germany	Sweden	Portugal	Romania	Czech Rep	Slovak Rep
Distance method	25.5	14.3	13.5	5.6	17.5	6.1	12.0	7.5	7.5
Paired ratio	24.0	13.0	11.4	1.2	16.3	2.8	13.5	4.4	6.0
% difference	-6%	-9%	-16%	-78%	-7%	-53%	12%	-41%	-20%

A7.55 The 1800 / 800 MHz paired ratio benchmarks are lower than distance method benchmarks in all countries except Romania. This result reflects the fact that the value of 2.6 GHz relative to 800 MHz is higher in the UK than in most benchmark countries.

[45] To take a very simple example, suppose that the true values for 1800 MHz, 800 MHz and 2.6 GHz are 2, 3 and 0 respectively, but the observed 2.6 GHz value is 1. The correct ratio is 2/3 or 67%, but the observed ratio will be ½ or 50%.

A7.56 Table A7.4 compares distance method benchmarks for 1800 MHz with the paired ratio to 2.6 GHz.

Table A7.4: Paired ratios of 1800 MHz to 2.6 GHz

	Austria	Italy	Germany	Portugal	Romania	Czech Rep	Slovak Rep
Distance method	25.5	13.5	5.6	6.1	12.0	7.5	7.5
Paired ratios	140.7	24.2	6.2	7.2	9.9	11.0	8.4
% difference	452%	78%	11%	18%	-17%	47%	13%

A7.57 The 1800 MHz / 2.6 GHz paired ratio benchmarks are higher than distance method benchmarks in all countries except Romania. This result also reflects the fact that the value of 2.6 GHz relative to 800 MHz is higher in the UK than in most benchmark countries.

Interpretation of benchmarks

Country-specific factors

A7.58 In light of October 2013 consultation responses, we have considered whether there are country-specific factors which we should take into account in interpreting benchmarks.

A7.59 Vodafone (Annex 4, page 9) said that we had failed to consider many important country-specific factors and the extent to which these might affect auction prices relative to UK values. Vodafone identified three main factors that it suggested are likely to drive spectrum value to a significant extent: market profitability; demand for 2G spectrum; and urbanisation.

A7.60 We discuss these factors in turn below. In each case we have presented evidence relating to the empirical relationship between the proposed spectrum value driver and observed auction prices (by band), based on the sample of countries in our benchmarking exercise, to see whether or not this provides support for the hypothesis in question.

A7.61 We also discuss the potential significance of the date of the award for the interpretation of market value.

Market profitability

A7.62 We first consider Vodafone's suggestion that market profitability is a key driver of spectrum value, which can affect the relevance of international benchmarks.

