Annex 1: Review of Ofcom's estimate of Market Value of 800 MHz spectrum

INTRODUCTION AND EXECUTIVE SUMMARY

This paper re-examines the recent UK spectrum auction in the light of Ofcom's Further Consultation[1]. We assess the evidence that the auction bids provide for determining the market value of 800 MHz, and setting spectrum fees for 900 MHz.

We first consider the marginal bidder analysis (for EE), an approach which Vodafone still considers to provide the best way to estimate ALF-relevant values in the UK. Such an approach allows the use of the fullest amount of information possible from the auction. However the auction data has limitations due to the structure of the auction which prevented bidders revealing their true valuation across all lots and the incentives bidders had to make bids which did not reflect their underlying valuations of the spectrum.

We recap Vodafone and Frontier's analysis and explain why it is significantly more robust than Ofcom's in that it involves EE's actual bids, and considers a large number of bid points. This is superior to a simplistic analysis based on a few selected bids, or based on adding in entirely hypothetical additional bids, both of which can give undue weight to bids (or lack of bids) which may be distorted by the factors noted above. In particular, our multi-bid analysis can tease apart many of the elements of EE's bids related to coverage, contiguity and strategic premiums (see Annex 1.4: Glossary for a definition of these terms). Our analysis gives a valuation of **£17.9m - £21.4m per MHz**[2] for a unit of 2x5MHz of 800 MHz, absent such premiums. Nothing in Ofcom's latest analysis undermines this conclusion.

We further explain why a unit of 2 x 5 MHz without premiums is the appropriate increment for determining ALFs. Setting ALFs using a larger increment of 2 x 10 MHz (including premiums) would impose far greater risks of fallow spectrum.

Only in very unlikely circumstances would setting ALFs based on an increment of 2 x 10 MHz result in an outcome which results in a more efficient allocation of spectrum than setting ALF based on a 2 x 5 MHz increment. Ofcom has notably failed to assess the real balance of risks here. Given that Ofcom has agreed that the costs associated with fallow spectrum (if a 2 x 10 MHz increment were used) are substantially greater than the costs of a potential misallocation of spectrum between users (in the case of using a 2 x 5 MHz increment) the use of a 2 x 5 MHz increment when setting ALF will clearly best meet Ofcom's objective of ensuring efficient spectrum use.

[1] Annual licence fees for 900 MHz and 1800 MHz spectrum, Further consultation 1 August 2014

[2] These figures and others presented in this paper have not been adjusted by the addition of costs for DMSL for reasons set out in Vodafone's First Response.

We next identify serious problems and deficiencies with Ofcom's claim that the market value of 2 x 10 MHz of 800 MHz significantly exceeds the prices for 800 MHz spectrum paid at the auction. Given that the auction was designed by Ofcom to determine an appropriate allocation of spectrum by setting prices and the market value, at a time when it was aware that the results of the auction would be a major input into the setting of ALFs, this assertion appears to contradict previous Ofcom statements.

In any case, we show that there is no basis at all in the bid evidence for such a claim. Indeed, certain decisions made by Ofcom when designing the auction, such as the setting of relatively high reserve prices on 800 MHz spectrum would, if anything, tend to lead to the auction prices paid being above the market value.

All Ofcom's specific arguments that the prices paid are below market value are seriously flawed:

Packing Problem:

We show that a careful treatment of reserve prices dissolves the apparent "packing problem" which Ofcom alleges to be a cause of prices not reflecting market value: that problem arose because of the way the reserve price rule was implemented, or because the reserve prices were set too high. After removing this effect, the opportunity cost for 2 x 10 MHz of 800 MHz spectrum is seen to be around **£25m - £26m per MHz,** which is a reasonable estimate of the market value of 2 x 10 MHz **including premiums**. The prices paid at auction by Vodafone and Telefonica closely reflect this opportunity cost, though they slightly over-estimate it owing to the reserve price effects. This is as would be expected from a competitive auction, especially an auction using a second-price mechanism.

Spectrum Caps:

Ofcom's consultation suggests that the overall spectrum cap on EE suppressed the 800 MHz price revealed at auction below the market price. However, in setting the auction rules Ofcom identified that there was a strong risk that operators would bid for large packages of spectrum in order to exclude other bidders from the spectrum (strategic value), rather than because the operator would make efficient use of the spectrum (usage value).[3] Ofcom recognised that such bids would result in an inefficient allocation of spectrum and a less competitive market, and put in place spectrum caps to prevent such an inefficient outcome. EE is now at its overall cap, so is right at the limit of what Ofcom considered acceptable in terms of its ability to exclude other players. If ALFs are to lead to an efficient outcome then they should reflect solely the value due to the use operators can make of the spectrum, rather than any value generated from depriving other operators of the use of that spectrum. We consider it highly alarming that Ofcom speculates about how much extra EE might have bid to become yet more dominant, extrapolating from bids at the boundary of the

[3] See Ofcom 4G auction statement at paragraph 1.10 discussed at Section 5 of Annex 3.1

spectrum cap, and treats this as a relevant factor, indeed the most relevant factor, in setting ALFs. Such an approach directly contradicts Ofcom's duties and objectives under the European Common Regulatory Framework and the Direction.[4]

Non-linear pricing:

For both 800 MHz and 2600 MHz paired lots, there is a wide price range between the points where demand was one more than supply and where demand was one less than supply. However there is no price within this range where demand for spectrum would exactly equal supply (i.e. the market would clear with all spectrum being allocated). So there is no linear clearing price.

For 2600 MHz (C lots), the relevant price range is from £5.5m to £6.4m per MHz: at any price in that range, either 15 or 13 lots can be sold but not 14. Ofcom estimate the "market value" to be at the bottom of the range i.e. the highest price - £5.5m per MHz - at which it is possible to clear all 14 actual lots. This is quite reasonable, for the obvious reason that a price where demand exceeds supply, and hence all blocks are allocated, is clearly more efficient than a price where supply exceeds demand, and one or more blocks is unallocated.

For 800 MHz (A lots), the relevant price range is from £25.4m to £31.9m per MHz: at such a price it is possible to sell either 7 lots or 5 lots of 2 x 5MHz, but not 6. So for reasons of efficiency (and consistency), Ofcom should again estimate the "market value" at the bottom of that range i.e. the price at which it is at least possible to clear all actual 800 MHz lots. But instead, Ofcom estimate the market price as above the top of the range! This is a major inconsistency and totally out of line with Ofcom's claim to be conservative.

We conclude by examining the difference between the opportunity cost calculations for 2 x 10 MHz (based on real auction bids and results) and Ofcom's latest analyses (LRP, ASM or hypothetical additional bids). We show that all of Ofcom's methods are non-robust and unreliable, and further are quite unsuited for making comparisons between UK and international auctions. Use of such methods also belies Ofcom's claim to be conservative in its treatment of the evidence.

It follows therefore that the **ceiling** for an estimate of full market value of 800 MHz spectrum arising from the UK Action (even including strategic and contiguity premiums and a marginal unit of 2 x 10 MHz) should be no more than £25m - £26m per MHz.

[4] See further analysis in Annex 3.1

MARGINAL BIDDER ANALYSIS (MARKET VALUE WITHOUT PREMIUMS)

We broadly welcome Ofcom's decision to use marginal bidder analysis, where suitable bids are available (in particular EE's bids in the UK auction). This is in line with Vodafone's recommendation in our previous consultation response. However, we are deeply concerned about the lack of robustness of Ofcom's particular approach. EE's overall bid pattern is clear, but there is a lot of variation ("noise") in individual bids and resulting bid increments. Some of this variation is not easily explained in terms of reasonable underlying valuations (for example incremental bid values increase rather than decrease as holdings of substitute spectrum increase) and must therefore reflect at least in part either strategic bidding or strategic valuations. By relying on a single pair of bids Ofcom's analysis is unduly influenced by that noise.

Annex 1.1 re-caps Vodafone and Frontier's marginal value analysis for EE's auction bids. We list below several advantages of this assessment method compared to Ofcom's own marginal bidder analysis:

1. Our method uses bids that EE ***actually*** made in the auction, and the packages for which they were made. It does not attempt to impute additional hypothetical bids to EE, or "read across" from bid pairs in which both bids exist (such as 2+4, and 4+4) to other bid pairs for which only one bid exists (such as 1+7).

2. Our method considers ***multiple*** pairs of bids. It does not depend on picking one or two pairs of bids, and simply asserting that they are more relevant than others. It is thus robust to variations and idiosyncrasies in individual bid pairs (of which there are several in EE's bids), especially when using the median analysis.

3. Our method provides a way to examine important elements of EE's bids, such as coverage premium (first block), contiguity premium (for even numbers of blocks) and strategic premium (also for even numbers of blocks, and for large packages approaching EE's cap).

Our analysis gives a valuation of £17.9m - £21.4m per MHz for a unit of 2 x 5MHz of 800 MHz, absent such premiums.

We are concerned that Ofcom considers only a few of EE's large packages (the ones approaching the cap) and treat them as "most relevant" for the purposes of ALF. However these are precisely the packages **least** suitable for assessing the relevant usage values relevant to translation into 900 MHz spectrum, since they are **most** at risk from strategic value and bidding considerations.

A conservative treatment of the evidence[5] would assign a relatively low weight to these potentially problematic packages when setting ALF; not assign all the weight to these packages.

THE APPROPRIATE UNIT FOR ALF

Ofcom has clearly given some thought as to whether the unit for ALF pricing should be set at 2 x 10 MHz (and so include a contiguity premium) or instead set at 2 x 5 MHz (and so exclude a contiguity premium).

In particular, there is a long analysis in Annex 6 of the further consultation (6.97 to 6.128); though very regrettably this was all done using "illustrative examples" rather than via a best attempt to assess the real-world situation that Ofcom currently faces. Table 6.19 shows that there could be efficiency risks either way. Setting the pricing unit at 2 x 5 MHz may fail to lead to efficient relinquishment of 2 x10 MHz. By contrast, setting the pricing unit at 2 x 10 MHz may lead to an inefficient relinquishment of 2 x 5 MHz.

However, Ofcom's decision to use a 2 x 10 MHz increment does not correctly reflect this analysis, as it does not properly consider the true balance of risks. In particular, Ofcom does not consider which of the following two situations is **in practice** more likely:

a) Vodafone and Telefonica will inefficiently retain 2 x 10 MHz which could have been used more efficiently by EE; or

b) Vodafone/Telefonica will inefficiently relinquish 2x5 MHz (or less), which cannot be used more efficiently by EE

A moment's thought shows that a) is prima facie highly unlikely. How can Vodafone or Telefonica's **private** value for such a huge chunk of spectrum, with an already rolled out 900 MHz network, really be as low as EE's values as expressed in the auction? Handing back so much spectrum would destroy deployed networks.[6]

Even if Vodafone or Telefonica had a lower unit value for some marginal spectrum than EE would have for a 2 x 10 MHz block, there is very little chance that they could efficiently relinquish 2 x 10 MHz either individually or jointly:

- Neither operator on their own is likely to relinquish 2 x 10 MHz, as to do so would leave them with 2 x 7.4 MHz, which is likely to be a sub optimal residual holding;

- The likelihood of Telefónica and Vodafone together relinquishing 2 x 10 MHz of spectrum at the same time is also very small. The two operators are likely to have different private valuations of spectrum such that even if the operator with

[5] As Ofcom claims to be applying in its Further Consultation at 1.34.
[6] See Annex 7 to Vodafone's First Response and Ofcom's acknowledges this point at A 5.10 of the Further Consultation

lower value relinquishes some spectrum, the other operator is unlikely to simultaneously relinquish the necessary remainder of the spectrum.

There are a number of potential scenarios where some marginal spectrum is relinquished inefficiently:

- One or both of Vodafone/Telefonica might hand back 2 x 2.5 MHz; or

- If there are significant premia for multiples of 10 MHz then Vodafone and Telefónica could trade between them such that one held 2 x 10 MHz and the other 2 x 20 MHz, with the remaining 2 x 5 MHz spectrum relinquished.

Ofcom already acknowledges that spectrum lying fallow is likely to lead to greater efficiency losses than a re-allocation of spectrum. Since the latter risk is prima facie much more likely than the former, and creates the higher inefficiency risk (fallow spectrum), Ofcom should not set ALF based on a unit of 2 x 10 MHz. Its failure to follow through on this logic is thus contradictory and disturbing.

