Revising Annual Licence Fees

A REPORT PREPARED FOR VODAFONE

December 2013

Revising Annual Licence Fees

Contents

Revising Annual Licence Fees

Executive Summary

This report assesses the context in which Ofcom is required to revise the annual licence fees ('ALFs') for 900 MHz and 1800 MHz spectrum. It is structured as follows:

- Section 1 sets out Ofcom's objectives when reviewing the ALFs;
- Section 2 considers the sources of value to users of spectrum and the resulting market value;
- Section 3 looks at the circumstances in which ALFs set at market value can result in an optimal allocation of spectrum, and issues that arise if market value cannot be accurately determined; and
- Section 4 considers the potential methodologies for determining the market value of 900 and 1800 MHz spectrum, and the appropriateness of using the recent auction fees for 800 MHz and 2.6 GHz spectrum to estimate the market value for the bands subject to ALFs.

Our main conclusions are as follows.

National Regulatory Authorities ('NRAs') such as Ofcom have specific duties with respect to spectrum, including the setting of any usage fees. The overarching EU framework requires that such fees be objectively justified, transparent, non-discriminatory and proportionate and set "to ensure optimal use of spectrum."[1] Ofcom's duties including these requirements have been implemented in UK primary legislation through two Acts[2].

Setting ALFs to reflect the market value of spectrum is consistent with an optimal allocation of spectrum, if the market value is known with certainty. However, where the market value is uncertain, there is a strong asymmetry in the welfare losses associated with different outcomes: setting an ALF above the true market value will lead to significant welfare losses compared to setting ALFs conservatively, where the welfare loss may be small, or zero if spectrum is currently optimally allocated.

This is because, where spectrum is returned and lies fallow (following the imposition of an ALF that is in excess of the true market value), even for a small period, there will be a significant and persistent impact on society's welfare. A

1 Art 13 Authorisation Directive

2 The 2003 Communications Act, and the 2006 Wireless Telegraphy Act

recent report for the Department of Culture Media and Sport[3] found that public mobile communications were worth £30.2bn in 2011, and that 80% of this value (about £24bn[4]) derived from the **consumer surplus** generated from its use. If valuable spectrum was unallocated for a period of time as a result of a reassignment, consumers would be denied the potential benefits from using this spectrum. In practical terms, this would mean that mobile users would face higher prices and reduced quality of service and content, and service providers would have a smaller addressable market.

There is no evidence that current allocations of spectrum subject to ALFs are sub-optimal. The existence of sunk costs means that current holders who have invested in equipment dependent on their spectrum allocations will generally be the most efficient users of this spectrum on a forward-looking basis. To the extent that re-allocation of spectrum could increase efficiency, operators will have incentives to trade spectrum between them independently of the level of ALFs (provided the ALF is not excessive).

Given the strongly asymmetric effect on welfare of estimation errors where market value is uncertain, an ALF set based on a *conservative* estimate of market value will be most efficient in terms of ensuring optimal use and maximising expected potential welfare.

When setting ALFs it is important that market value is not confused with the private value an operator may place upon particular spectrum. The market value is the value at which the market 'clears', that is the demand for spectrum with private values higher than this market value is equal to the supply of spectrum. This value is equivalent to the opportunity cost of not allocating an increment of spectrum to the 'next best' user, i.e. the private value of the marginally excluded user. Importantly, the market value is not equal to the private value of the current or optimal user, and setting the level of ALFs to reflect current users' private values would have a dampening effect on future investment, particularly where existing holders have incurred significant sunk costs based on their spectrum holdings.

There are a number of potential sources of value attached to spectrum, which makes it difficult in practice to derive the market value by determining the private value of spectrum to each and every operator through business modelling.

---

3 Impact of radio spectrum on the UK economy and factors influencing future spectrum demand. Final Report for Department for Business, Innovation and Skills and Department for Culture, Media and Sport

4 Over ten years mobile services are estimated to generate a net present value consumer surplus of between £246 and £314bn. Ibid, Figure B.19.

Approaches used to date when setting ALFs have focussed on network cost models, to estimate the private value to operators resulting from potential savings in network equipment costs resulting from additional marginal spectrum. Alternatively, benchmarks of past market transactions, such as spectrum trades or auctions, can provide direct information on the market value of spectrum in the context of each specific transaction.

In practice, none of these approaches on its own is likely to be able to accurately determine the appropriate market value of any single block of spectrum. In particular:

- attempting to replicate the business plans of operators under varying combinations of spectrum holdings is complicated, and the results would be critically dependent on assumptions of future demand for mobile services;
- network cost modelling, where demand is assumed to be fixed, is methodologically simpler, but will tend to over-estimate private values and hence market values;
- spectrum trades could in principle provide information on market values (net of any ALFs to be paid on the spectrum), but directly comparable trades are infrequent; and
- auction results give some estimates of the immediate market value of spectrum in the bands being auctioned, but may be poor proxies for the value of spectrum in other bands or in other markets.

ALFs can only enhance efficiency if the fees reflect forward-looking value to users over time. This means that a decomposition of market values into annual fees requires an analysis of how value is expected to change over time. If ALFs are to be set at a constant level, then they should be set to reflect the long-term value of the spectrum, which may be lower than implied by current valuations due to expected increases in the supply and fungibility of spectrum in the medium and long term.

1 Ofcom's objectives

National Regulatory Authorities ('NRAs') such as Ofcom have specific duties with respect to spectrum, including the setting of any usage fees. These duties are ultimately derived from the relevant EU framework which requires that such fees be objectively justified, transparent, non-discriminatory and proportionate and set "to ensure optimal use of spectrum"[5].

The EU Framework has been implemented in primary UK legislation through the 2003 Communications Act, which set up Ofcom and set out its overall duties, and the 2006 Wireless Telegraphy Act, which concerns spectrum management. Ofcom has summarised which duties it considers to be particularly relevant in relation to the assignment of spectrum which can be used for mobile cellular services[6]:

- the optimal use for wireless telegraphy of the electro-magnetic spectrum;
- the desirability of encouraging investment and innovation;
- the desirability of encouraging the availability and use of high speed data transfer services throughout the United Kingdom; and
- having regard to the interests of consumers in respect of choice, price, quality of service and value for money.

Ofcom broadly interprets its obligations to ensure that spectrum is used optimally. It notes for example that it seeks to ensure that "the spectrum is used in a way that maximises the value that citizens and consumers derive from it, including broader social benefits, and taking into account the specific consumer and citizen interests, including the interests of particular groups within society".[7]

The Wireless Telegraphy Act allows for the Secretary of State to make directions to Ofcom in fulfilling its duties under the Act. Ofcom was directed by Statutory Instrument to meet its duties by revising the ALFs paid by holders of 900 and 1800 MHz spectrum to:

- reflect the full market value of the spectrum; and

5 Art 13 Authorisation Directive

6 Assessment of future mobile competition and award of 800 MHz and 2.6 GHz paragraph 3.48.

7 SRSP: The revised Framework for Spectrum Pricing, Consultation 29 March 2010 paragraph 1.7,

- have particular regard to the sums bid for licences in the auction of 800 MHz and 2.6 GHz spectrum.[8]

Ofcom is now examining how to set ALFs consistent with its duties, the EU Authorisation Directive and relevant UK law.

8 The Wireless Telegraphy Act 2006 (Directions to OFCOM) Order 2010

2 Spectrum value

2.1 Private value of spectrum

2.1.1 Sources of value

Spectrum suitable for mobile communications is a scarce resource, with potential demand for spectrum from operators being greater than the available resource. This scarcity implies that the holder of spectrum can extract economic value (rent) from the spectrum, i.e. using the spectrum can increase profitability for the holder.