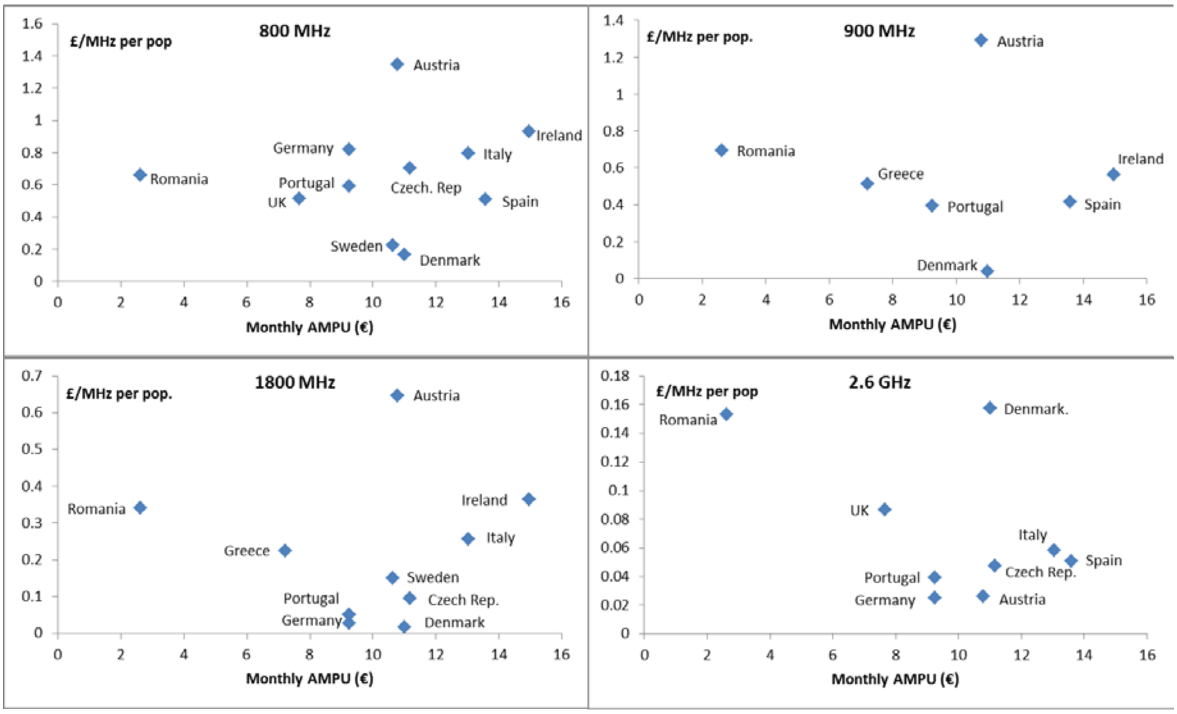
A7.63 If mobile sector profitability has a consistent effect on auction prices, it is not clear that this would differ between spectrum bands. We therefore consider that any such effect is likely to be of limited importance to the assessment of relative benchmarks on which our analysis now focuses.

A7.64 In addition, the argument that markets with higher profitability can be expected to exhibit higher auction prices appears to rest on the proposition that bidders will compete away their downstream profits in inflated auction prices for spectrum.

A7.65 If a market has fewer incumbents and limited expectation of entry, future profits may be expected to be high, but there is also a risk that competition in auctions will be limited (due to the smaller number of bidders), in which case high expected profitability may not be reflected in high spectrum prices. In Annex 8, we have considered specific evidence as to the level of competition in auctions (such as restrictions placed on incumbent bidders). However, in general, we expect that auctions with fewer bidders will tend to be less competitive than auctions with more bidders, while mobile markets with fewer competitors will tend to be more profitable than those with fewer competitors. This suggests that the relationship between market profitability and auction prices is not clear-cut.

A7.66 Evidence as to the relationship between average margin per user (AMPU) and auction prices is presented in Figure A7.1 below. The scatter plots are based on a small number of evidence points, as we have limited the analysis to auctions included in our benchmarking sample. We consider these scatter plots do not provide clear evidence of a positive relationship in any of the relevant spectrum bands, or collectively.

Figure A7.1: AMPU scatter plots[46]



AMPU figures taken from Vodafone May 2012 "Spectrum: renewal and pricing in Europe" (http://www.vodafone.com/content/dam/vodafone/about/public_policy/policy_papers/public_policy_series_14.pdf)

A7.67 In summary, we do not consider that there are strong grounds in principle for expecting that a more profitable mobile sector will be associated with higher spectrum auction prices. Nor does the available evidence provide support for such a relationship. Furthermore, even if such a relationship existed, it is not clear that this would materially affect the relative value of different bands.

Demand for 2G spectrum

A7.68 We also consider Vodafone's argument that, other things being equal, the value of spectrum bands suitable for provision of 2G services (i.e. 900 MHz and, to a lesser extent, 1800 MHz) is likely to be higher in countries where demand for 2G services is significantly higher (proportionately) than in the UK.