Even without this prima facie consideration, a particular problem with Ofcom's approach is that there is a total of 2 x 35 MHz of spectrum in the 900 MHz band, so it is not possible to allocate all of this spectrum to operators in blocks of 2 x 10 MHz. Any optimal allocation must include all available spectrum and so must have one or more operators holding spectrum which is not part of a 2 x 10 MHz contiguous block. As such there is no possible allocation of spectrum where the private value of all allocated spectrum incorporates a contiguity premium. Setting ALF to include a contiguity premium therefore seriously increases the risk that the ALF will be set above the private value of the optimal holder of the final 2 x 5 MHz of spectrum (or smaller), leading to inefficient relinquishment of spectrum.

Accordingly, we conclude that the appropriate unit for ALF pricing must be at most 2 x 5 MHz and not 2 x 10 MHz. For such a unit, all of EE's premiums as expressed in the 4G auction become irrelevant for value. Any coverage premium is irrelevant, since EE's existing 800 MHz block already achieves sub-GHz coverage. Any contiguity premium is irrelevant, since a 2 x 5 MHz unit of 900 MHz spectrum cannot be placed contiguous with EE's 800 MHz holdings. Any strategic premium is irrelevant for determining efficient usage of the spectrum (and would likely be muted anyway, given the impossibility now, post Auction, of excluding any operator from sub-GHz spectrum). A price of **£17.9m - £21.4m** per MHz of 800 MHz - suitably adjusted to 900 MHz - remains, therefore the most appropriate basis for valuation.

THE MARKET VALUE WITH PREMIUMS IS CLOSE TO THE AUCTION PRICE

While not our preferred method, Vodafone has also considered in the alternative a full opportunity cost analysis **including** EE's contiguity and strategic premiums. We further take into account H3G's expressed bids in the auction, including any strategic premiums. We ensure that opportunity costs are evaluated subject to market competition constraints.

We show this gives a result close to the prices paid at auction by Vodafone and Telefonica (as would indeed be expected from an efficient auction); not significantly above the prices paid at auction, as Ofcom now claims.

First, we recap our decomposition analysis for Vodafone and Telefonica from the real auction, and show that the price paid for 2 x 10 MHz of 800 MHz was about £27m - £27.5m per MHz. We observe that since this was affected by the reserve price (via a fictional bidder for all A1 lots at the reserve price), it must *exceed* the true opportunity cost to other bidders (and not understate it, as Ofcom claims).

We next instruct the auction software to remove the fictitious bidder from the system, since this takes us closer to the true opportunity cost for Vodafone and Telefonica to win 800 MHz spectrum. A roughly equivalent approach is to lower the reserve price just enough to ensure that the fictitious bidder no longer influences the prices paid by Vodafone and Telefonica.

Importantly, the counterfactual allocations (without Telefonica or Vodafone) involve some reshuffling between EE, which gets four lots of 800 MHz, and H3G, which gets 2600 MHz instead of 800 MHz. The alleged "packing problem" vanishes completely, showing that it was simply an artefact of the reserve price rule. Further, since all 800 MHz spectrum is allocated in units of 2 x 10 MHz in the counterfactual, the opportunity cost fully incorporates any premiums. The price paid for 800 MHz is about **£25m - £26m per MHz.**

For a sensitivity test, we check whether additional EE bids for 2 x 15 MHz of 800 MHz (bids which might have been made under a different reserve price rule) could make a difference to the counterfactual allocation, and show that they do not. We perform further sensitivity tests, adjusting H3G's bids in line with a slightly lower reserve price (and assuming that H3G would continue to attempt to win an opt-in package at the reserve price). Finally, we add in some possible bids that H3G might have made if their value for a second A1 lot had been very close to their expressed value for a first A1 lot (and hence close to the reserve price). We show that once again such bids do not greatly affect the price of 800 MHz paid by Telefonica and Vodafone. Again all 800 MHz spectrum is allocated in 2 x 10 MHz blocks in counterfactuals, so includes any contiguity premium.

The full set of calculations is shown in Annex 1.2.

THE EFFECT OF SPECTRUM CAPS

Ofcom's further consultation suggests that, by preventing some bids being made, the overall spectrum cap on EE suppressed the 800 MHz price revealed at auction below the market price. This is a problematic, and indeed alarming, argument for a number of reasons:

- A "market price" is only defined with respect to an adequately competitive market-place, in Ofcom's own words a "well-functioning market" and the overall spectrum cap imposed by Ofcom was an essential measure to ensure such a competitive environment in the UK. EE is now exactly at its overall cap, so is right at the limit of what Ofcom considered acceptable.

- Asking how much EE might hypothetically pay to breach this cap could perhaps serve to elucidate EE's strategic value in weakening or excluding competitors, but would reveal little about EE's intrinsic usage value for additional spectrum. Indeed there is evidence that an element of strategic value (strategic premium) was already reflected in EE's bidding as packages approached the cap (as we consider in Annex 1.1 below).

- The strategic value expressed within the Auction is likely to be strongly related to the particular circumstances of the auction. Incorporating transient strategic value related to the specifics of the Auction within ALF values is likely to lead to prices being set above an efficient level. For example EE would likely have had particularly high strategic value associated with large packages of spectrum in the Auction due to a combination of circumstances related to the launch of LTE, the spectrum being auctioned and the design of the auction:

    - The fact that, absent spectrum acquired in the auction, Vodafone and Telefónica would not have had spectrum suitable for the rapid widespread roll out of LTE and the competitive harm that would have occasioned to their respective businesses;

    - The fact that H3G as an opted in bidder, was guaranteed to acquire some spectrum, in conjunction with a large EE package, would significantly reduce the supply of LTE spectrum available to Telefónica and Vodafone.

Nevertheless, we have tested whether the price of 800 MHz was influenced by EE's spectrum cap by adding in additional bids that EE might have made under a weaker cap, but again in a more robust way than Ofcom. We add in *all* additional bid packages up to a higher cap, not just a single additional bid package for 3A1 + 7C. We are very doubtful about such a "hypothetical bid" procedure, but perform it simply because Ofcom has already started down this route, and we wish to examine if adding a plausible set of hypothetical bids makes a difference to prices paid for 800 MHz.

We show that weakening EE's cap simply increases the competition and price for 2600 MHz spectrum, and allows EE to secure even more of the paired 2600 MHz band. However, it does not significantly increase the opportunity cost for 800 MHz spectrum. The full set of calculations is shown in Annex 1.3.

THE EFFECT OF NON-LINEAR PRICING

Ofcom have observed that for 2600 MHz paired lots, there is a price range where it would have been possible to sell *one more* lot than the supply, or *one less*, but not **exactly** the supply (2.79-2.81). However, the same applies to 800 MHz lots (as Ofcom note in 2.79). So there is no linear clearing price for either category.

For 2600 MHz (C lots), the relevant price range is from £5.5m per MHz (the price at which Niche drops demand from 3 to 2) to £6.4m per MHz (the price at which Telefonica drops demand from 2 to 0). At any price in that range, either 15 or 13 lots can be sold but not 14. Since there are not 15 lots available, Ofcom estimate the market price to be at the bottom of the range i.e. the highest price - £5.5m per MHz - at which it is possible to clear all 14 actual lots. This is fairly reasonable, for the obvious reason that a market price cannot possibly exceed the highest price at which it is possible to sell all available lots. It is also broadly in-line with Ofcom's claim of being conservative (2.81).

For 800 MHz (A lots), there is a very similar issue. In the price range from £25.4m per MHz (a price at which EE prefers 0A + 8C to 1A + 7C) to £31.9m per MHz (a price at which EE prefers 0A + 8C to 2A + 6C), it is possible to sell either 7 or 5 blocks of 2 x 5MHz, but not exactly 6, the actual supply. So for consistency, Ofcom should again estimate the market price at the bottom of that range i.e. the price at which it is at least possible to clear all actual 800 MHz blocks. This gives a figure broadly consistent with Vodafone's decomposition analyses (see Annex 1.2) and slightly below the constrained LRP. It also aligns with Vodafone's reserve price analysis in our last submission, where we showed that £25.4m per MHz was an upper bound on the market price. (If the reserve price had been set any higher than that, there would have been unsold spectrum, and Ofcom would be forced to acknowledge that the reserve price had exceeded the market price.)

But instead, Ofcom estimates the market price for 800 MHz as *above* the top of the range. **This is a major inconsistency and totally out of line with Ofcom's claim to be conservative in its treatment of the evidence.**

THE UNRELIABILITY OF OFCOM'S ANALYSIS METHODS

We observe that the opportunity cost for 2 x 10 MHz of £25m - £26m per MHz, as ascertained from the auction bids and results, is nowhere near the £31.2m or more alleged under Ofcom's latest preferred analyses (LRP, ASM or hypothetical additional

bids). Such methods can greatly depart from the prices paid at auction, but this is simply because they are not robust and, generally, highly unreliable.

LRP

As we have shown, this method is unreliable because it is impossible to fit linear prices to a non-linear combinatorial auction especially where the non-linearities are very large (as they are in the UK). Under different possible variants of the LRP considered in recent consulations, the 800 MHz prices range from £22.4m up to more than £34m, without Ofcom providing a convincing rationale for preferring any of them.

ASM

This method is unreliable for all the detailed reasons we have given in our previous consultation responses. Most fundamentally, like the LRP, different versions give very different results, with no objective rationale for preferring one version to any other. All versions attempt to read a few (probably strategic) bids in a real auction across to a radically different - indeed physically impossible - hypothetical auction, one which would have had very different drivers of value.

Hypothetical Bids

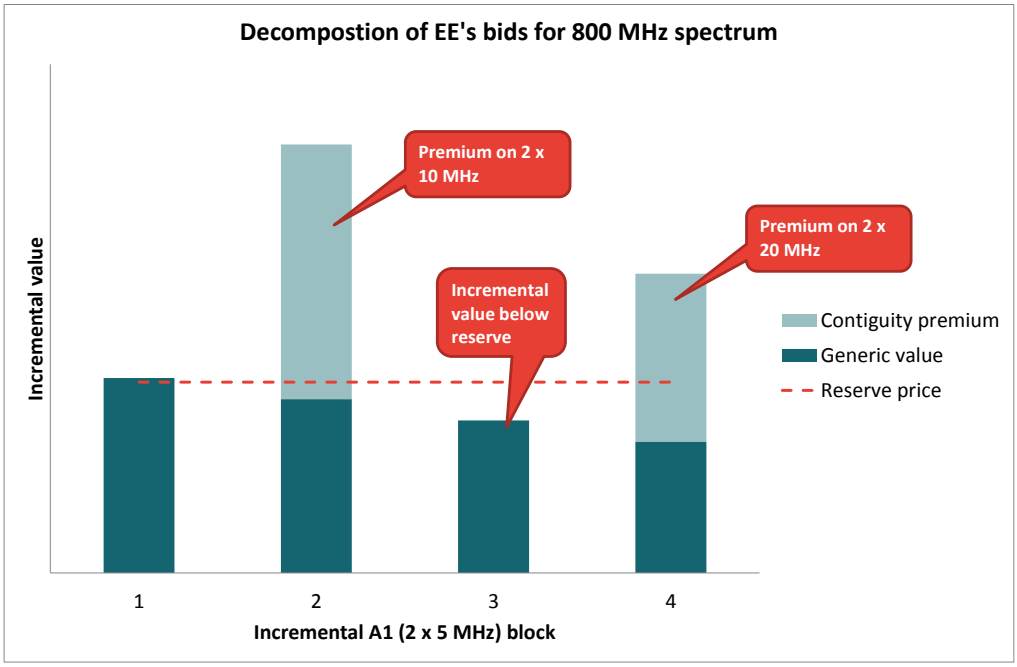
This method is unreliable because it is to a very large extent subjective guesswork. Further, Ofcom has applied it in a piecemeal and inconsistent way as we show in Annex 1.3. Hypothetical bids do have a role within sensitivity analyses, but are only credible where they show that a real result is robust under plausible hypothetical variations (e.g. see Annexes 1.2 and 1.3). Hypothetical bids which predict outcomes very different from a real result are of little or no value.

The fact that Ofcom relies on these speculative and unreliable methods - rather than more robust methods linked to actual auction prices and bids - is deeply concerning, and belies Ofcom's claim to be conservative in its treatment of the evidence.