For a given increment of spectrum and operator, this 'private' value can derive from a combination of factors:

- additional capability, e.g. allowing operators to launch new services which will generate positive returns;
- reduction in costs, e.g. allowing operators to maintain a fixed level of demand with a lower level of expenditure in network equipment; and
- additional capacity, e.g. being able to offer additional capacity that would not be economically feasible without the additional spectrum.

The value due to additional capability can derive either from the incremental profits that may be expected from offering a particular service, or the ability to retain existing customers where other operators have acquired this capability.

The potential for incremental spectrum to reduce costs is due to the fact that it is generally cheaper to install additional capacity on existing cell sites than acquiring and operating additional cell sites. Additional spectrum increases the potential capacity per base station, and thus the threshold above which new base stations must be acquired. Such cost savings will apply to those areas of the country where the combination of density of demand, existing spectrum and cell sites does not provide sufficient capacity.

While networks are being rolled out, spectrum at a lower frequency than existing spectrum could reduce forward-looking costs by reducing the cost of coverage, due to the better propagation characteristics of low frequency spectrum[9]. However, once a basic 'coverage layer' has been achieved, the cost of adding capacity may be similar to higher frequency spectrum, as capacity is generally added in urban areas where the number of cell sites is driven by capacity

9 The lower frequency spectrum may provide additional coverage on a grid designed for higher frequency spectrum by providing coverage in 'white spots' previously not covered.

requirements rather than coverage. The advantages of low frequency spectrum may also be offset by the greater overall quantity of higher frequency spectrum which can offer increased capability for LTE networks if large contiguous holdings are available, allowing wider carriers to be deployed than at lower frequencies.

In some areas of very high traffic density, it may not be practical to build additional base stations, and thus the amount of spectrum available may place a hard constraint on capacity. In this case additional spectrum can allow additional capacity to be offered, potentially resulting in incremental revenues and hence profits. The value to the operator of such marginal demand will depend on the incremental profit (margin) generated by the additional capacity.[10]

All operators face significant uncertainty when attempting to estimate their private value of incremental spectrum. This is because such estimates critically depend on a range of factors which are uncertain, such as the future customer demand for data services, the likely future availability of spectrum, and the spectrum efficiency that future mobile standards will be able to achieve.

2.1.2 Variation over time

Given the need to invest in equipment, spectrum suitable for mobile communications will only have general value if there is a reasonable expectation that it will be available for a number of years. Recognising this, spectrum suitable for mobile communications is generally licenced on a long-term basis.

However, over the longer term, factors driving the private valuations of spectrum can vary over time as the market changes, for example as demand increases, technology evolves or new spectrum becomes available. The value of spectrum in a given period (i.e. the value generated in the period by the holder of the spectrum, or the value foregone by other operators from not having spectrum over this period) will reflect the changes in valuation from these factors.

2.1.3 Variations between bands

Operators' private values of a given block of spectrum will vary depending on the physical characteristics of the spectrum and the available network and terminal equipment which uses this band.

The private value of spectrum in a band will critically depend on the availability of equipment that can use the band. Bands where equipment for the most efficient forward-looking technology is readily available will have higher

10 While demand for mobile services has been growing strongly in volume terms, revenues and hence margins have been relatively stable. As the available spectrum increases to meet the demand for increased volume, the margin per block of spectrum may be expected to fall.

valuations than bands which only support legacy technologies, or for which equipment availability will be limited.

Availability of equipment for a given band will depend on whether the band is standardised for a given technology, and also the degree to which operators both regionally and globally plan to deploy the technology in the band. In particular, manufacturers of terminals will generally produce a small number of variants of any one device covering broad regions, each supporting a subset of bands for any given technology. If few operators plan to deploy a given technology in a band, then there will be limited incentive for terminal manufacturers to include this band in the regional variant.

As noted above, lower frequency spectrum can reduce the fixed costs of coverage when available in periods when networks are being rolled out. This has led to operators valuing low frequency spectrum more highly in auctions than higher frequency spectrum. However, once the basic 'grid' of coverage base stations is established, the advantages in terms of greater coverage will be smaller, for example through providing higher quality of service or increased indoor coverage.

When considering the value of spectrum for additional capacity, differences between bands may be much smaller, as capacity is generally required in urban areas, where the number of cell sites is largely driven by capacity requirements. In urban areas high and low frequency spectrum may be largely substitutable for additional capacity providing incremental capacity at similar costs. For LTE networks, the additional end user bandwidth potentially available from wide carriers may lead to operators assigning a premium to bands which offer large contiguous spectrum holdings.

2.2 Variation in private valuations between users

Notwithstanding the significant uncertainties inherent in estimating the private value of any one block of spectrum, its value to different users will depend on a range of factors, including the operators':

- existing spectrum holdings; and
- existing sunk investments, such as network infrastructure or customer base.

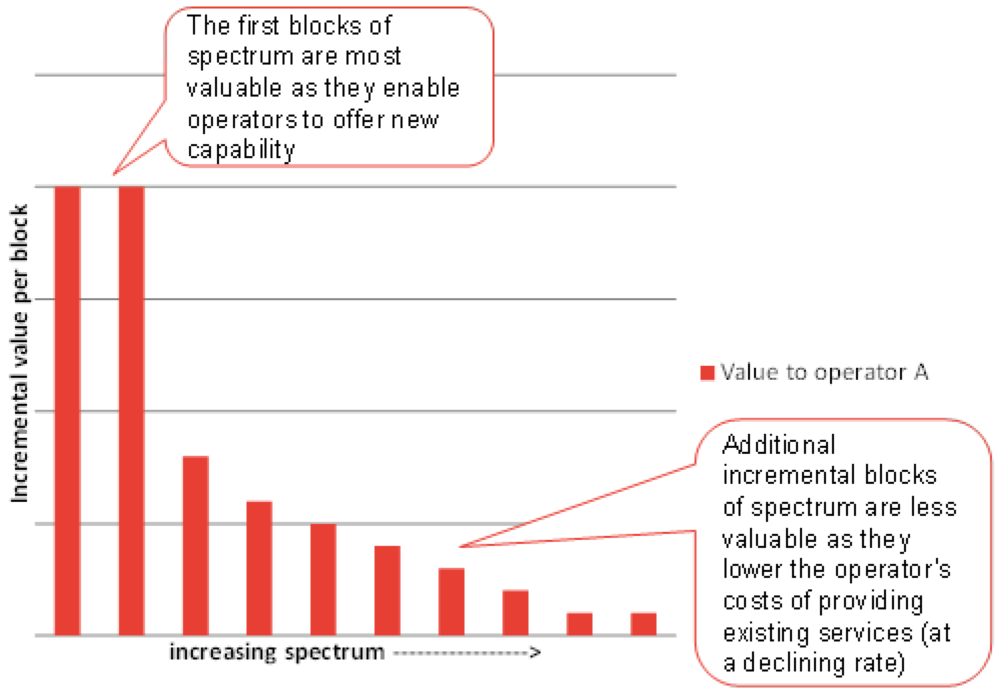
2.2.1 Relationship with existing spectrum holdings

Operators whose existing spectrum holdings allow the roll-out of a technology which increases the spectrum efficiency and/or maintains their competitive advantage (such as LTE), will value additional spectrum which provides this capability less than operators that do not already possess such spectrum, i.e. there is a premium attached to the minimum amount of spectrum that allows a new profitable technology to be rolled out.