A7.69 While 1800 MHz has previously been a major GSM band, and continues to support some legacy 2G networks, it is now (as we discuss below) also a major LTE band supporting 4G services. As a result, it is not clear that the UK's comparatively low share of 2G subscribers means that the market value of 1800 MHz spectrum will be lower than in, for example, Greece or Romania. Rather, we consider that the value of 1800 MHz is likely to be driven to a substantial extent by the opportunity it provides to offer 4G services. As a result, we do not consider there are strong grounds in principle for considering that the market value of 1800 MHz spectrum should be higher in countries with higher demand for 2G services.

[46] We note that the scatter plots do not include data for the Slovak Republic.

A7.70 On the other hand, 900 MHz spectrum may be more valuable in countries with higher demand for 2G services, as this band continues to support operators' existing GSM operations. However, we note that:

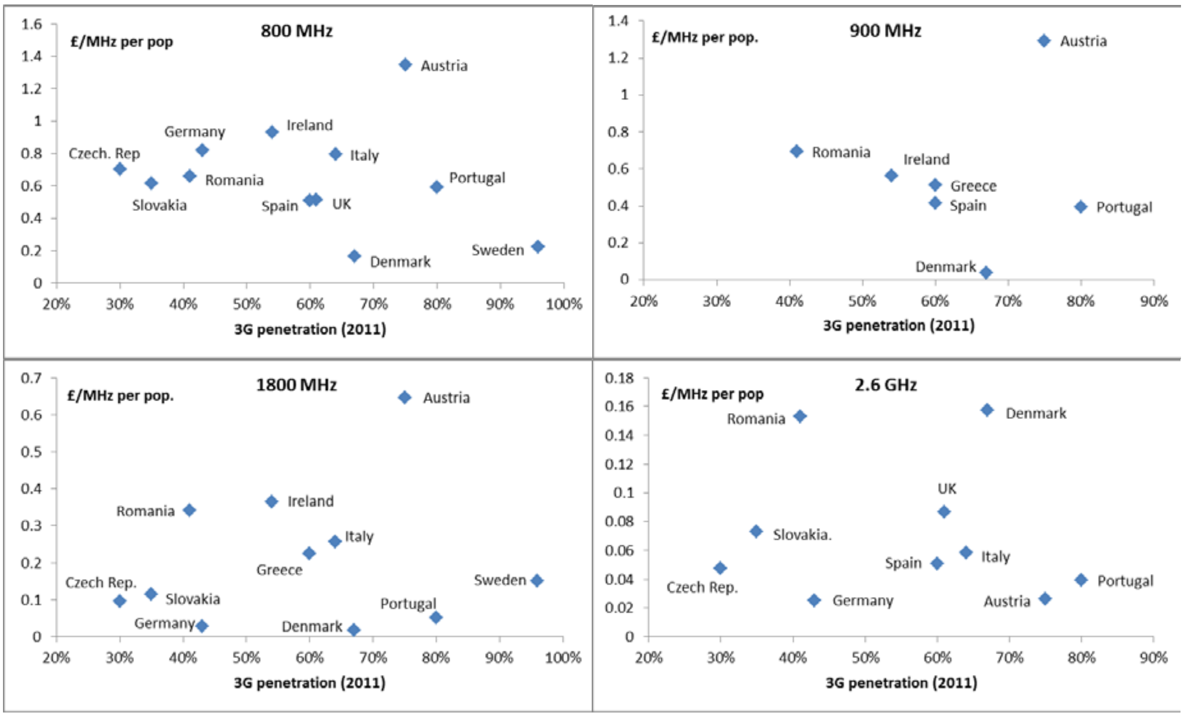
a) Auction prices are generally determined by the value of the marginally excluded bidder. As a result, bidders seeking to retain their right to 900 MHz spectrum (which they need in order to serve current demand) may well have a higher value for this spectrum in countries with a high level of 2G traffic, but this will not necessarily be reflected in auction prices if other operators do not have similar considerations relating to legacy services.

b) As spectrum licences are typically awarded for long periods of time, auction prices are likely to reflect the forward-looking value of spectrum, as well as the short term need for operators to serve current traffic. The relative importance of different technologies, which may be associated with certain bands, will likely change substantially over the period for which licences are awarded.