Annex 1.1: Robust Marginal Bidder Analysis

We briefly recap Vodafone and Frontier's marginal value analysis for EE's auction bids. This decomposed EE's bid increments for 800 MHz spectrum by imputing a **generic value** (one which declines with increasing numbers of 800 MHz lots) and a **premium** (one which spikes for packages containing 2 x 10 MHz multiples of spectrum). We previously described this as a "contiguity" premium; however, it most likely reflects a mixture of true contiguity premium (additional usage value for a 2 x 10 MHz carrier) and strategic premium (value of excluding other operators from 800 MHz, and any elements of strategic bidding). See Annex 1.4. We do not attempt to divide the premium into its parts and do not need to; since none of them are relevant for ALF all should be excluded.

Figure 1. Illustrative decomposition of EE's valuation



Source: Frontier analysis of bid data

The decomposition was performed using two methods:

- Method A assumed that the generic value of spectrum declined linearly and that the value of the premium was constant in absolute terms going from 1 to 2 blocks, as going from 3 to 4 blocks;
- Method B assumed that the generic value of spectrum declined linearly and that the value of the premium was a constant proportion of the total valuation in the overall value from 1 to 2 blocks as from 3 to 4 blocks.

The incremental valuations were estimated by comparing pairs of bids where only the number of A1 blocks bid for differed. Given the range of incremental bids for 800 MHz blocks, depending on the additional spectrum included in packages, we also used two sets of input data to the calculations:

- The mean incremental valuation across all corresponding bid pairs; and
- The median incremental valuation across all corresponding bid pairs.

Calculations based on mean values imply equal weight given to each observation, but can be distorted by outliers, for example relatively high valuations for strategic reasons. Calculations based on median values should be more robust to outliers.

Table 1. Implied valuation of second block of 800 MHz spectrum excluding premium

Method	Data	Result (£million)
Method A	Mean values	195
	Median values	179
Method B	Mean values	214
	Median values	198

Source: Frontier analysis of bid data

Ofcom does not seem to realize that filtering out strategic value (along with other irrelevant drivers of value) is a major strength of the method, and not a weakness. In particular Ofcom have complained (2.91) that Vodafone's model "*provides an inaccurate prediction of" EE's actual bids, and that "the size of the contiguity premium implied in Vodafone's model … is especially inaccurate for some of EE's actual bids, e.g. it is significantly overstated for the largest packages which are most relevant for the purpose of ALF*".

Our response is that the "model" applied by Vodafone/Frontier does not seek to predict each and every bid by EE. Most significantly, it estimates *usage value* of generic spectrum, and does not include separate elements of *strategic value* or *strategic bidding* for packages. Departures from the model are indeed very likely to occur in bids for the largest packages, which are most subject to strategic premiums.

Consider, for instance the graph shown below (Figure 5 in our previous consultation response). It is quite clear that the incremental bids rise sharply as EE's package approaches the edge of their spectrum cap. The relevant question is why? As stated in our previous submission (emphasis added).

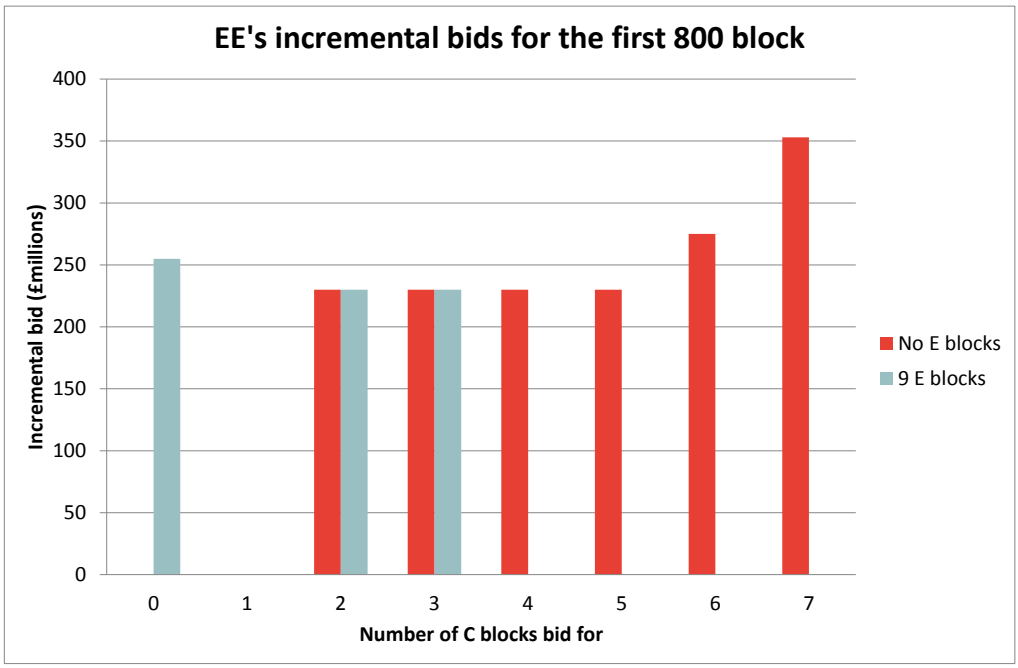
> *In general it would be reasonable to expect operator's marginal valuation of spectrum to* ***decrease*** *as the overall holding of spectrum held increased. This is because as the overall holding of spectrum increases the proportion of the country where spectrum is a binding constraint will reduce. This means that as the overall holding increases, additional spectrum will have less of an impact in terms of avoiding additional equipment and/or peak capacity. While there may be exceptions, as shown by the apparent contiguity premia for 800 MHz spectrum, these are likely to be due to synergies within bands of spectrum.* ***It is unlikely that***

an increase in holdings of high frequency spectrum would increase the marginal value of low frequency spectrum or vice-versa.

There are a range of explanations why incremental bid values could increase even if marginal valuations decline:

- *Strategic value, which will tend to increase as the overall amount of spectrum bid for increases, as bidding on larger packages is more likely to exclude a competing operator entirely; or*
- *Strategic bidding, as bids for larger packages are more likely to be included in the price determination for other bidders*"

Figure 2. Analysis of EE's incremental bidding



Source: Frontier Analysis of Ofcom bid data

Given that strategic values and/or strategic bidding considerations are a strong suspect here, it is unacceptable for Ofcom to simply ignore them. Ofcom's approach appears to be that since it cannot tell how much strategic considerations were involved, it assumes that they were none at all. All bids are deemed to reflect a spectrum usage value, however anomalous. Further, since EE actually won a big package, Ofcom assume that these anomalous usage values are the most relevant ones. This cannot be correct. As one drawback, it greatly exaggerates the decline in the 800 MHz contiguity premium with increasing 2600 MHz spectrum, and gives an improbably tiny premium of only £30m for the largest packages (a point Ofcom puzzle over in A6.81).

In summary, we are concerned that Ofcom considers EE's large packages (the ones approaching the cap) as "most relevant" for the purposes of ALF, when it is clear that these are precisely the packages **least** suitable for assessing the relevant usage values, since they are **most** at risk from strategic value and bidding considerations. A truly conservative analysis would assign a relatively low weight to these potentially problematic packages when setting ALF: and not assign all the weight. Vodafone's/Frontier's analysis is conservative in this way; Ofcom's is not.

Annex 1.2: Decompositional Analysis for Telefonica and Vodafone

The outcome of the UK auction principal stage was, as is widely known, as follows:

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	5	790,761,000
Telefonica	0	1	0	0	550,000,000
EE	1	0	7	0	588,876,000
H3G	1	0	0	0	225,000,000
Niche	0	0	3	4	186,476,000
Totals	4	1	14	9	2,341,113,000

Table A1.2a: Real Auction Outcome (Principal Stage)

If Vodafone's bids had been excluded then the outcome would have been as follows:

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	2	0	6	0	310,500,000
H3G	1	0	2	0	100,000,000
Niche	0	0	3	5	1,000,000
HKT	0	0	0	2	10,250,000
MLL	0	0	0	2	1,011,000
Unsold	1	0	1	0	240,000,000
Totals	4	1	14	9	**790,761,000**

Table A1.2b: Outcome excluding Vodafone Bids

If Telefonica's bids had been excluded then the outcome would have been as follows:

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	4	(33,000,000)
EE	2	0	6	0	310,500,000
H3G	1	0	2	0	100,000,000
Niche	0	0	2	5	(52,500,000)
Unsold	1	0	0	0	225,000,000
Totals	4	1	14	9	**550,000,000**

Table A1.2c: Outcome excluding Telefonica Bids

Note that the "Opportunity Cost" column may include strategic premiums arising from strategic value or strategic bidding by other bidders, and so does not necessarily represent the true usage opportunity cost (as defined in Annex 1.4). Further, for both Vodafone and Telefonica it includes a reserve-price contribution from a fictitious bidder,

so further departs from the true opportunity cost to real bidders. We will discuss these effects later in this annex.

Decompositional approach

Vodafone has previously proposed a "decompositional" approach to breaking down the price paid per bidder in different categories[7]. This determines how much each bidder would have had to pay if they had bid exclusively for smaller packages than they actually won. Ofcom has stated[8] that this is "a broadly sensible alternative way of deriving auction prices by band" though with some criticism of averaging together prices for different bidders. We avoid that objection herein by focusing only on individual bidders.

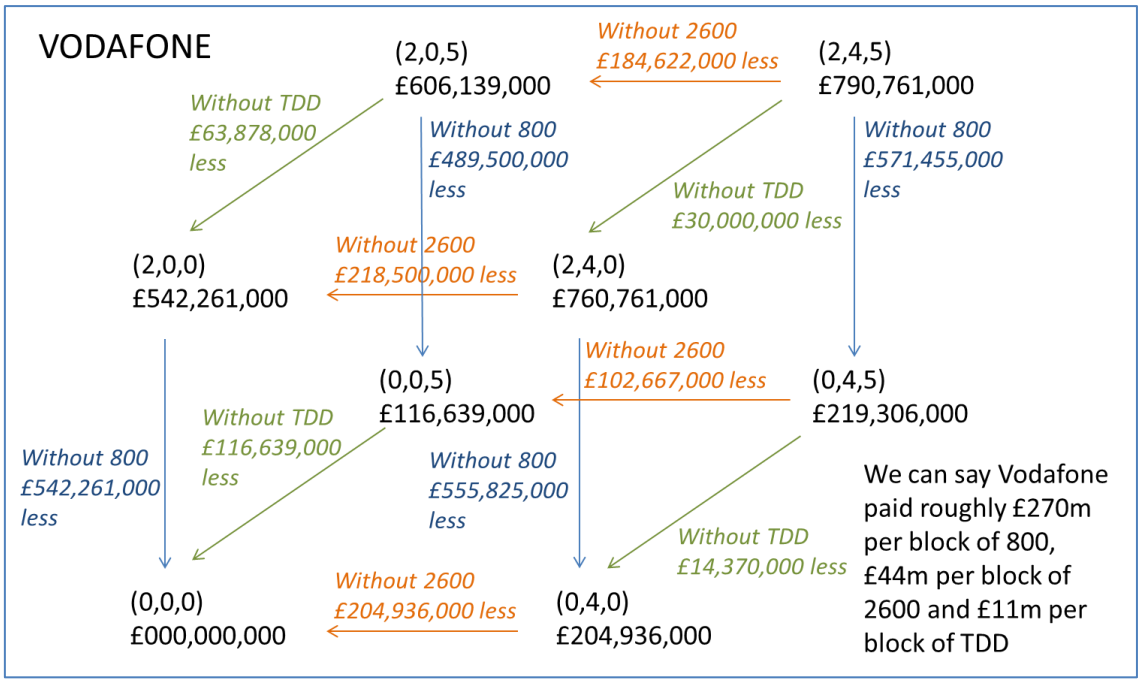
The calculation method is very straightforward: we add a single extra bid for the smaller package, and make sure this extra bid is high enough to ensure the bidder wins the smaller package concerned. We then examine the price the bidder would pay for this smaller package, and compare it to the price paid for the larger package. By comparing prices between packages in this way, we can ascertain the prices paid per band.

Synergies between bands can be handled by varying the order of removing bands, leading to progressively smaller packages, and then averaging (though this time for only a single bidder). This is in outline similar to the decomposition approach Ofcom uses in A6.3 - A6.22, but more precise, since it includes the effects of core pricing (where a base price may be more than the Vickrey price in some cases), and accounts for any synergies between bands in a more systematic and objective way.