Operators that have a relatively large holding of spectrum (relative to the traffic on their network) will value additional 'capacity' spectrum less than operators that are capacity constrained across much of their network, due to the lower potential cost savings available and/or the lower value of any traffic foregone.

These two effects, the premium attached to a minimum amount of spectrum and the diminishing value of incremental spectrum are illustrated below:

Figure 1. Illustrative value of minimum and incremental spectrum



Source: Frontier Economics

In reality the relationship between potential spectrum holdings and valuations for existing operators will be more complex.

Inter-relationships between the value of a given block of spectrum and other spectrum holdings give rise to combinatorial effects, i.e. the value of a given block to any user will be dependent on both its existing holdings of spectrum and also on any other spectrum that may become available at the same time.

Spectrum can only be added to networks in discrete increments. For example, the value of marginal spectrum in a given band will depend on the minimum increment of contiguous spectrum that is required to offer services using that spectrum (for instance, GSM carriers use 200 KHz of paired spectrum, whereas

3G carriers require 5 MHz of contiguous paired spectrum). Marginal spectrum available in smaller increments will have limited value.

At certain points additional spectrum could provide additional capabilities, for example a large contiguous holding could allow higher bandwidth LTE services to be provided. At these points the value of incremental spectrum may increase reflecting the value of this capability.

2.2.2 Sunk network costs

Mobile networks are characterised by high levels of sunk costs. When considering the effects of sunk costs on private valuations of incremental spectrum, we are principally concerned with investments in the radio access network such as:

- cell sites;
- the infrastructure that serves these cell sites; and
- the equipment sited on these cell sites.

To the extent that spectrum is required for continued operations, overall private spectrum valuations may also reflect sunk investments in other assets, including intangible assets such as brand, customer base and employees.

Given that private valuations will be dependent on forward-looking costs, which exclude sunk costs, the existence of sunk assets will lead to asymmetries in the private valuation of spectrum. In general, existing users of spectrum will have higher private valuations of their own existing spectrum than other operators who, on a forward-looking basis, would need to invest in much more equipment to use the spectrum[11].

Operators may also tend to have higher valuations for spectrum that is similar to their existing spectrum, either in the technology that the spectrum can be used for or its physical characteristics. This is because such spectrum can be deployed re-using some of the existing sunk assets. For example, an operator that has already deployed a basic coverage layer (the 'grid') based on higher frequency spectrum[12] for one technology e.g. 2G will be able to deploy a coverage network based on additional high frequency spectrum for another technology e.g. 4G more effectively than an operator whose grid is optimised for low frequency spectrum.

---

11 Potential new entrants who would need to invest in core network, brand and customer base to use spectrum would have a still lower valuation of the spectrum, all else being qual.

12 For example operators who initially rolled out coverage networks using 1800 MHz spectrum.

The value of a given increment of spectrum, in terms of reducing network costs, will also depend on the degree to which the existing network is traffic constrained. This in turn will depend on both the amount of existing spectrum deployed, the technologies deployed and the volume of traffic. All other things equal, greater traffic will increase the value of spectrum. A larger customer base would also be expected to increase the value attached to being able to launch new services, both because a larger customer base provides more opportunities to upsell and because of the value associated with retaining existing revenues.

The terminals used by existing customers may also impact on private valuations, for example due to the need to continue supporting customers who have handsets that only allow the use of legacy technologies such as GSM.

2.3 Market value of spectrum

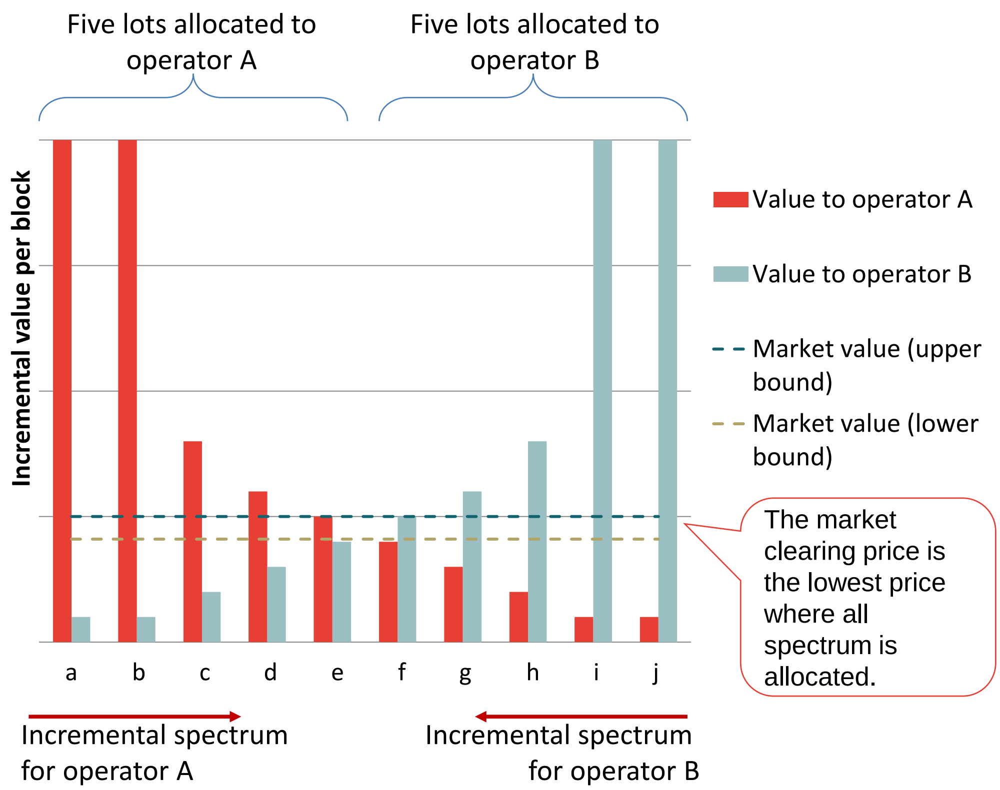
For each operator, the private value of a given amount of spectrum will generally vary from band to band. Moreover, within a band, the private value will vary between operators depending on a wide range of factors, including their existing spectrum holdings. However, for any band there will be a price of spectrum at which the market will 'clear', i.e. the price where demand for spectrum will equal the supply of spectrum in a band. This market value is a function of the private values of all potential users across the range of potential spectrum allocations. In theory, provided a regulator knows the private values of spectrum of all potential users, it can derive the 'market value'.

Figure 2 below illustrates this in the simplest case where there are two potential users (Operators A and B) of ten blocks of spectrum (a to j), each with identical private values, and hence demand, for spectrum at a given price. Operator A's demand for each incremental block of spectrum is measured left to right, whereas Operator B's demand for each incremental block of spectrum is measured right to left.

The market value is the lowest price where the market clears and there is no excess demand for spectrum, i.e. the point at which the price is above the value to all non-optimal users of the spectrum. In the simplified example below, the market clearing price is just above the marginal excluded operator's value for the marginal increment of spectrum.

As the market value is dependent on the value to the marginally excluded user, *it is not dependent on the private value of the spectrum to optimal users*. In particular the market value is not influenced by the high private value that the operators may have for a minimum amount of spectrum.

Figure 2. Illustration of market value of spectrum



Source: Frontier Economics

In the illustration above, where spectrum is allocated in discrete blocks, any price between the market value upper and lower bounds could be consistent with allocative efficiency in a static sense. However, dynamic considerations described in Section 3.2.2 below indicate that the lower bound is the efficient price when taking account of Ofcom's broader duties (see section 1 above).