A7.71 We have also considered the available empirical evidence. Vodafone provided data in their submission which aimed to reflect differences in 2G traffic levels across benchmark countries, but this was confidential. However, Vodafone’s argument implies that 900 MHz and 1800 MHz spectrum should be valued more highly in countries with relatively high 2G traffic than in countries where a majority of customers are using 3G and 4G enabled devices, and so access to GSM bands is less vital for serving customers. This suggests a negative relationship between 3G penetration rates and auction prices for the ALF bands.

A7.72 We present scatter plots of 3G penetration and auction prices in Figure A7.2 below. These scatter plots do not indicate that there is a negative correlation between these factors for the 900 MHz and 1800 MHz bands. This evidence does not therefore provide support for the argument that the ALF spectrum bands are valued more highly in countries where there is higher demand for 2G services..

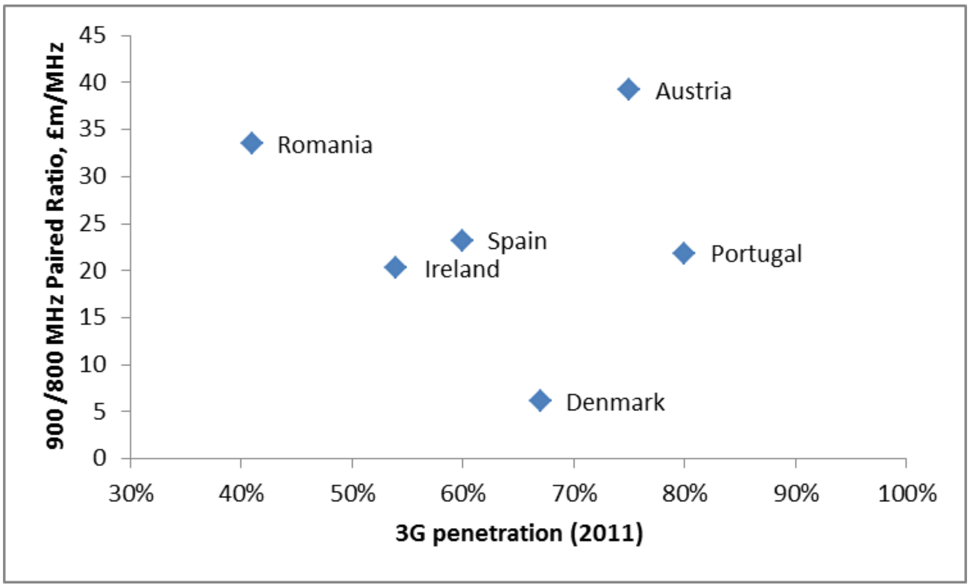
Figure A7.2: 3G penetration scatter plots



3G penetration refers to the proportion of the population carrying a 3G-enabled handset. Figures are taken from GSMA European Mobile Industry Observatory 2011 (available at: http://www.gsma.com/publicpolicy/wp-content/uploads/2012/04/emofullwebfinal.pdf).

A7.73 In addition to looking at the absolute value of auction prices by band, we also consider the relationship between 3G penetration and the 900 MHz / 800 MHz paired ratio, presented in Figure A7.3 below. Comparing 3G penetration rates against a relative value – the 900 MHz / 800 MHz paired ratio – should in principle control for the presence of other country-specific factors. However, benchmarks from the six countries on which we have data do not provide evidence of a negative relationship.

Figure A7.3: 900 MHz / 800 MHz paired ratio to 3G penetration



A7.74 In summary, we consider that in principle there may be a positive relationship between the value of 900 MHz in a country and the importance of 2G, but we do not have evidence to confirm this. Our approach is to take account of demand for 2G services only in specific instances where there is, in our view, clear evidence that it is particularly relevant to that country (in particular we do so for Romania).