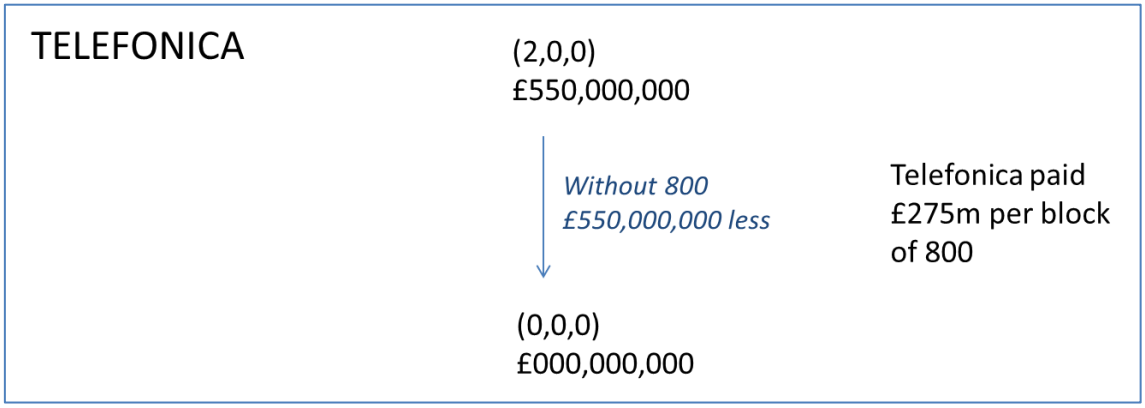
The results are shown below for Vodafone:

7 "Observations from the UK 800 MHz and 2600 MHz auction 2013" Vodafone, July 2013

8 October 2013 consultation, A8.33



A similar (simpler) exercise can be conducted for Telefonica:



FICTITIOUS BIDS, HIGH RESERVE PRICES AND THE OPT-IN RULE

We next show how to compensate for the impact of special auction conditions such as reserve pricing through fictitious bids, and the opt-in rule. In particular, as mentioned above, the pricing of Vodafone's and Telefonica's 800 MHz packages was partly determined by bids from an imaginary bidder who was prepared to offer the reserve price for each A1 lot. Since that fictitious bidder is not a real or potential operator with a usage value for the spectrum, we conclude that the "Opportunity Cost" column in the Vodafone and Telefonica tables must exceed the opportunity cost to real bidders.

The easiest way to assess the size of this effect is by simply removing the fictitious bidder from the system and reverting to the more natural reserve price rule used in previous CCAs (such that the price paid for a winning package must at least exceed the sum of the reserve prices of its component lots). Ofcom could easily have used this simpler rule and initially proposed to do so in consultations on the auction design, so such a procedure is very plausible.

Pricing Without Fictitious Bids

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	5	770,261,000
Telefonica	0	1	0	0	498,000,000
EE	1	0	7	0	388,875,000
H3G	1	0	0	0	225,000,000
Niche	0	0	3	4	186,476,000
Totals	4	1	14	9	2,068,612,000

Table A1.2d: Outcome without Fictitious Bids (Principal Stage)

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	4	0	748,500,000
H3G	0	0	6	0	(65,000,000)
Niche	0	0	2	5	(52,500,000)
HKT	0	0	0	2	10,250,000
MLL	0	0	0	2	1,011,000
Unsold	0	0	0	0	0
Totals	4	1	14	9	**770,261,000**

Table A1.2e: Outcome excluding Vodafone Bids

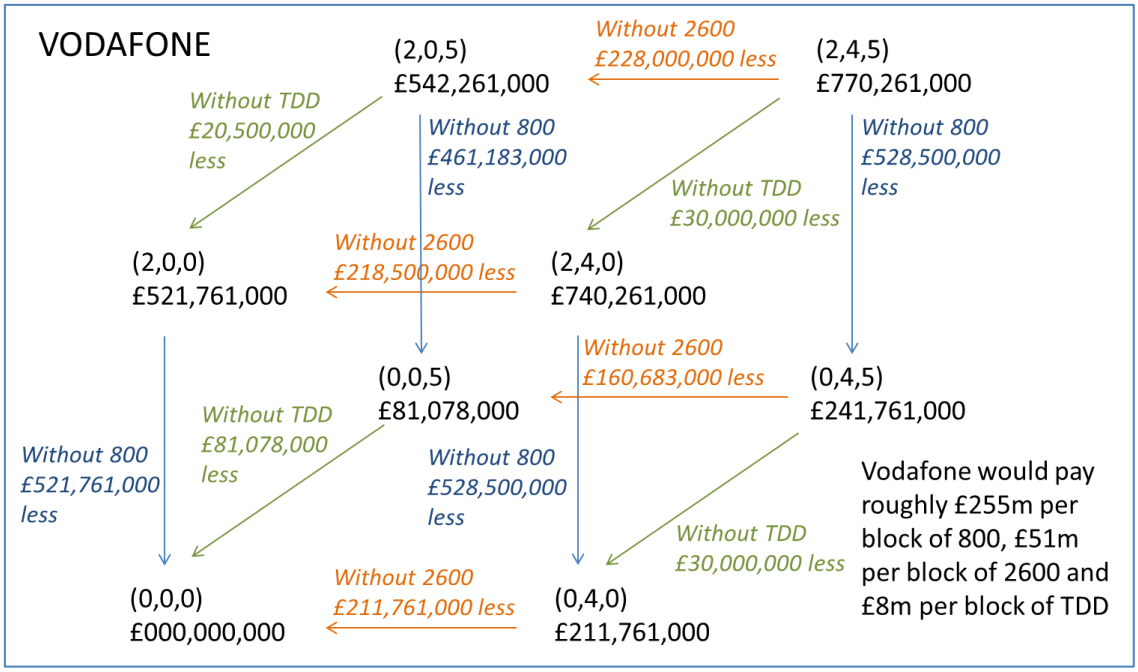
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	4	(33,000,000)
EE	4	0	4	0	748,500,000
H3G	0	0	4	0	(165,000,000)
Niche	0	0	2	5	(52,500,000)
Unsold	0	0	0	0	0
Totals	4	1	14	9	**498,000,000**

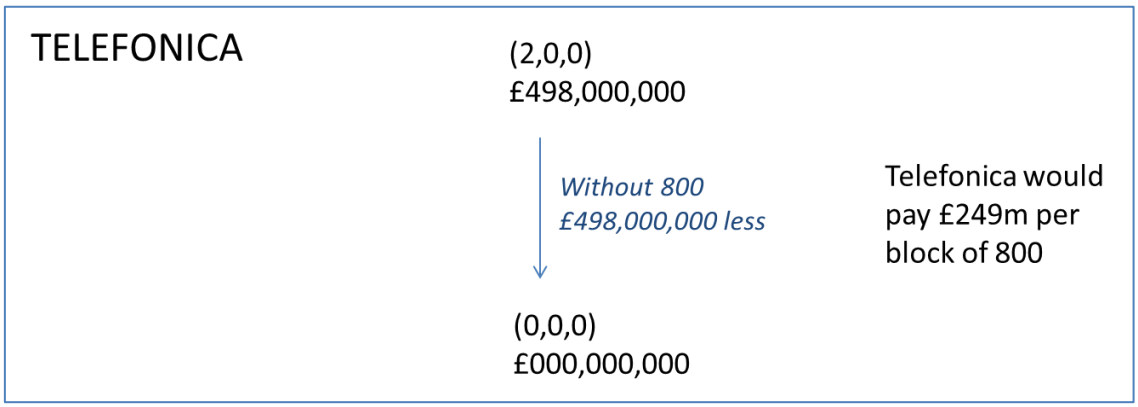
Table A1.2f: Outcome excluding Telefonica Bids

Note that there is no unsold spectrum in these scenarios: all the 800 MHz spectrum is reallocated by shuffling 800 MHz and 2600 MHz between H3G and EE (with a bit of

additional re-allocation to the other players). There is accordingly no "packing problem".

The corresponding decompositions for Vodafone and Telefonica are shown below.





We observe that the prices here are determined by real losing bids made in a real auction, and so (apart from any strategic considerations) ought to reflect real opportunity costs to the alternative users of spectrum. Further those opportunity costs are evaluated subject to all the relevant competition rules: operators stay within their spectrum caps, and the opt-in bidder receives at least one of its opt-in packages. To show this pricing conclusion is robust, we have also performed some relevant sensitivity analyses as below.

Sensitivity Analysis 1: Lower Reserve Price

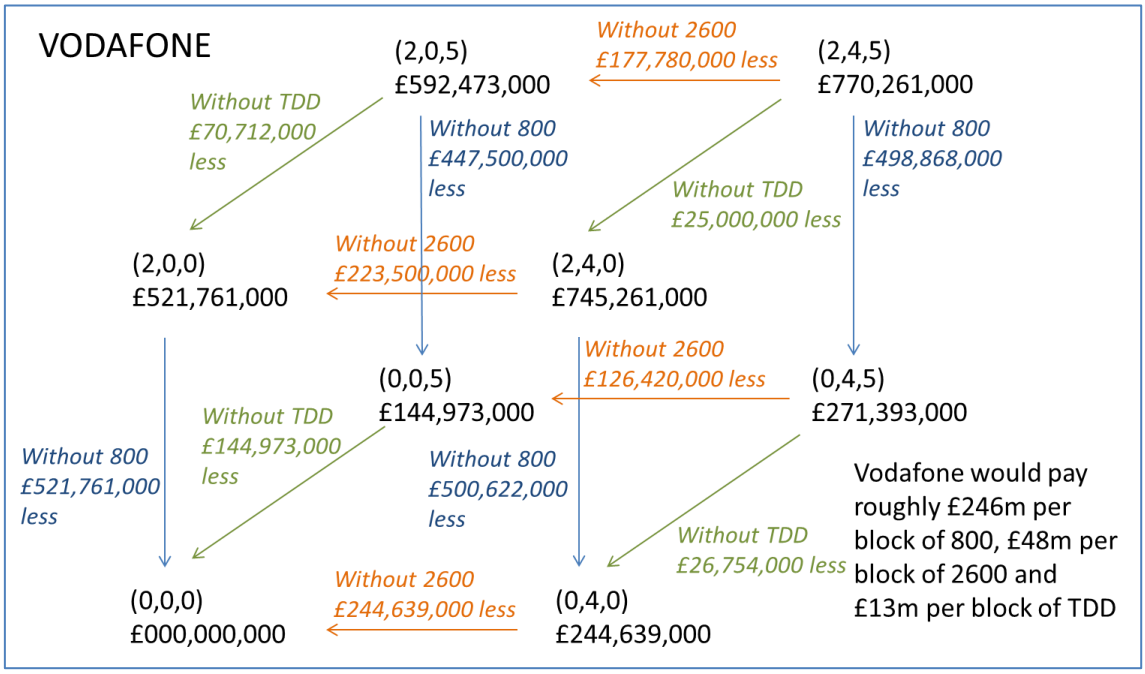
An alternative procedure for removing fictitious bids is to recalculate the auction prices with a lower reserve price, set just low enough that the fictitious bidder does not make an appearance. It turns out that a reserve price of **£173m** (or lower) per A1 block is sufficient to do this, which is again plausible (it is well within the range that Ofcom might have chosen). Here is the effect:

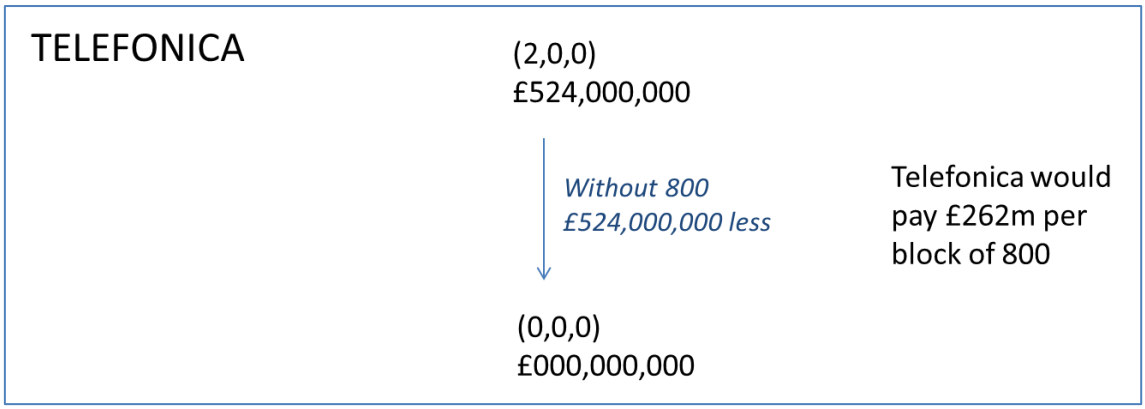
BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	5	770,261,000
Telefonica	0	1	0	0	524,000,000
EE	1	0	7	0	536,876,000
H3G	1	0	0	0	199,000,000
Niche	0	0	3	4	186,476,000
Totals	4	1	14	9	2,216,613,000

Table A1.2g: Outcome with Lower Reserve Price (Principal Stage)

The opportunity cost analysis for Vodafone and Telefonica is exactly as in Tables A1.2e and A1.2f, but notice that the price paid by Telefonica (£524m) now exceeds the opportunity cost (£498m) by £26m. Similarly, the price paid by H3G (£199m) exceeds the new reserve price (£173m) by £26m. This is a core pricing effect: the minimum price paid by Telefonica and H3G as a coalition must be at least £723m, or £52m higher than the sum of £498m and £173m.