3 Efficient allocation

Allocative and productive efficiency will occur when resources are allocated in such a way such that overall (static) economic welfare is maximised. An allocation is efficient if there is no other allocation which increases overall welfare. Productive efficiency is achieved where no alternative mix of inputs can produce output at lower costs.

Static efficiency requires that all spectrum with value be used. If valuable spectrum is not used, then this will either result in some unmet demand, with a consequent loss of allocative efficiency, and/or the cost of production being unnecessarily raised, resulting in a loss of productive efficiency.

3.1 Spectrum trading

The fact that spectrum is tradable[13] should result in an efficient allocation of spectrum across operators where barriers to trading are small[14]. There will be an incentive for an operator with a lower valuation to trade spectrum with an operator with a higher valuation, and receive a payment in return. As spectrum is successively traded, all spectrum should be assigned to those users that have the highest valuations, with the prices being paid in trades reflecting the market clearing price, i.e. market valuations.

Ofcom has made an increasing proportion of spectrum tradable, including spectrum for mobile communications, in order to allow for the potential efficiencies that trading can bring. While the number of spectrum trades has been relatively low, this may reflect the fact that current allocations are optimal[15] rather than necessarily being an indication of failings in the trading regime. Where spectrum trading can be implemented or improved, this should be considered the best option for ensuring allocatively efficient outcomes. Where there are barriers to trading, regulators should first consider policy tools which enable efficient trading.

---

13 By 'spectrum trading' we include any kind of commercial transaction which includes a spectrum assignment between two parties such as a trade, lease, or spectrum swap.

14 See "Spectrum pricing policy" George Houpis, Director, Frontier Economics and James Bellis, Associate Director, Frontier Economics, Vodafone Policy Paper Series • Number 14 • May 2012

15 Particularly given the impact of sunk costs on valuations, meaning that current holders typically have higher valuations.

3.2 Role of ALFs in ensuring efficient allocation

3.2.1 Static efficiency

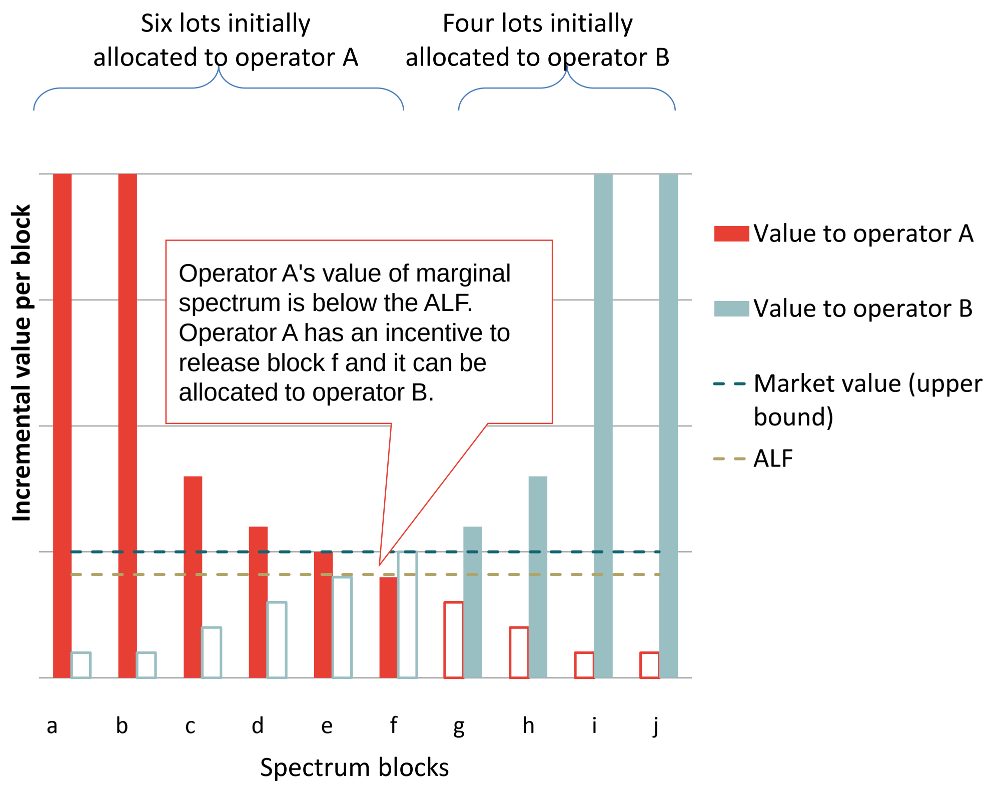
Annual licence fees can also, in principle, lead to an efficient allocation of spectrum by making it uneconomic for sub-optimal users to continue to use the spectrum.

When valuing spectrum, operators will take account of the ALFs associated with the spectrum, which will reduce the net value of the spectrum. The private value of a block of spectrum will be the net present value of the cash flows from using the spectrum less the net present value of the associated ALFs. If the forward-looking cost of the ALFs exceeds the value derived from using the spectrum, then the private value of the spectrum would be negative and the operator would seek to dispose of the spectrum, either through a trade or, if it is already in the hands of the optimal user, by returning the spectrum to the government.

In order to ensure that sub-optimal users vacate the spectrum, the licence fee should be set at a level that exceeds the value of the spectrum to sub-optimal users. In order to ensure that the spectrum is acquired and/or retained by the optimal users, the price must be set below the marginal value for those users.

Setting the price to reflect the market value achieves this optimal allocation as illustrated below.

Figure 3. Illustration of reallocation of spectrum with ALF



Source: Frontier Economics

In the illustration above, Operator A is initially allocated six blocks of spectrum (a to f), and Operator B is allocated four blocks of spectrum (g to j). This is a sub-optimal allocation as there is an alternative allocation which could increase welfare. Specifically, operator B has a higher valuation for block f than operator A.

Setting the ALF for the spectrum at the market value will mean that continuing to hold this spectrum will reduce profitability for Operator A as the net value of the marginal block (the value of the spectrum less the ALF payments) will be negative. In this case the operator would be expected to release the spectrum, which will allow the spectrum to be reassigned to Operator B (for whom the spectrum has value, net of ALFs).

3.2.2 Dynamic efficiency

While the value of the ALF could be set up to upper bound of the market value in this example and still be consistent with an *allocatively* efficient outcome, this would conflict with *dynamic* efficiency considerations, in particular dampening future investment incentives.

Efficient allocation

In general, the higher private values of optimal operators compared to the market value will reflect competitive advantage resulting from previous, sunk investments. For example, once an operator has sunk costs in network equipment which is reliant on a given spectrum band, it may continue to pay ALFs even if they were raised considerably above the market value (returning the spectrum would leave the unrecovered value of the sunk assets stranded). Similarly other sunk investments, such as in brand or in the customer base, will tend to increase operators' private values.

An increase in ALFs above the market value would effectively be a partial transfer of the value of the sunk investments from the operator to the government, and could result in the operator not fully recovering its initial investments in these assets. This partial expropriation of the value of operators' assets would set a regulatory precedent, and could lead to operators foregoing future investments due to the perceived regulatory risk. This would appear to conflict with Ofcom's broader duties, such as encouraging investment and innovation, described in Section 1.

3.2.3 Conclusion

In theory, setting ALFs at to reflect market value should result in an efficient allocation of spectrum. However, the efficient allocation of spectrum under ALFs assumes that market value can be determined with certainty.