Urbanisation

A7.75 The propagation advantages of low frequency spectrum mean that mobile networks in areas with lower population density are less costly to serve with sub-1 GHz spectrum. This is consistent with the suggestion by Vodafone that sub-1 GHz spectrum is likely to be more valued in less urbanised countries. However, sub-1 GHz spectrum also provides advantages in providing coverage deep indoors in urban areas.[47] As this effect works in the opposite direction, it is ambiguous as to whether, in principle, the value of sub-1 GHz spectrum is higher in countries which are less urbanised than the UK.

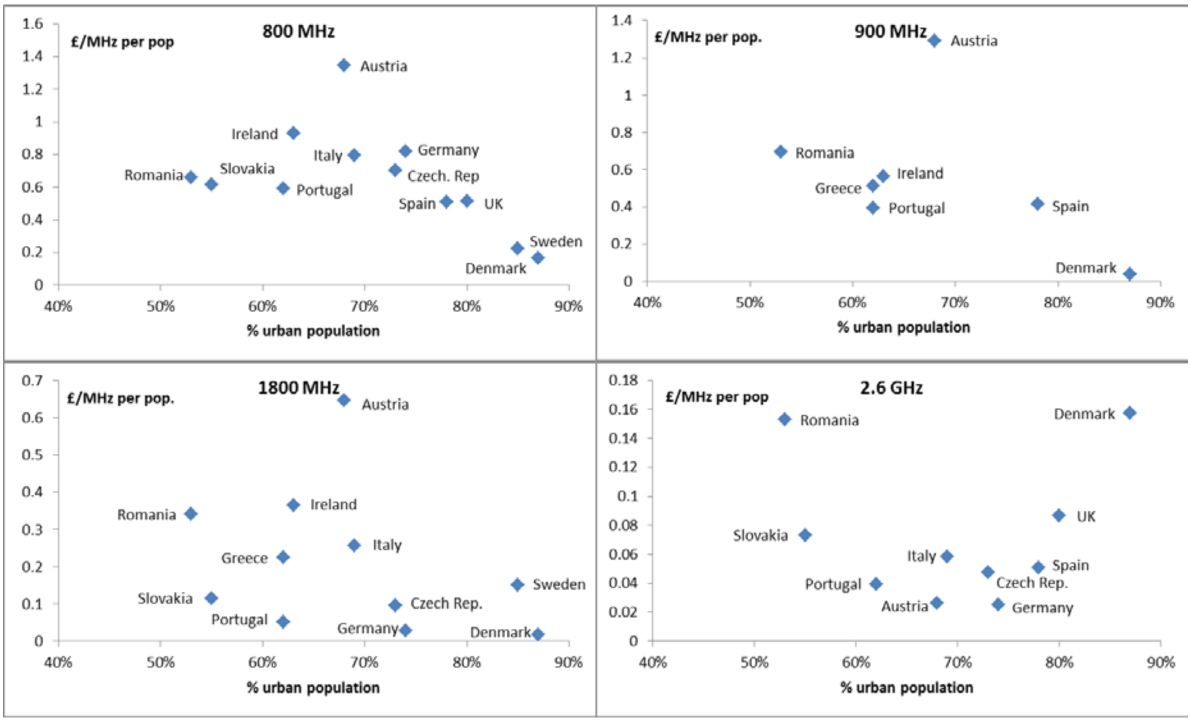
A7.76 We have considered whether there is an empirical relationship between auction prices and urbanisation. The scatter plots in Figure A7.4 below:

a) Are broadly consistent with a negative relationship between urbanisation and auction prices for sub-1 GHz spectrum. This is slightly clearer in the case of 800 MHz than 900 MHz;

b) Do not provide evidence of a relationship between urbanisation and auction prices for 1800 MHz or 2.6 GHz spectrum.