The decompositional analysis gives the following results in this case:





Sensitivity Analysis 2: Additional EE bids for 2x15MHz of 800 MHz

An objection to both the above analyses is that if the reserve price rule had been different (no fictitious bids, or lower reserve price overall) then this may have encouraged EE to place marginal bids for 3 A1 lots (2 x 15 MHz of 800 MHz) spectrum, since these would now stand a chance of becoming winning bids. In particular, if EE's valuation for a third 800 MHz block was close to (but slightly below) the reserve price, then there would have been no point in submitting such bids in the real auction; yet the bids could have been desirable under alternative reserve price rules.

However, it is easy to test for such an effect by adding additional bids for 2 x 15 MHz packages (up to EE's spectrum cap) at the highest possible increment allowed by this scenario, namely the original reserve price of £225m. In particular, we re-run the winner and price determination with the following additional bids by EE:

Package	Bid	Rationale
3A1	£875,001,000	£650.001m (2A1) + £225m
3A1 + 5E	£950,500,000	£725.5m (2A1 + 5E) + £225m
3A1 + 9E	£1,315,000,000	£1090m (2A1 + 9E) + £225m
3A1 + 2C	£1,090,000,000	£865m (2A1 + 2C) + £225m
3A1 + 2C + 5E	£1,233,858,000	£1008.858m (2A1 + 2C + 5E) + £225m
3A1 + 3C	£1,260,478,000	£1035.478m (2A1 + 3C) + £225m
3A1 + 4C	£1,370,478,000	£1145.478m (2A1 + 4C) + £225m
3A1 + 5C	£1,458,478,000	£1233.478m (2A1 + 5C) + £225m
A1 + A2	£475,000,000	£250m (A2) + £225m
A1 + A2 + 9E	£987,000,000	£762m (A2 + 9E) + £225m
A1 + A2 + 2C	£757,000,000	£532m (A2 + 2C) + £225m
A1 + A2 + 3C	£953,478,000	£728.478m (A2 + 3C) + £225m
A1 + A2 + 4C	£1,195,478,000	£970.478m (A2 + 4C) + £225m
A1 + A2 + 5C	£1,293,478,000	£1068.478m (A2 + 5C) + £225m

Significantly, the auction results and prices with these additional bids are exactly as shown in Table 1.2d ("Outcome without Fictitious Bids") and Table 1.2g ("Outcome with Lower Reserve Price"). EE's bid for 4A1 + 4C continues to be the relevant one for determining opportunity costs: the bids for 2 x 15 of 800 MHz have no effect.

This demonstrates that hypothetical additional EE bids for 2 x 15 MHz would have no impact on opportunity costs or prices paid by Vodafone and Telefonica, even if the hypothetical bid increments went right up to the original reserve price.

Sensitivity Analysis 3: Varying H3G's Bids for Opt-in Packages

A further objection is that H3G's bids would likely have been different with a different reserve price. As shown in Vodafone's memo[9] and Geoffrey Myers' paper[10] H3G bid strategically to take advantage of the opt-in rule, bidding exactly the delta in reserve price between its opt-in packages. The likely aim was to secure one of those packages at exactly the reserve price. Ofcom appear to have accepted this analysis (see footnote 23 to the Further Consultation). Accordingly, it is plausible that if the 800 MHz reserve price had been lower, then H3G's bids would have reflected the alternative difference in reserve prices. While this has no impact on our first analysis (which simply excludes the fictitious bids), we now test what effect varying H3G's bids might have had.

In this test we lower the A1 reserve price to just below £200m, and vary H3G's bids accordingly. It turns out that any price up to **£199m** will prevent the appearance of the fictitious bidder; this again is well within the plausible range of reserve prices which Ofcom might have chosen. We retain a £25m difference between the A1 and A2 reserve prices, so the A2 reserve price is £224m. We modify H3G's supplementary bids for packages containing 800 MHz spectrum to reflect the new reserve price deltas:

Package	Bid	Rationale
A1	£539,500,000	£400.5m (4C) + £199m – £60m
A2	£564,500,000	£400.5m (4C) + £224m – £60m
A1 + 4E	£561,500,000	£422.5m (4C + 4E) + £199m – £60m
A1 + 5E	£569,500,000	£430.5m (4C + 5E) + £199m – £60m
A1 + 9E	£599,500,000	£460.5m (4C + 9E) + £199m – £60m
A1 + 2C	£639,500,000	£500.5m (6C) + £199m – £60m

The auction results are as follows:

[9] "Observations from the UK 800 MHz and 2600 MHz auction 2013", Vodafone, July 2013

[10] "The innovative use of spectrum floors in the UK 4G auction to promote competition" http://www.lse.ac.uk/researchAndExpertise/units/CARR/pdf/DPs/DP74-Geoffrey-Myers.pdf

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	5	796,261,000
Telefonica	0	1	0	0	524,000,000
EE	1	0	7	0	562,876,000
H3G	1	0	0	0	199,000,000
Niche	0	0	3	4	199,500,000
Totals	4	1	14	9	2,281,637,000

Table A1.2h: Outcome with Lower Reserve Price (Adjusting H3G Bids)

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	4	0	748,500,000
H3G	0	0	6	0	(39,000,000)
Niche	0	0	2	5	(52,500,000)
HKT	0	0	0	2	10,250,000
MLL	0	0	0	2	1,011,000
Unsold	0	0	0	0	0
Totals	4	1	14	9	**796,261,000**

Table A1.2i: Outcome excluding Vodafone Bids

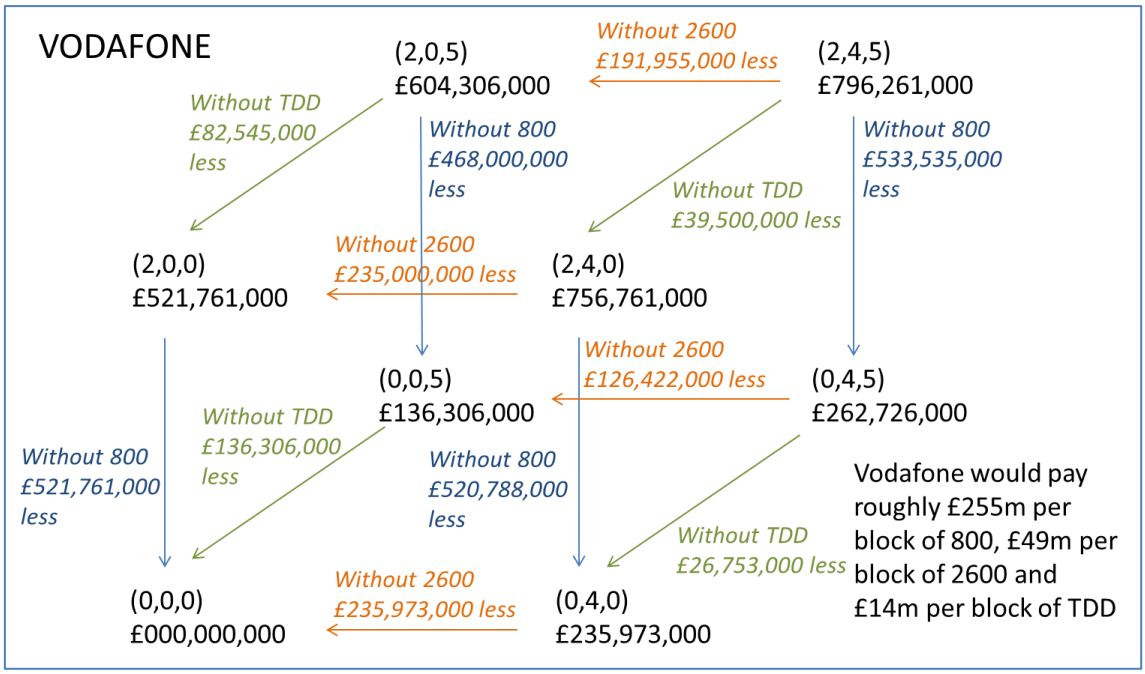
Notice that Vodafone's opportunity cost is uplifted by £26m compared to Table A1.2e, because the difference between H3G's bids for A1 and 6C has been reduced by £26m.

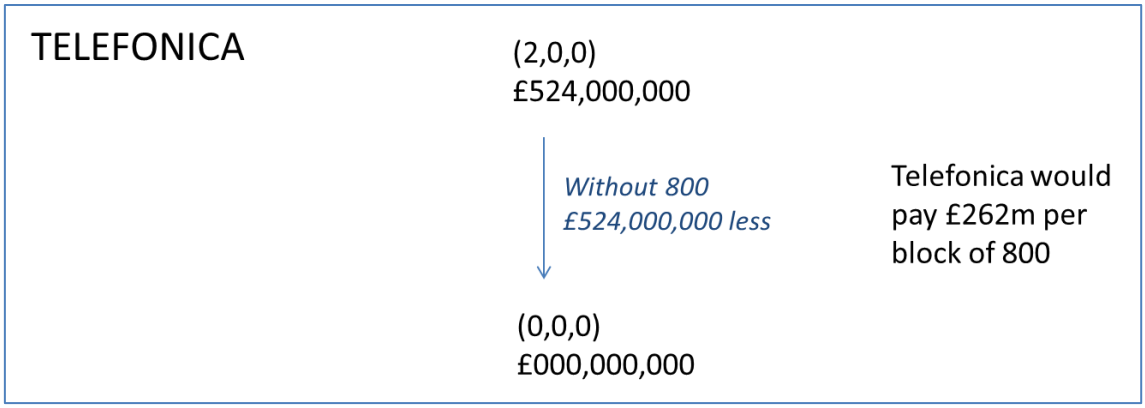
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	4	(33,000,000)
EE	4	0	4	0	748,500,000
H3G	0	0	4	0	(139,000,000)
Niche	0	0	2	5	(52,500,000)
Unsold	0	0	0	0	0
Totals	4	1	14	9	**524,000,000**

Table A1.2j: Outcome excluding Telefonica Bids

Similarly, Telefonica's opportunity cost is uplifted by £26m compared to Table A1.2f, because the difference between H3G's bids for A1 and 4C has been reduced by £26m.

The decompositional analyses under this scenario are as follows:





Additional Sensitivity Analyses

We can continue with further sensitivity analyses, such as combining an adjustment in H3G's bids with additional EE bids for 2 x 15 MHz of spectrum. The results of this are again those shown in Table A1.2h to A1.2j: just as for sensitivity analysis 2, hypothetical additional bids by EE do not make any difference.

A further set of scenarios considers that H3G might have had a marginal value for a *second* A1 lot close to the £225m reserve price, but avoided making supplementary bids for packages containing 2 A1 lots which had no hope of winning. However, under different rules or a lower reserve price (e.g. £199m) it might have attempted such bids. Such scenarios are strained, since the valuation of the second lot would need to be rather finely tuned to make any difference (between £199m and £225m), and H3G would need to depart from its strategy of acquiring spectrum at exactly the reserve price.

Nevertheless we can explore the effect of adding additional H3G bids to sensitivity analysis 3. We first adopt a marginal value of £212m for the second A1 lot, which is right in the middle of the critical range which might make a difference. Next we consider what would happen if the value was instead right at the top of the critical range.