3.3 ALFs under uncertainty

As market values are uncertain and are likely to fluctuate over time as new information becomes available, there is a risk that the regulator's estimate differs materially from the true market valuation. This could occur either because the original estimate is inaccurate or because the market valuation changes over time in a way which was not predicted.

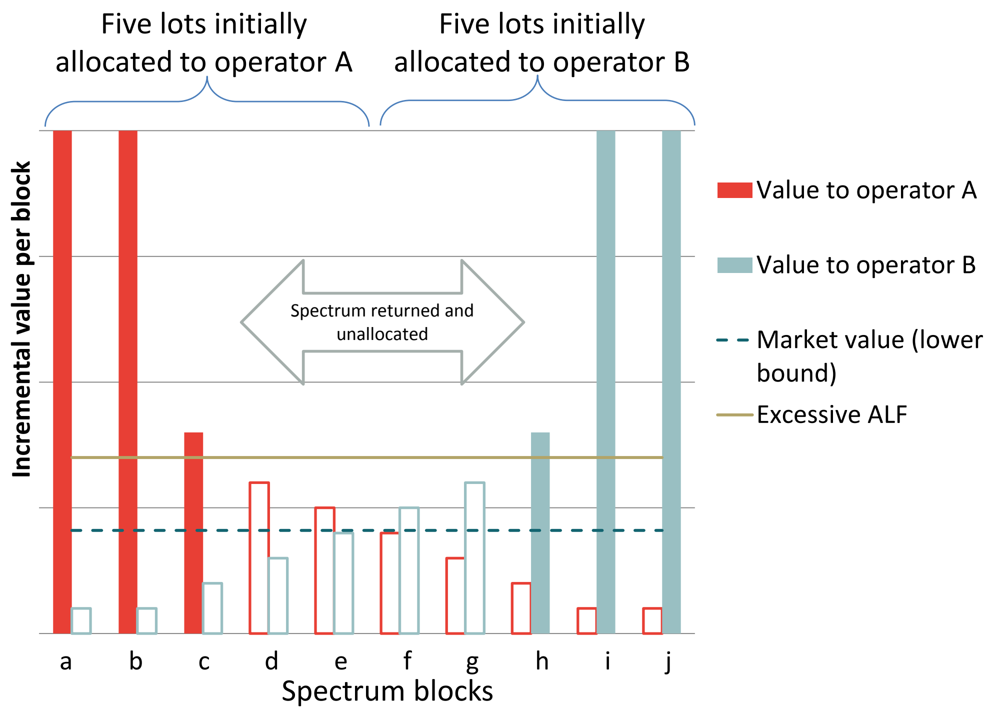
In the sections below we consider the impact of a setting ALFs which diverge from the true market value due to estimation errors. We begin with the simple case without spectrum trading. We then consider the more realistic case where spectrum is tradable.

3.3.1 The impact of ALFs which diverge from market value

If the ALF is above all operators' valuations, then marginal spectrum will be returned by the current holder, but will not be taken up by any other operator at that price. The resulting welfare loss will be significant as all of the value associated with the unused spectrum is foregone. This is illustrated in **Figure 4** below, where operator A is initially allocated spectrum blocks a to e, and operator B is initially allocated blocks f to j. When the regulator introduces an excessive

ALF, blocks d, e, f and g are returned to the regulator as their net value is negative to the operators.

Figure 4. Illustration of impact of excessive ALFs

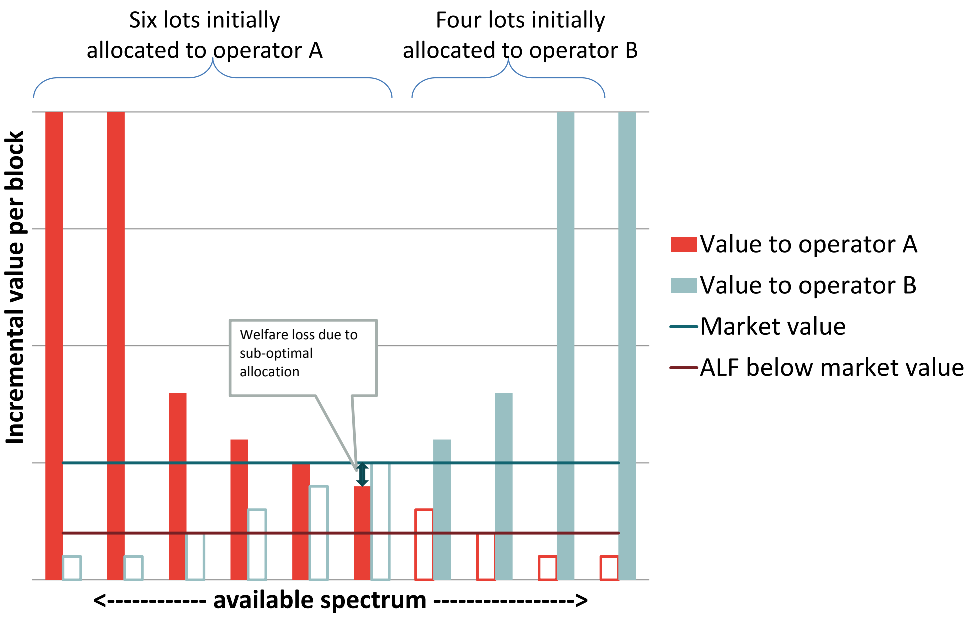


Source: Frontier Economics

Conversely, if the ALF is set below the market value, then there will be excess demand and, absent trading, a sub-optimal user may continue holding the spectrum. As a result, there will be a potential welfare loss, due to the difference in the value of the blocks between the optimal and sub-optimal users, as illustrated below.

Efficient allocation

Figure 5. Impact of setting ALF below true market value without trading



Source: Frontier Economics

However, in the case that the existing allocation of spectrum is already optimal, there will be no welfare loss associated with setting ALFs below the market value[16].

The potential outcomes when setting ALFs under uncertainty are summarised in the table below. The purpose of the table is to demonstrate the asymmetric effect of setting ALFs which are above, or below, the true market value due to estimation errors.

16 The existence of sunk costs means that it is relatively likely that existing allocations will be optimal from a static perspective.

Table 1. Potential change in welfare when setting ALFs under uncertainty without trading

<table>
<tr><th>Level of ALF</th><th>Current holder is highest value user</th><th colspan="2">Current holder is not highest value user</th></tr>
<tr><td>ALF above value of optimal user</td><td>Spectrum returned and not re-allocated
Total welfare associated is lost</td><td colspan="2">Spectrum returned and not re-allocated
Total welfare associated is lost</td></tr>
<tr><td>ALF above the true market value but below value of optimal user</td><td>Spectrum use continues
No net effect on static welfare but reduction in dynamic efficiency</td><td colspan="2">Spectrum returned and reallocated to highest-value user
Increase in welfare of difference in value</td></tr>
<tr><td rowspan="2">ALF below true market value</td><td rowspan="2">Spectrum use continues
No net effect on welfare</td><td>ALF is above value to current sub-optimal user</td><td>Spectrum returned and reallocated to higher value user
Increase in welfare of difference in value</td></tr>
<tr><td>ALF is below value to current sub-optimal user</td><td>Spectrum use continues
No net change of welfare</td></tr>
</table>