[47] Paragraph 4.82, Ofcom, *Assessment of future mobile competition and award of 800 MHz and 2.6 GHz*, Statement (24 July 2012)

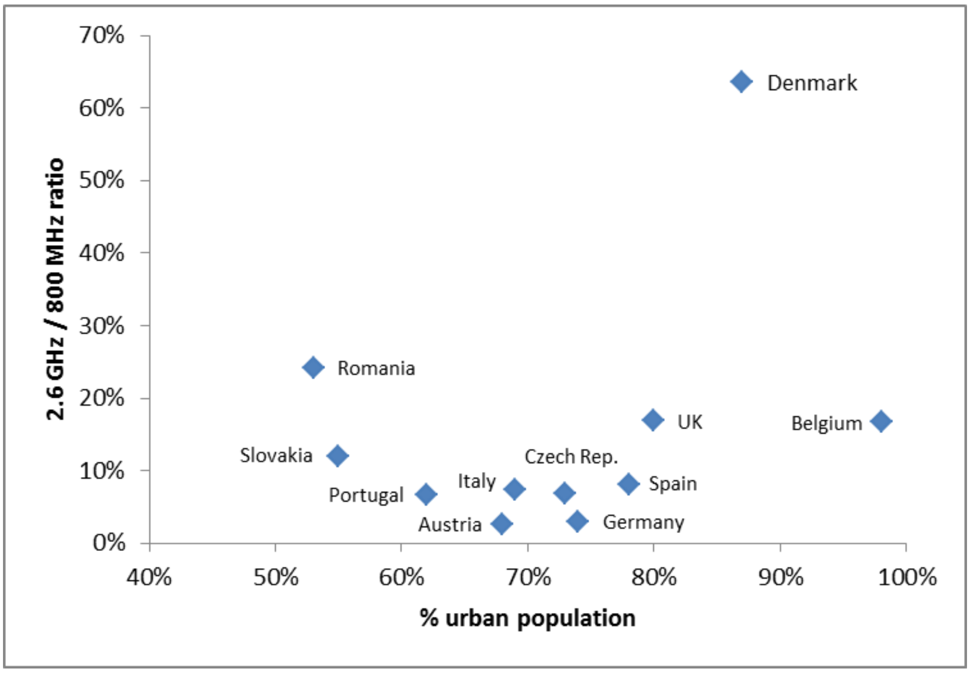
Figure A7.4: Urbanisation scatter plots



Urbanisation data taken from World Bank (http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS)

A7.77 We also consider the relationship between urbanisation and the ratio of 2.6 GHz and 800 MHz auction prices, presented in Figure A7.5. Under Vodafone's hypothesis, we would expect this ratio to display a positive correlation with urbanisation levels because more urbanised countries would value 2.6 GHz relatively more than sub-1 GHz spectrum. However the scatter plot does not provide clear evidence of such a relationship. We note that, although the 2.6 GHz / 800 MHz ratio for Denmark (a highly urbanised country) is particularly high, the particular circumstances of the Danish auction for 800 MHz (which we discuss in Annex 8) may have contributed to a low price, and in any case there is not a clear pattern of correlation.

Figure A7.5: 2.6 GHz / 800 MHz ratio to urbanisation levels



A7.78 These results need to be treated with some caution in view of the limited number of evidence points in each band, and the level of variability. On balance we consider that it is appropriate to take account of substantial differences in urbanisation when interpreting our benchmarks for the UK market value. In countries which are less urbanised than the UK, we consider this creates a risk (other things being equal) that the market values of 800 MHz and 900 MHz may overstate the UK market values of these bands. In these cases we consider that the likelihood of overstatement, and the scale of any potential overstatement, is unknown.

Date of award

A7.79 We have also considered whether the timing of awards may have affected the value of spectrum. Specifically, the development of LTE ecosystems for the 900 MHz and 1800 MHz bands over recent years may have increased the value of these bands to excluded bidders, and hence their auction prices. If so, older auction results may understate the current value of these bands in the UK.