Package	Bid	Rationale
2 A1	£751,500,000	£539.5m (A1) + £212m
2A1 + 4E	£773,500,000	£561.5m (A1 + 4E) + £212m
2A1 + 5E	£781,500,000	£569.5m (A1 + 5E) + £212m
2A1 + 9E	£811,500,000	£599.5m (A1 + 9E) + £212m
2A1 + 2C	£851,500,000	£639.5m (A1+ 2C) + £212m

The auction results are as follows:

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	5	796,261,000
Telefonica	0	1	0	0	537,000,000
EE	1	0	7	0	575,876,000
H3G	1	0	0	0	199,000,000
Niche	0	0	3	4	199,500,000
Totals	4	1	14	9	2,307,637,000

Table A1.2k: Outcome from Further Adjusting H3G Bids

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	4	0	748,500,000
H3G	0	0	6	0	(39,000,000)
Niche	0	0	2	5	(52,500,000)
HKT	0	0	0	2	10,250,000
MLL	0	0	0	2	1,011,000
Unsold	0	0	0	0	0
Totals	4	1	14	9	**796,261,000**

Table A1.2l: Outcome excluding Vodafone Bids

This is identical to Table A1.2i. In fact even a value of £225m for H3G's second A1 lot (the largest possible in this scenario) has no impact on Vodafone's opportunity cost.

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	4	(33,000,000)
EE	2	0	6	0	310,500,000
H3G	2	0	2	0	312,000,000
Niche	0	0	2	5	(52,500,000)
Unsold	0	0	0	0	0
Totals	4	1	14	9	**537,000,000**

Table A1.2m: Outcome excluding Telefonica Bids

This is a different re-arrangement from Table A1.2j, but not a hugely different opportunity cost: Telefonica's price is £268.5m per 800 MHz block. A value of £225m for H3G's second A1 lot could in principle raise the price right up to £275m per block.

A very similar effect would be obtained if a new entrant bidder (e.g. Niche) happened to have a valuation for an A1 block in the range £199m - £225m, and decided to bid this under a different reserve price rule. In the counterfactual excluding Telefonica the new entrant might win an A1 block (and H3G would win A1 + 2 C). Still, this is even less likely than H3G having a value in the relevant range; also, even if the new entrant did have such a value, they would most likely have bid it in the original auction. (The new entrants' bid patterns show many bid increments below the reserve price, suggesting that they did not appreciate the effect of the fictitious bids in the auction rules.)

SUMMARY

When determining a "market value" for the purpose of setting ALFs within the overall framework of the Common Regulatory Framework and the Direction, the best alternative usage of spectrum must be assessed subject to the objectives set by that framework and any relevant competition rules necessary for a "well-functioning market", especially any reasonable spectrum caps, trading restrictions and/or reservation mechanisms (like an opt-in rule). Some alternative usages would be impermissible because they breach one or more of the competition rules, leading to an uncompetitive market. We have shown from the auction bids that the best *permissible* alternative involves a reshuffling of spectrum between EE and H3G. In that alternative, all spectrum is sold so there is no packing problem, and all spectrum is allocated in 2 x 10 MHz blocks, so any contiguity premium is fully priced in. Additional bids that EE might have made for 2 x 15 MHz do not contribute to the best permissible alternative.

The results from the decompositional analysis are highly robust, with few (if any) changes under the various sensitivities. When priced against real bids, the cost for either Vodafone or Telefonica is around £250 - £260m per 800 MHz block or **£25m - £26m per MHz**. The decomposition for the real auction results gives slightly higher prices, owing to fictitious bids, but the effect of these can be easily removed.

But is this £25m - £26m figure a fair estimate of *usage* opportunity cost i.e. the additional value that EE/H3G could gain from using the extra spectrum, or is it inflated by strategic premiums?

- For H3G it seems clear that their bids for an A1 lot and 4C lots were affected by strategic considerations, as it is unlikely that their difference in usage value for these two packages was exactly the difference in reserve prices. Still, it is hard to tell in which direction the strategic delta goes: the difference in usage value might easily have been greater than or less than £165m. Sensitivity analysis 3 also shows that varying H3G's bid delta has relatively little impact on the 800 MHz prices paid by Vodafone and Telefonica.

- For EE, it is highly likely that the bid for 4A1 + 4C lots was inflated by strategic value (since if it won this much, there would be only one other licensee at 800 MHz) or strategic bidding (since EE were highly unlikely to win this much, the bid could be used for price-setting). However, such issues also affect EE's bid for A1 + 7C. This is also likely to have been inflated by strategic value, since winning so much 2600 MHz spectrum would reduce the number of competitors at 2600 MHz, and ensure only one competitor was able to launch a full 2x20 MHz carrier. Or EE might have been attempting to price-set at 2600 MHz, and may have been surprised when this odd bid became its winning bid.

- On balance, it is more likely that the strategic value element is higher for EE's large 800 MHz packages than their large 2600 MHz packages, since excluding competitors from higher value low frequency spectrum is prima facie more useful than excluding them from lower value high frequency spectrum. Similarly, since a large 800 MHz package was much less likely to win than EE's large 2600 MHz package, it would be a safer candidate for price-setting. Thus the difference in usage value is likely to be somewhat below the delta in EE's bids.

In conclusion, while £25m - £26m is unlikely to be the true usage opportunity cost for 2 x 10MHz of 800 MHz spectrum (including contiguity and/or strategic premium), it is the most robust guide to the usage opportunity cost including such premiums that we can determine from the auction bids. It is especially helpful that the strategic elements in bids tend to cancel, although some strategic premium is likely to remain. On balance, the usage opportunity cost is likely to be somewhat below the £25 - £26m figure, so a conservative treatment would use it as an upper bound on market value. Since it was reflective of the price paid at auction by 2 x 10 MHz winners (as would be expected from a good auction design, see Annex 1.4) it also provides a useful point of comparison with international auctions.

Annex 1.3: Effects of Varying EE's Spectrum Cap

In this annex, we explore what might have happened in the 4G auction if EE had faced a weaker spectrum cap. This is a rather hypothetical question, and we do not claim to place any great confidence in the answer. However, Vodafone believe that this analysis provides a further useful sensitivity test against the results shown in Annex 1.2. In particular, we show that the 800 MHz price is robust against plausible hypothetical variations in the spectrum cap. This is a much more credible result than claiming that the 800 MHz price would change significantly in the hypothetical (which is what Ofcom have attempted to show).

The most substantive issue is that if EE **had** been given a weaker cap, then it could easily have used it to bid for (and indeed win) additional **2600 MHz spectrum**, rather than setting a higher price for **800 MHz spectrum.** Since Ofcom has only considered hypothetical bids for EE which increase the 800 MHz component (and not further bids which increase the 2600 MHz component), it has failed to examine this issue properly.

Our approach starts by examining EE's bid increments for additional 2600 MHz spectrum, as packages approach their overall cap. In the tables below, "x + y" means a package containing *x* blocks of 800 MHz and *y* C lots. And "x + y -> (y+1)" describes the bid increment for a further C lot.

No 800 MHz spectrum	0 + 7 -> 0 + 8	0 + 6 -> 0 + 7	0 + 5 -> 0 + 6	0 + 4 -> 0 + 5
	£153.5m	£72.5m	£111.7m	£102.3m

Average: £110m

One A1 lot	1 + 6 -> 1 + 7	1 + 5 -> 1 + 6	1 + 4 -> 1 + 5	1 + 3 -> 1 + 4
	£150.5m	£156.7m	£102.3m	£160.442m

Average: £142.485m

Two A1 lots	2 + 5 -> 2 + 6	2 + 4 -> 2 + 5	2 + 3 -> 2 + 4	2 + 2 -> 2 + 3
	£126.522m	£88m	£110m	£170.478m

Average: £123.75m

Four A1 lots	4 + 3 -> 4 + 4	4 + 2 -> 4 + 3	4 + 0 -> 4 + 2
	£229.522m	£123m	£268.856m (£134.428m per lot)

Average: £155.344m

A2 lot	2 + 5 -> 2 + 6	2 + 4 -> 2 + 5	2 + 3 -> 2 + 4	2 + 2 -> 2 + 3
	£195.522m	£98m	£242m	£196.478m

Average: £183m

A2 plus 2A1 lots	4 + 3 -> 4 + 4	4 + 0 -> 4 + 3
	£179.522m	£695.856m (£231.952m per lot)

Average: £218.844m

Notice that these bid increments are quite variable but all rather large: they are nearly all around £100 - £200m. Further, there is no sign of diminishing returns, where the

valuation of marginal C blocks drops as more C blocks are acquired; if anything there seem to be accelerating returns (the most marginal increment usually has higher value than the average of the last four). This is rather strong evidence that if EE **had** been allowed to bid for extra spectrum, it would probably have put in further increments of at least £100m for additional C blocks, which when considered against the bids placed by other bidders would have been sufficient to win those blocks. The accelerating returns also support the hypothesis of strategic value, squeezing rivals out of 2600 MHz.

We can use these increments to reconstruct what might have happened if EE had faced weaker caps. The simplest approach is to add further marginal C lots for EE at an increment equal to the averages calculated in the above table. Note this is rather "conservative" regarding additional C lot values, because of the accelerating returns we actually observe. We also take a "conservative" approach for packages containing the A2 lot, assuming that the marginal increment for additional C lots is only the same as the smaller marginal increment for the corresponding A1 package. (Otherwise the delta between A2 and A1 packages narrows sharply, or even becomes positive, which is unrealistic.)

Package	Bid	Rationale
9C	£960,000,000	£850m (8C) + £110m
10C	£1,070,000,000	£960m (9C) + £110m
A1 + 8C	£1,191,985,000	£1049.5m (A1 + 7C) + £142.485m
A1 + 9C	£1,334,470,000	£1191.985m (A1 + 8C) + £142.485m
2A1 + 7C	£1,483,750,000	£1360m (2A1 + 6C) + £123.75m
2A1 + 8C	£1,607,500,000	£1483.75m (2A1 + 7C) + £123.75m
4A1 + 5C	£1,953,344,000	£1798m (4A1 + 4C) + £155.344m
4A1 + 6C	£2,108,688,000	£1953.344m (4A1 + 5C) + £155.344m
A2 + 7C	£1,387,750,000	£1264m (A2 + 6C) + £123.75m
A2 + 8C	£1,511,500,000	£1447m (A2 + 7C) + £123.75m
2A1 + A2 + 5C	£1,807,344,000	£1652m (2A1 + A2 + 4C) + £155.344m
2A1 + A2 + 6C	£1,962,688,000	£1807.344m(2A1+A2+5C)+£155.344m

We further add in 3 + y packages up to the new cap, making a "generous" valuation equal to the value of 2 + y plus £225m (so assuming EE's marginal value for a third lot of 800 MHz could have been almost as high as the auction reserve price). The basis of all these choices is to create the most sympathetic case possible to Ofcom's claim that EE's bids for 2 x 15 MHz of 800 MHz would have been important in determining prices.

Package	Bid	Rationale
3A1	£875,001,000	£650.001m (2A1) + £225m
3A1 + 5E	£950,500,000	£725.5m (2A1 + 5E) + £225m
3A1 + 9E	£1,315,000,000	£1090m (2A1 + 9E) + £225m
3A1 + 2C	£1,090,000,000	£865m (2A1 + 2C) + £225m
3A1 + 2C + 5E	£1,233,858,000	£1008.858m (2A1 + 2C + 5E) + £225m
3A1 + 3C	£1,260,478,000	£1035.478m (2A1 + 3C) + £225m
3A1 + 4C	£1,370,478,000	£1145.478m (2A1 + 4C) + £225m

3A1 + 5C	£1,458,478,000	1233.478m (2A1 + 5C) + £225m
3A1 + 6C	£1,585,000,000	£1360m (2A1 + 6C) + £225m
3A1 + 7C	£1,708,750,000	£1483.75m (2A1 + 7C) + £225m
A1 + A2	£475,000,000	£250m (A2) + £225m
A1 + A2 + 9E	£987,000,000	£762m (A2 + 9E) + £225m
A1 + A2 + 2C	£757,000,000	£532m (A2 + 2C) + £225m
A1 + A2 + 3C	£953,478,000	£728.478m (A2 + 3C) + £225m
A1 + A2 + 4C	£1,195,478,000	£970.478m (A2 + 4C) + £225m
A1 + A2 + 5C	£1,293,478,000	£1068.478m (A2 + 5C) + £225m
A1 + A2 + 6C	£1,489,000,000	£1264m (A2 + 6C) + £225m
A1 + A2 + 7C	£1,612,750,000	£1387.75m (A2 + 7C) + £225m

What are the results? Well, as expected EE simply win more 2600 MHz spectrum. If EE's cap is set 10MHz higher, they win an A1 + 8C package; if is set 20MHz higher, they win an A1 + 9C package. The prices paid by Telefonica and Vodafone for 2 x 10 of 800 MHz are around £27m - £28m per MHz, but again over-state the opportunity costs to other bidders because of the reserve price rule. However, as in Annex 1.2 we can easily eliminate this effect by removing the fictional bidder. The opportunity cost of 2x10 MHz of 800 MHz is still about **£25m - £27m per MHz**.