Source: Frontier Economics

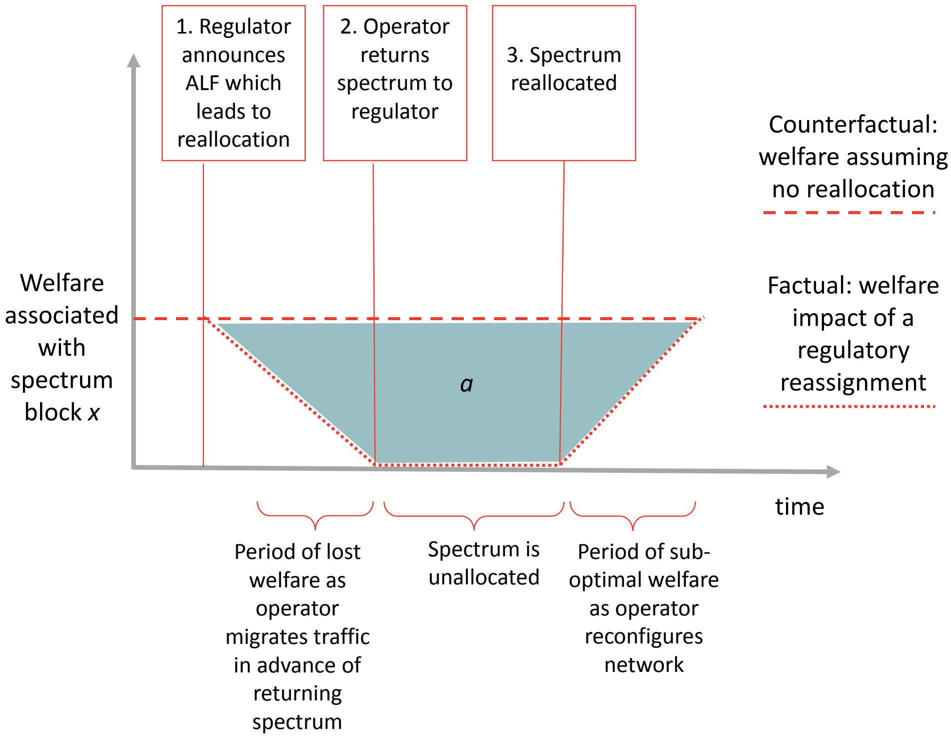
The risks associated with setting the 'wrong' ALF (i.e. an ALF which diverges from the true market value) are clearly asymmetric in terms of the magnitude of welfare losses. In the case of the ALF being set below the market value, there may be no welfare loss at all if the current allocation is optimal. Even where the current user is not the highest-value user, the value potentially foregone will only be the difference between the valuation of the optimal user and current user for marginal blocks of spectrum.

In the case of the ALF being set *above* the true market value, the spectrum may become unused, and the entire value associated with the spectrum will be foregone from the moment that the spectrum is returned. Even prior to the spectrum being returned, there is likely to be a period of sub-optimal use as the holder migrates traffic and reduces demand in order to minimise the disruption associated with the spectrum being returned. Even if the ALF is reduced and the spectrum is subsequently re-allocated to the same operator, by auction or other mechanism, there will be a lag before it is used optimally as the operator will have to make investments to reconfigure its network (for example by decommissioning existing cell sites, which become uneconomic as a result of incremental spectrum).

The impact of this welfare loss is illustrated in the shaded area *a* in **Figure 6** below. The chart illustrates the impact of a decision by a regulator to set an ALF which leads to a return of spectrum and requires a reduction in ALFs before the spectrum can be reallocated (in the factual) compared to the welfare that would observed if the price is set at the market level (in the counterfactual).

The welfare loss associated with returning spectrum, illustrated by the shaded area *a,* represents not just the loss of producer surplus which would accrue to the holder of the spectrum, but additionally the loss of consumer surplus to consumers who would have used the spectrum to access content or services using mobile networks.

Figure 6. Welfare loss from spectrum return due to excessive ALF



Source: Frontier Economics

This indicates that, even though ALFs could in theory be revised in the light of evidence that they had been set above market value, the welfare impact of such estimation errors would persist even after spectrum was successfully reallocated.

3.3.2 ALFs with uncertainty and trading

Where there is uncertainty on market values, spectrum trading has practical and theoretical advantages as a mechanism to encourage efficient allocation compared to ALFs. Under trading, reallocation of spectrum occurs directly between two market participants, without the spectrum needing to be returned to the government. As a result, there is no risk that the spectrum will be unallocated, with the large welfare losses that could result.

As the valuation is determined endogenously between market participants, the valuation under trading is more likely to reflect the true market value than the ALF, which is determined exogenously. Due to information asymmetries, market participants will have a better understanding of their private valuations of spectrum than the regulator. Valuations in a trading regime can be updated frequently with the latest information while the regulatory valuations underlying ALFs will be based on past data. Through a process of negotiation, information on valuation can be shared between market participants leading to a more robust valuation for all participants.

The imposition of ALFs up to the market value does not affect the incentives to trade spectrum. The expected ALFs simply reduce the absolute valuation equally for all parties, compared with the valuations absent ALF. Thus ALFs and trading can co-exist, with trading encouraging efficient outcomes even in the case where ALFs are set below the market value.

The potential outcomes of setting ALFs, with uncertain estimates of the market value, in the presence of trading can be illustrated in the table below.

Efficient allocation

Table 2. Potential outcomes when setting ALFs under uncertainty, with trading

<table>
<tr><th>Level of ALF</th><th>Current holder is highest value user</th><th colspan="2">Current holder is not highest value user</th></tr>
<tr><td>ALF above value of optimal user</td><td>Spectrum returned and not re-allocated
Total welfare associated is lost</td><td colspan="2">Spectrum returned and not re-allocated
Total welfare associated is lost</td></tr>
<tr><td>ALF above true market value but below value of optimal user</td><td>Spectrum use continues
No net effect on static welfare but reduction in dynamic efficiency</td><td colspan="2">Spectrum returned and reallocated or traded to highest-value user
Increase in welfare of difference in value</td></tr>
<tr><td rowspan="2">ALF below true market value</td><td rowspan="2">Spectrum use continues
No net effect on welfare</td><td>ALF is above value to current sub-optimal user</td><td>Spectrum returned and reallocated or traded to higher value user
Increase in welfare of difference in value</td></tr>
<tr><td>ALF is below value to current sub-optimal user</td><td>Spectrum traded to higher-value user
Increase in welfare of difference in value</td></tr>
</table>

Source: Frontier Economics

This illustrates that trading mitigates the risk of potential welfare losses in the case that ALFs are set below the market value, as sub-optimal holders of spectrum are exposed to the opportunity cost of continuing to hold spectrum. However, trading does not mitigate the risk of welfare losses resulting from ALFs being set too high, as in this case spectrum will be returned and there will be no potential buyers of marginal spectrum.

3.4 ALFs and investment

Mobile networks are underpinned by long term sunk investments which are dependent on spectrum availability. A regime in which ALFs were not predictable would therefore create uncertainty about whether continuing to operate using a given increment of spectrum would be financially viable in the future, for example if ALFs were to increase substantially.

If spectrum which was previously relied upon to deliver services were to become commercially unviable because of the ALF regime, then there is a risk that some of these assets would become 'stranded', i.e. that the operator could not fully recover its value. This regulatory risk would lead to inefficient hedging when making investments in the first place, which would reduce the efficiency of investments. In order to mitigate the risk of assets being stranded, operators would tend to favour solutions which had a lower level of sunk costs, even if the overall level of costs in the long run were higher.