A7.80 The **900 MHz** band is not currently a core LTE band, and is still commonly used for GSM and UMTS services; we are aware of only a limited number of examples of deployments of LTE900 networks from operators in Sweden and the Czech Republic towards the end of 2013. However this may be due, in part, to operators finding it difficult to free enough 900 MHz spectrum from legacy services for use with new technologies, although this consideration is less relevant from the perspective of the valuation of the spectrum by a marginal excluded bidder.

A7.81 The number of LTE devices on this band has been increasing since 2012, and we noted this in our February 2013 *Consultation on variation of 900 MHz, 1800 MHz and 2.1 MHz mobile licences,*[48] which was published during the UK 4G auction and so is likely to be reflective of expectations at that time.

A7.82 While the increasingly developed ecosystem may make LTE use for 900 MHz networks more common in the future, the timing of this is currently uncertain due to the issues in re-farming spectrum. We consider that there is limited evidence of a change in LTE900 expectations over the period of auctions we are considering, and we do not take this factor into account in our interpretation of benchmarks.

A7.83 In the case of **1800 MHz**, we have considered the following evidence relating to the development of LTE1800:

- Network deployments: An LTE1800 network was first deployed in Europe by CenterNet and Mobyland (Poland) in September 2010. In March 2011, T-Mobile announced its intention to deploy an LTE1800 network in Germany[49]; this was launched four months later in July 2011. In November 2011, we received an application from EE to use its 1800 MHz licences for LTE services. We consulted on this issue, saying we were minded to vary EE's licence to allow LTE use, in March 2012, [50] before approving the request in an August 2012 statement. By September 2012, 33% of LTE networks had been launched on the 1800 MHz band.[51]

- Device compatibility: There were a number of LTE1800-enabled devices available at the beginning of 2011. The LTE1800 ecosystem developed rapidly during the first half of 2012, and in the March 2012 consultation mentioned above we stated that LTE1800 equipment was commercially available. By April 2012 there were more LTE devices compatible with 1800 MHz than with 800 MHz[52], and this trend was reinforced in September 2012 by the launch of the iPhone 5 supporting LTE1800 but not LTE800.

A7.84 In light of the available evidence, we consider that:

- Increased interest in Europe in 1800 MHz for LTE can reasonably be dated between late 2011 and early 2012. As noted above, in March 2012 we published a notice setting out our intention to vary EE's 1800 MHz licences to enable it to

[48] Table 1, Ofcom, *Consultation on variation of 900 MHz, 1800 MHz and 2.1 MHz mobile licences*, February 2013, http://stakeholders.ofcom.org.uk/binaries/consultations/variation-900-1800-2100/summary/condoc.pdf

[49] http://www.gsma.com/spectrum/wp-content/uploads/2012/03/gsaalanhadden1800mhzworkshop250311.pdf

[50] Table 2, Ofcom, *Notice of proposed variation of Everything Everywhere's 1800 MHz spectrum licences to allow use of LTE and WiMax technologies,* March 2012, http://stakeholders.ofcom.org.uk/binaries/consultations/variation-900-1800mhz-lte-wimax/summary/condoc.pdf

[51] GSA report, http://www.gsacom.com/news/gsa_360.php

[52] This is based on data from GSMA.

provide services using LTE technology in those frequencies, as it requested in November 2011. Leading consumer devices with LTE1800 also appeared in 2012. Auctions which took place after early 2012 are therefore likely to reflect the emergence of an LTE1800 ecosystem.

- It is possible that operators would have anticipated in mid-2011 the development of the 1800 MHz LTE ecosystem, and factored this into their auction strategies accordingly. However, we do not have clear evidence that this was the case. We consider that uncertainty around the ecosystem may have meant that the value of 1800 MHz was lower (by comparison with 2013 valuations) to some degree in auctions conducted in 2011 (Italy, Sweden and Portugal). We consider there is an unknown risk that the market value of 1800 MHz in these auctions understates the UK market value of 1800 MHz, but at a smaller scale of potential understatement.