Importantly, EE's bids for 2 x 15 MHz packages are largely irrelevant for setting Vodafone's and Telefonica's prices. After eliminating fictitious bids, we see that EE's bids for 4A1 + 5C and/or 4A1 + 6C are the price-setters (with one exception) and again the packing is solved by shuffling H3G onto an alternative opt-in package. Overall, the results shown below are remarkably similar to those obtained in Annex 1.2.

Accordingly, we find no evidence whatsoever that the 800 MHz prices paid understate market prices because of EE's cap. Hypothetically weakening that cap causes no substantive change to the prices Vodafone and O2 would or should pay for 800 MHz MHz spectrum. It simply further increases the competition on 2600 MHz, and further reduces the amount of 2600 MHz won by EE's competitors.

EE cap raised by 10 MHz

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	4	809,526,000
Telefonica	0	1	0	0	540,265,000
EE	1	0	8	0	643,376,000
H3G	1	0	0	0	225,000,000
Niche	0	0	2	5	158,000,000
Totals	4	1	14	9	2,376,167,000

Table A1.3a: Outcome with 10MHz higher cap (Principal Stage)

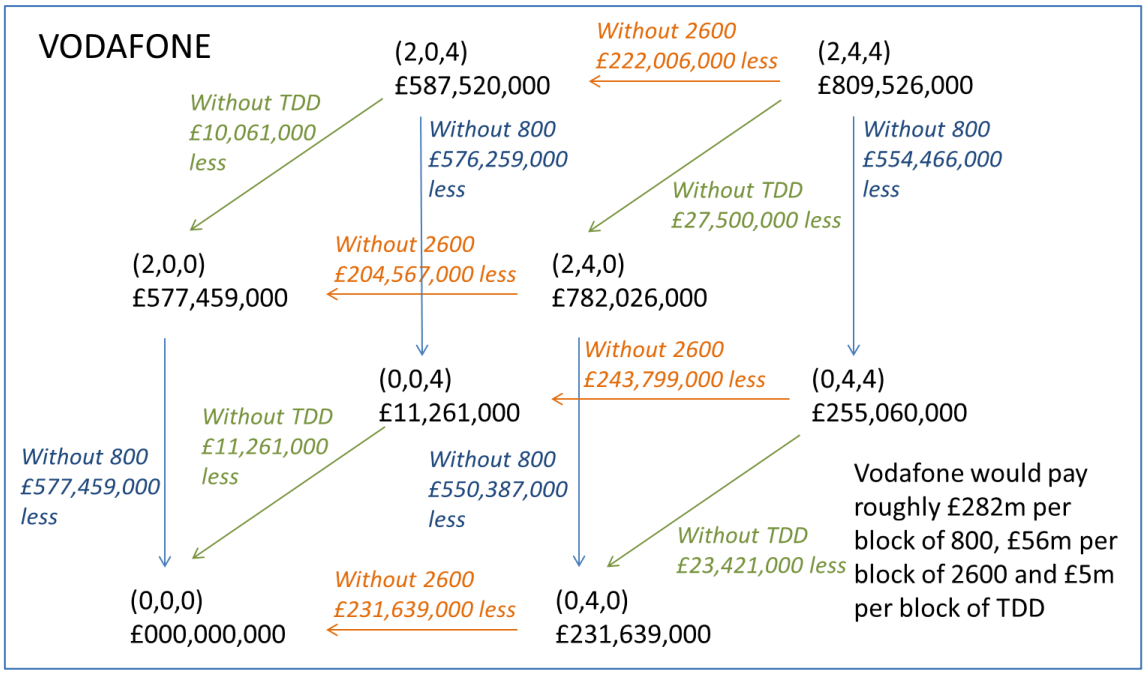
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	2	0	7	0	291,765,000
H3G	1	0	2	0	100,000,000
Niche	0	0	3	5	53,500,000
HKT	0	0	0	2	10,250,000
MLL	0	0	0	2	1,011,000
Unsold	1	0	0	0	225,000,000
Totals	4	1	14	9	**809,526,000**

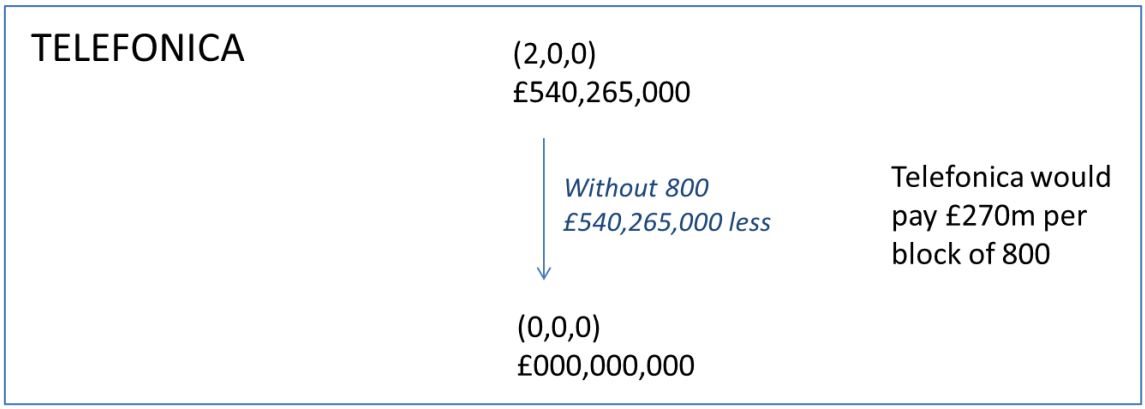
Table A1.3b: Outcome excluding Vodafone Bids

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	5	(29,000,000)
EE	2	0	7	0	291,765,000
H3G	1	0	0	0	0
Niche	0	0	3	4	52,500,000
Unsold	1	0	0	0	225,000,000
Totals	4	1	14	9	**540,265,000**

Table A1.3c: Outcome excluding Telefonica Bids

The corresponding decompositions for Vodafone and Telefonica are shown below.





EE cap raised by 20 MHz

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	3	5	767,218,000
Telefonica	0	1	0	0	567,274,000
EE	1	0	9	0	743,620,000
H3G	1	0	0	0	225,000,000
Niche	0	0	2	4	158,220,000
Totals	4	1	14	9	2,461,332,000

Table A1.3d: Outcome with 20MHz higher cap (Principal Stage)

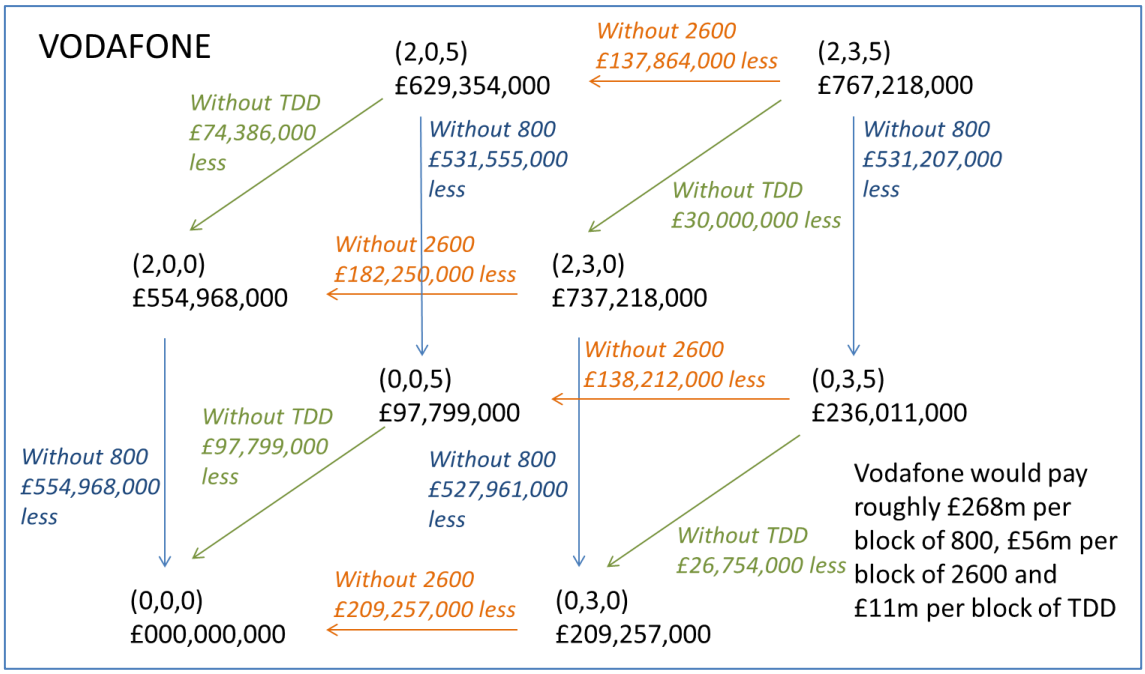
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	6	0	774,218,000
H3G	0	0	4	5	(135,000,000)
Niche	0	0	2	4	0
Unsold	0	0	0	0	0
Totals	4	1	14	9	**767,218,000**

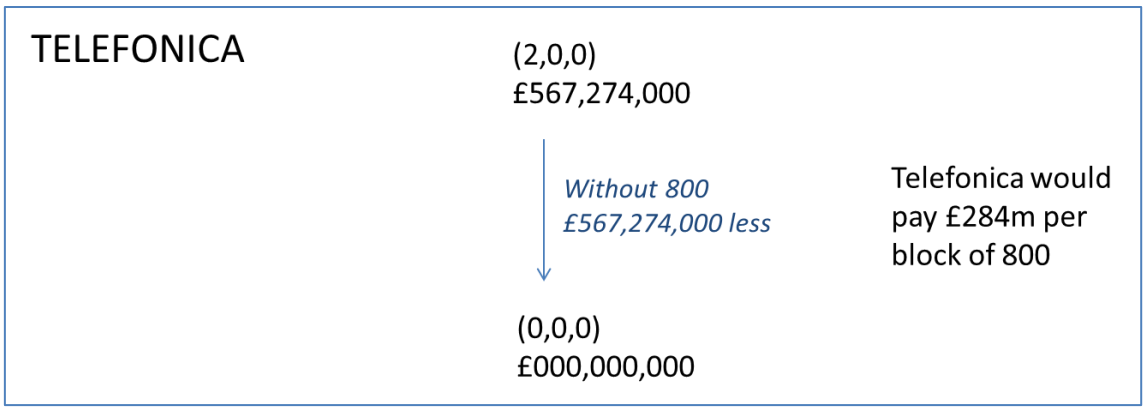
Table A1.3e: Outcome excluding Vodafone Bids

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	4	66,744,000
EE	2	0	8	0	273,030,000
H3G	1	0	0	0	0
Niche	0	0	2	5	2,500,000
Unsold	1	0	0	0	225,000,000
Totals	4	1	14	9	**567,274,000**

Table A1.3f: Outcome excluding Telefonica Bids

The corresponding decompositions for Vodafone and Telefonica are shown below.