Uncertainty over the future value of spectrum would also increase the value of the option to delay investments. For example in the period prior to a review of the level of ALFs, it could be commercially sensible to delay investment until after the review, when the charges - and hence the commercial viability of spectrum - were fully known. This increase in the value of the option to delay would result in a dampening of investment incentives, and hence a reduction in dynamic efficiency.

In order to ensure efficient investment, NRAs should put in place an ALF regime which provides predictability and certainty for the level of payments in the medium term. Updating ALFs frequently to reflect new information would lead to inefficient outcomes.

In addition, NRAs should take account of the fact that spectrum valuations will be expected to change over time. This should take into account predictable changes due to known issues, such as the expected availability of new spectrum or the removal of constraints on the use of existing spectrum. NRAs also will need to take account of possible fluctuations in valuations as new information becomes available and/or perceptions change.

NRAs can further reduce uncertainty by providing guidance on how the ALF (and trading) regime will operate, covering such issues such as the process for returning and re-allocating spectrum subject to ALFs and the increments that can potentially be returned.

3.5 Conclusion

Setting ALFs to reflect market values will in theory result in an efficient allocation of spectrum. However, there are risks of inefficient outcomes if NRAs over-estimate the true market value or if the market value changes over time.

Efficient allocation

These risks are strongly asymmetric, with the welfare losses from setting ALFs which are above the true market value being significantly greater than the potential welfare losses from setting ALFs below the true market value.

Where spectrum is returned and lies fallow, even for a small period, there will be a significant and persistent impact on society's welfare. A recent report for the Department of Culture Media and Sport[17] found that public mobile communications were worth £30.2bn in 2011, and that 80% of this value (about £24bn[18]) derived from the **consumer surplus** generated from its use. If valued spectrum was unallocated for a period of time as a result of a reassignment, the consumers would be denied the potential benefits from using this spectrum. In practical terms, this would mean that mobile users would face higher prices and reduced quality of service and content, and service providers would have a smaller addressable market. Even where spectrum is not returned, ALFs set above a market valuation would increase perceived regulatory risk potentially resulting in reduced investment and innovation in the future.

The ability to trade spectrum mitigates the risks related to setting ALFs too low, but does not reduce the risks related to setting ALFs too high, further increasing the asymmetry in losses.

Given the significant uncertainty in estimating private values and deriving the market value, and the strong asymmetry of outcomes with respect to the direction of measurement error if the ALF were set at the 'wrong' level, the optimal policy is to set the ALF based on a conservative estimate of market value. This will reduce the risk of a significant reduction in welfare which could result from setting the ALF above the true market value.

Finally, as mobile networks are underpinned by long term sunk investments which are dependent on spectrum availability, it is important that NRAs put in place an ALF regime which provides predictability and certainty for the level of payments over time – otherwise dynamic efficiency will be compromised.

17 Impact of radio spectrum on the UK economy and factors influencing future spectrum demand. Final Report for Department for Business, Innovation and Skills and Department for Culture, Media and Sport

18 Over ten years mobile services are estimated to generate a net present value consumer surplus of between £246 and £314bn. Ibid, Figure B.19.

4 Determining market value based ALFs

In order to avoid inefficient outcomes under an ALF regime, the market value of spectrum needs to be appropriately determined. There are three potential methods to estimate market value:

- business modelling;
- network cost modelling; and
- benchmarks from transactions in the jurisdiction or other, similar jurisdictions.

Each of these approaches has certain weaknesses, and it is unlikely that a regulator could in practice appropriately determine the market value of a spectrum band from any single approach.

This section looks at the likely robustness of data from these three sources, and comments on what inferences can be drawn from recent spectrum auctions when estimating the market value for 900 and 1800 MHz spectrum.

4.1 Business modelling

4.1.1 Business modelling underlying operators' valuations

Operators' bids in auctions, and any trades between operators, will be based ultimately on financial models of the value of spectrum to the business. In the case of an existing operator, the value of the spectrum is the difference in net present value of the business (enterprise value) with the spectrum, compared to the counterfactual of not having the spectrum.

The models used by operators are typically discounted cash flow ('DCF') models of revenues and costs, with underlying models of demand and network dimension. DCF models typically need to forecast forwards 10 years or more, with cash flows after the end of the forecast period implicitly included through an estimate of terminal value.

DCF models are generally highly sensitive to input assumptions. Given the rapid rate of change in the mobile industry, any forecasts for a decade ahead will be subject to significant levels of uncertainty, in particular with respect to the level of revenues and demand. As a result, operators' spectrum valuations are likely to be subject to a high degree of uncertainty.

4.1.2 Requirements for Ofcom to assess market values

In order to estimate the market value of spectrum using a financial modelling approach, Ofcom would need to run DCF models for all operators, for a large range of potential allocations of the available spectrum across the operators.

Ofcom would need to populate these models based on existing financial and operational data from each of the operators, along with reasonable assessments of the likely market and technical developments.

The inputs to these models would be subject to a great degree of uncertainty, and so the output valuation would be correspondingly uncertain – this uncertainty is recognised in the use of multi-round auctions for spectrum in order to allow information sharing between participants in order to reduce uncertainty.

4.1.3 Conclusion

There is inherent uncertainty when using business modelling to estimate operators' private values. Ofcom recently acknowledged these uncertainties when it commissioned experts to model the business cases for existing UK mobile operators for 800 MHz and 2.6 GHz spectrum[19]. It noted in a statement:

"Modelling such complex businesses in an environment of uncertainty inherently requires a degree of pragmatism and simplification. … the results are at best indicative and do not give precise valuations of a spectrum package to different players or the value of different packages to a specific player."[20]

Ofcom concluded that, given the inherent uncertainties, "*the business case modelling plays a relatively minor role in informing the recommendations of the study, and serves more as a consistency check of the benchmarking results.*"[21]

Business modelling therefore does not appear to be a practical method for Ofcom to derive the market value of spectrum, because of the complexity of the task and the likely high level of uncertainty surrounding inputs and outputs. Ofcom's central estimate of market value derived from business modelling could be significantly different from those of the operators, risking inefficient market outcomes.

Business modelling could however provide some information on the **relative** valuations of spectrum bands, particularly where the main difference in valuation is believed to be due to the impact on network costs, rather than the demand side.

4.2 Network cost modelling

Ofcom has to date set ALFs employing a methodology known as Administrative Incentive Pricing (AIP), which estimates the opportunity cost of spectrum on the

19 Ofcom (2012) Assessment of future mobile competition and award of 800 MHz and 2.6 GHz.

20 Ibid. paragraphs 8.20, 8.22.

21 Ibid. paragraphs 8.22.

basis of models of network costs. Such network cost models aim to estimate the reduction in network equipment costs resulting from the availability of incremental spectrum. This is modelled by estimating the equipment costs needed to serve a given level of demand under two scenarios, with and without the marginal spectrum.

This is a pragmatic approach which minimises the number of assumptions that need to be varied under the scenarios with and without the incremental spectrum. By assuming that demand is fixed as spectrum varies, fewer assumptions need to be made about the demand side. Network cost modelling, while complex, can be based on known engineering principles and on unit cost information which can be gathered from operators. The approach can also be applied in a consistent way across technologies and applications.

However, the AIP approach suffers from a number of issues:

- the resulting valuations are, in principle, an upper bound on private valuations as, under a scenario of reduced spectrum, operators would in practice face a trade-off between (i) keeping demand fixed and installing additional equipment or (ii) foregoing marginal demand[22]; and
- the relationship between spectrum and equipment costs is a complex function, with Ofcom having to make further simplifying assumptions in order to make the modelling tractable.