- For auctions conducted before 2011 (Germany and Denmark), there was much less certainty about the LTE1800 ecosystem. This may have led 1800 MHz to be considerably undervalued (by comparison with 2013 valuations) in auctions conducted in 2010. We consider there is a larger risk that the market value of 1800 MHz in these auctions understates the UK market value of 1800 MHz, at a larger scale of potential understatement.

A7.85 The above paragraphs discuss the relevance of the date of an award with respect to the use of 900 MHz and 1800 MHz for LTE. Our view is that the position of these bands for 3G has not changed materially over the period of the awards we have considered. The 900 MHz band has been used to provide 3G services for several years. In contrast, it is unlikely that much value has been attached to the prospective use of the 1800 MHz band for 3G, particularly since the recent migrations from 2G in the 1800 MHz band (where they have happened) have been from 2G to LTE.

Strategic behaviour

A7.86 Several respondents to the October 2013 consultation alleged that operators in some auctions had the incentive and ability to behave strategically, and that this behaviour caused final auction prices for certain spectrum bands to diverge from market value, with the result that both absolute and relative benchmarks overstate or understate respective market values.

A7.87 These allegations relate to a number of different types of strategic behaviour, in particular:

- Strategic investment, where a bidder, with the aim of foreclosing downstream competition, bids above its intrinsic value of spectrum to prevent it being acquired by the bidder's downstream competitors.[53] Such a bidding strategy (whether or not it achieves its aim) by one or more bidders could result in auction prices that overstate market value. Price-driving, where a bidder overstates its true demand to raise the auction prices paid by other bidders. One potential motivation is to force a rival to spend more for one lot category, so that it has a smaller budget to compete for another category in which the price-driving bidder is interested. Another is to weaken downstream competition (by making it harder for the victim of price driving to finance other investments which could otherwise make it more competitive). Price driving could lead to auction prices that overstate market value in some bands, and possibly to prices that understate market value in other bands (if the victim of price driving is budget-constrained in the latter).

- Strategic demand reduction, where bidders reduce the auction price they pay for the spectrum they purchase by understating their true demand. A bidder may engage in strategic demand reduction unilaterally or coordinated with other bidders (such as through the use of bids as signals between bidders as to their intentions). Strategic demand reduction will lead to auction prices that understate market value.

- Signalling, for example where a bidder places a bid for one lot which is intended to send a signal to other bidders of its intentions in other lots in the same or different spectrum bands in the same auction. One example of signalling might be as part of a coordinated strategy of demand reduction.

A7.88 While operators may have some opportunity to engage in strategic behaviour, this does not necessarily mean that they will do so. In some cases they may be constrained by the auction design from making such bids (for example, spectrum caps are a regulatory safeguard aimed at preventing harmful effects on downstream competition from strategic investment). In other cases a successful strategy relies on a degree of coordination with other bidders that is not easy to establish or to maintain while avoiding detection.

A7.89 Even when strategic behaviour is possible, it can be risky, potentially leading bidders to overpay for spectrum, acquire spectrum for which they are not the highest-value bidder, or fail to acquire their preferred spectrum, without necessarily achieving their strategic objectives. As a result, it does not follow that operators with the opportunity to engage in strategic bidding will necessarily do so.

A7.90 Strategic behaviour involves a bidder departing from straightforward bids of its intrinsic value of the spectrum. This value is private to the bidder, and not generally visible. While some patterns of bidding may provide evidence of a strategic motive, allegations of strategic bidding are often difficult to prove or disprove.

[53] We distinguish here between intrinsic value and strategic investment value to a bidder. Intrinsic value is the bidder's value of the spectrum in the absence of strategic considerations.

A7.91 In the absence of clear evidence, we are not in a position to take the view that alleged cases of strategic bidding behaviour did or did not occur. In such cases, we identify the direction of understatement or overstatement consistent with the allegation, but we judge both the risk and the scale of any understatement or overstatement of market value arising from strategic behaviour as being unknown.