EE cap raised by 10 MHz: without Fictitious Bids

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	4	4	806,859,000
Telefonica	0	1	0	0	496,115,000
EE	1	0	8	0	443,375,000
H3G	1	0	0	0	225,000,000
Niche	0	0	2	5	158,000,000
Totals	4	1	14	9	2,129,349,000

Table A1.3g: Outcome with 10MHz higher cap but no Fictitious Bids (Principal Stage)

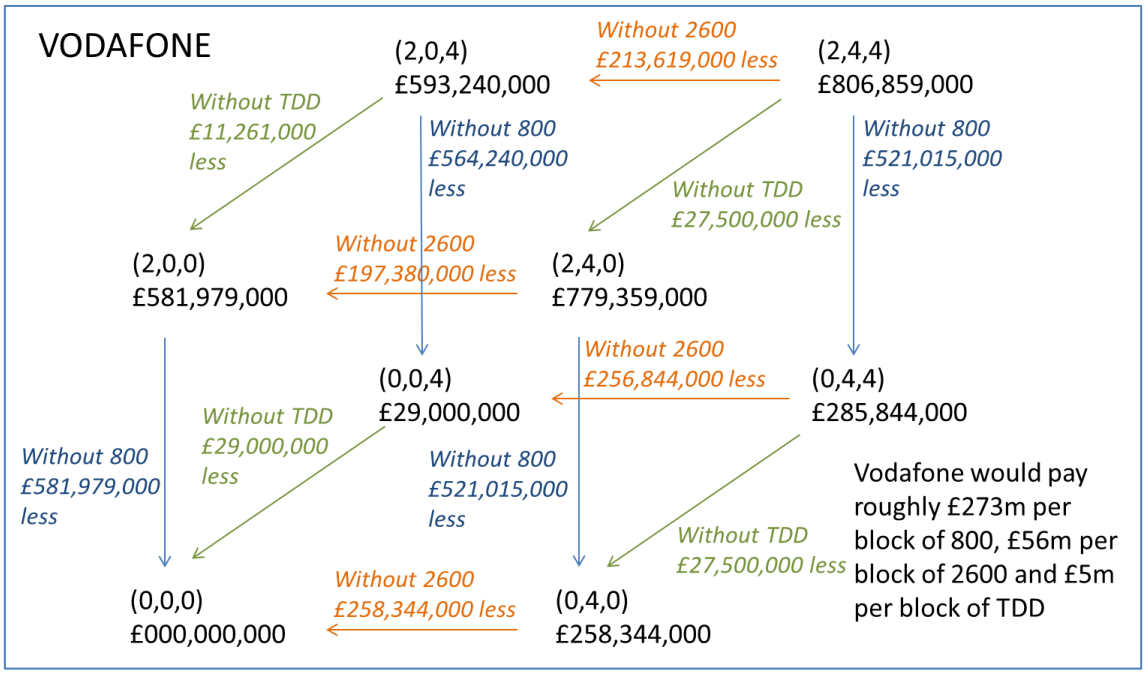
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	5	0	761,359,000
H3G	0	0	4	9	(105,000,000)
Niche	0	0	3	0	22,500,000
Unsold	0	0	0	0	0
Totals	4	1	14	9	**806,859,000**

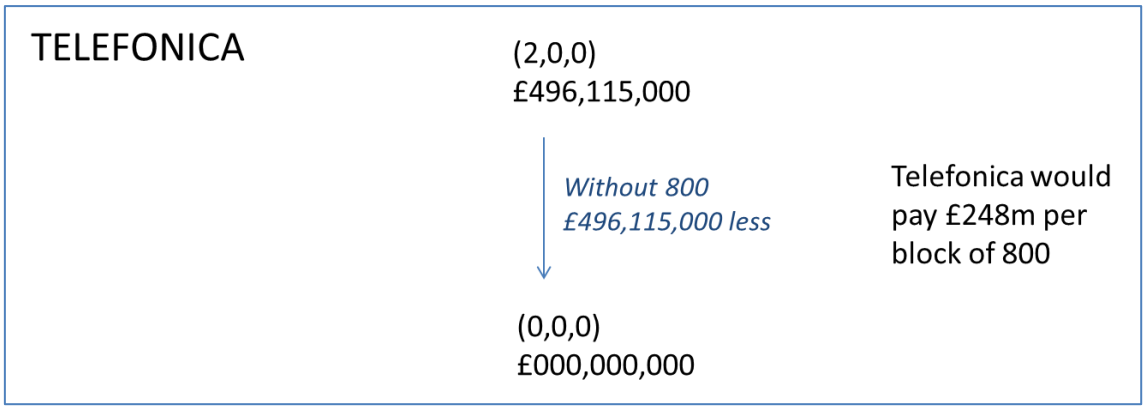
Table A1.3h: Outcome excluding Vodafone Bids

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	3	5	(97,744,000)
EE	4	0	5	0	761,359,000
H3G	0	0	4	0	(165,000,000)
Niche	0	0	2	4	(2,500,000)
Unsold	0	0	0	0	0
Totals	4	1	14	9	**496,115,000**

Table A1.3i: Outcome excluding Telefonica Bids

The corresponding decompositions for Vodafone and Telefonica are shown below.





EE cap raised by 20 MHz: without Fictitious Bids

BIDDER	A1	A2	C	E	Price paid (£)
Vodafone	2	0	3	5	767,218,000
Telefonica	0	1	0	0	522,883,000
EE	1	0	9	0	543,619,000
H3G	1	0	0	0	225,000,000
Niche	0	0	2	4	183,079,000
Totals	4	1	14	9	2,241,799,000

Table A1.3j: Outcome with 20MHz higher cap but no Fictitious Bids (Principal Stage)

BIDDER	A1	A2	C	E	Opportunity Cost (£)
Telefonica	0	1	2	0	128,000,000
EE	4	0	6	0	774,218,000
H3G	0	0	4	5	(135,000,000)
Niche	0	0	2	4	0
Unsold	0	0	0	0	0
Totals	4	1	14	9	**767,218,000**

Table A1.3k: Outcome excluding Vodafone Bids

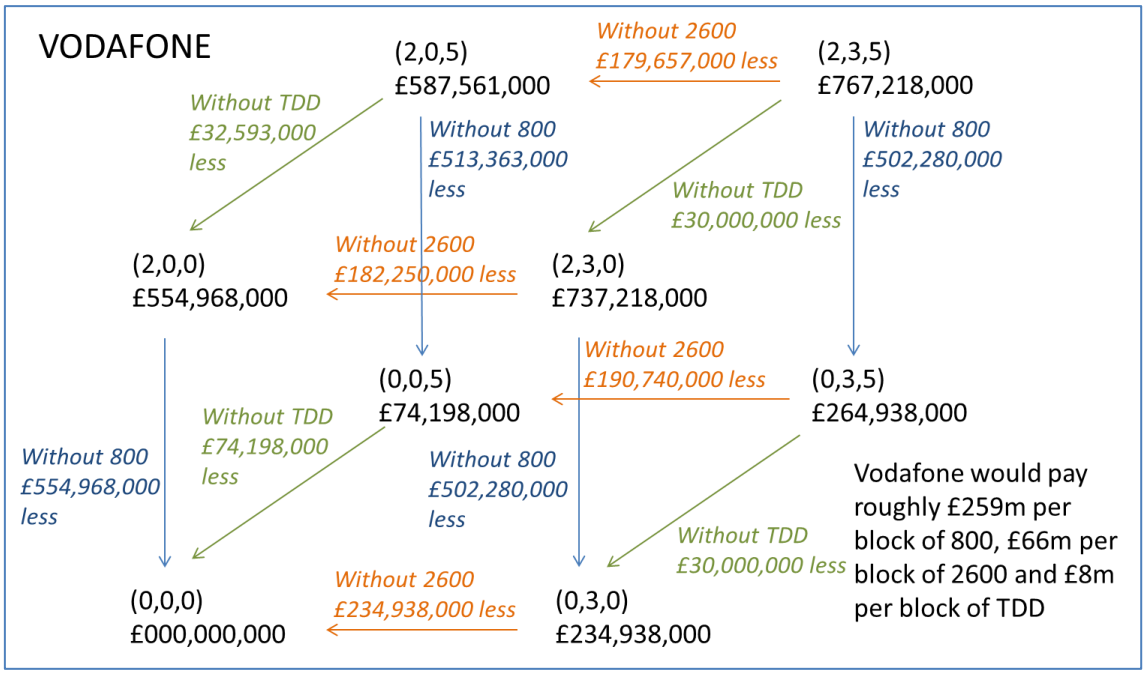
Note that this table is exactly the same as table A1.3e.

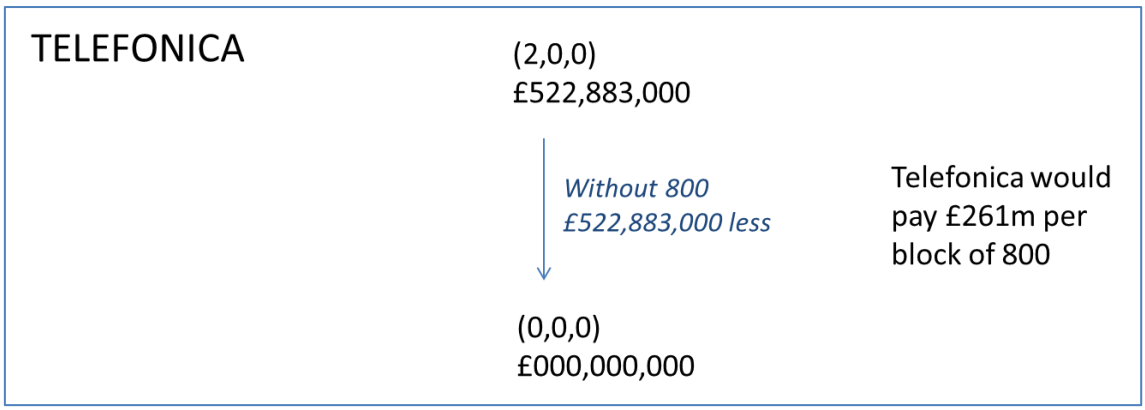
BIDDER	A1	A2	C	E	Opportunity Cost (£)
Vodafone	0	1	4	5	68,744,000
EE	3	0	7	0	374,280,000
H3G	1	0	0	0	0
Niche	0	0	3	4	55,000,000
Unsold	0	0	0	0	0
Totals	4	1	14	9	**498,024,000**

Table A1.3l: Outcome excluding Telefonica Bids

Notice that this is the only scenario we have observed where one of EE's 3 + y bids plays a part, and even here it does not make any real difference. Also note that Telefonica (and Niche) pay about £25m above the Vickrey price because of core pricing.

The final corresponding decompositions for Vodafone and Telefonica are shown below.





Annex 1.4: Glossary of Valuation Terms

Usage Value - The value a potential user of spectrum can achieve by using the spectrum themselves. Typically this is the business case difference between holding and not holding the spectrum, but considered against a background of fixed spectrum holdings and fixed spectrum prices for competitors.

Contiguity Premium - Any component of usage value that a potential user of spectrum gains by ensuring the spectrum is contiguous with other holdings.

Coverage Premium - Any component of usage value that a potential user of spectrum gains by acquiring the first lot of spectrum of a relevant type (e.g. sub-GHz spectrum), and which is not reflected in the usage value of second or subsequent lots of that type.

Usage Opportunity Cost - The maximum usage value which can be achieved by any potential user or combination of users of spectrum other than the holder.

Strategic Value - The value a potential holder of spectrum can achieve by depriving other parties of usage of the spectrum e.g. by weakening a competitor or causing a competitor to exit the market.

Private Value - The total value a potential holder of spectrum can achieve by holding the spectrum, including any strategic value.

Auction Price - The price which a spectrum holder must pay in a competitive auction (or similar market mechanism) to outbid other potential users, and so become or remain the holder of the spectrum.

Strategic Bid - Any bid placed in an auction which departs from a bidder's private value in an attempt at reducing the price paid by the bidder or increasing the price paid by other bidders.

Strategic Premium - Any difference between a bid value and the bidder’s usage value, or between the auction price and usage opportunity cost; this difference arising from strategic values and strategic bids.

How are these terms relevant to Auction Design?

Reserve prices in an auction incentivize entry from potential users with significant usage value, but deter "frivolous" or "speculative" bidders i.e. bidders with little or no usage value. Spectrum packaging and assignment rules can ensure that usage values include any relevant coverage and contiguity premiums wherever possible. Spectrum caps and/or reservations in an auction help to reduce strategic value, by preventing bidders from seriously weakening or excluding their competitors. Detailed auction design can minimise the scope for strategic bids e.g. incentivizing bidders so that their most important bids will be close to private value. Taken together these ensure that:

- Auction prices reflect usage opportunity costs; strategic premiums are minimal

- The auction is efficient: The eventual spectrum holders are the potential users with highest usage value, since only such a user will pay the auction price.

An auction can be said to reveal a "market price" ("market value") when these aims are achieved. There is a strong presumption that a well-designed and well-run auction will indeed achieve these aims and so reveal market value through the prices paid.