When setting ALFs under the AIP regime, prices were generally set at 50% of the estimated values resulting from network models[23].

4.3 Benchmarks from auctions

An alternative approach would be to derive estimate values from benchmarks, i.e. transactions for 'similar' spectrum which would be expected to reveal market valuations. There are two types of transaction for spectrum[24]:

1. auctions where the government assigns spectrum competitively; and
2. trades of spectrum between operators.

In principle, prices paid in trades could indicate a market price. However, even where trades are allowed, markets for trading spectrum tend to be illiquid and

22 If the value of this marginal demand is lower than the incremental costs of serving this demand, then operators would reduce demand rather than keeping demand fixed.

23 See for example: Ofcom (2009) Policy evaluation report: AIP Document for Information.

24 Other transactions such as mergers and acquisitions may result in the re-assignment of spectrum. But as this spectrum will be bundled with a wide range of other assets, this will not provide a robust source of information on the market value of spectrum.

trades infrequent. This is unsurprising because, as noted above, the existing holders typically have a higher valuation of spectrum than other potential users due to the existence of sunk costs. As a result, the conditions for a trade (i.e. where another potential user has a higher valuation than the existing user) will rarely exist[25]. Moreover, where trades do occur, prices paid will take account of the expected level of future ALFs associated with the spectrum and thus may not provide a true indication of gross market values before ALFs.

Auction data may therefore provide the only direct source of information on market values. Below we assess the availability of information from auctions. We then show how these values can be used to derive equivalent annualised values for setting ALFs. Finally, we assess the reliability of ALFs derived from auction benchmarks.

4.3.1 Auction prices as a measure of market value

Auctions are designed to establish the price at which the market for a given amount of spectrum clears. Depending on their design, auctions also allow for bidders to reduce the uncertainty on the values of licences by providing information on the valuations of other bidders.

Regulators often decide that if unconstrained bidding is allowed, then the resulting outcomes may not be optimal from an efficiency perspective. As a result, regulators typically place restrictions on the packaging of blocks and the amounts that all (or a subset) of the bidders can acquire; and they may impose obligations with regard to the use of spectrum and the levels of investment. Regulators may also reserve spectrum for a certain bidder or class of bidders, for example new entrants. Depending on the rules of the particular auction, such constraints may increase or reduce the prices paid compared to an unconstrained market clearing price[26].

4.3.2 Limitations on benchmarking

By definition, the spectrum subject to ALFs has not been auctioned. Any benchmarking used to estimate market values for the setting of ALFs can either be:

- within jurisdiction between different bands; or
- across jurisdictions for similar bands.

---

25 Where trades do occur they are typically associated with other transactions, such as changes in ownership.

26 Spectrum reservations would be expected to increase the price above the market level due to the resulting restriction in supply for other parties, while spectrum caps would be expected to depress prices.

We assess the robustness of each approach below

Benchmarking within jurisdiction

Differences in market value for bands within a jurisdiction are likely to reflect at least four principal differences:

- the physical characteristics of the band, i.e. high versus low frequency;
- local auction and competition conditions;
- scarcity of spectrum in the band; and
- the technologies available for the band on a forward looking basis.

The impact of differences in physical characteristics on network costs is relatively well understood and is likely to be consistent over time. It should be possible to control for these differences when using benchmarks to set ALFs.

Differences in the technologies available in the future will impact on all aspects of an operator's business: customer acquisition and retention, pricing and demand, and network costs. As a result, operators' bids for one spectrum band are unlikely to be robust benchmarks for their valuations of other spectrum bands where they would deploy different technologies.

Benchmarking across other jurisdictions

Even for the same band of spectrum, market valuations across different jurisdictions will vary - often significantly - reflecting a wide range of differences between jurisdictions including:

- the overall availability of spectrum prior to the auction, and the expected availability in the long term;
- demand-side factors, such as the level of penetration of different applications/technologies, usage and willingness to pay;
- the structure of the market in terms of the number of competitors and competitiveness;
- supply-side factors, such as costs of non-tradable inputs and the availability of and planning regulations on cell towers; and
- geographic factors, such as terrain and population distribution, which can affect network costs.

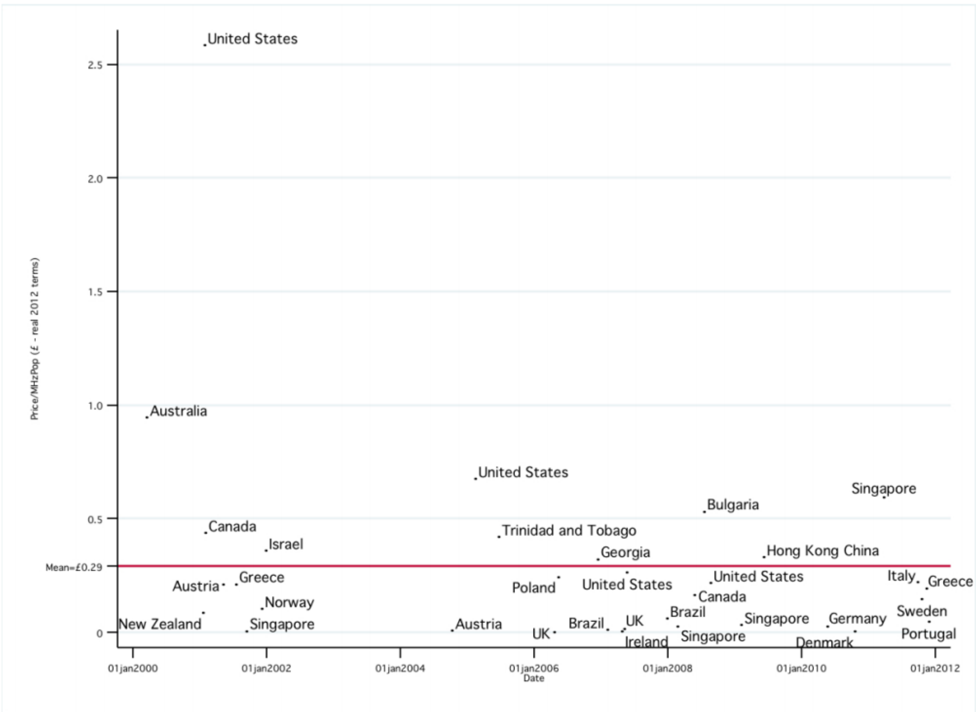
In addition, as noted above, the results of auctions can be also be affected by the constraints imposed by regulators and the auction rules applied.

In practice, there is a large amount of variation around benchmark results of auctions. By illustration, **Figure 7** shows the variation in auction results for 1800

MHz spectrum (from a report commissioned by Ofcom when considering potential reserve prices for 1800 MHz spectrum). .

Figure 7. Benchmarks of 1800 MHz auction results

Figure 5: Average prices in 1800MHz auctions



Source: Spectrum value of 800MHz, 1800MHz and 2.6GHz A DotEcon and Aetha Report for Ofcom July 2012

It is likely to be challenging to control for all of the factors outlined above in order derive reliable market values for spectrum in the UK. As a result, benchmarks from other jurisdictions are unlikely to provide robust estimates of **absolute** market values.

However, to the extent that the impact of the factors outlined above are correlated across different bands of spectrum, auctions in other jurisdictions may provide some indication of **relative** market values of different spectrum bands, even if the absolute valuations are of limited value. Auctions which include spectrum bands auctioned in the UK as well as bands subject to ALF in the UK could be used to benchmark the relative market values of 2.6 GHz and 800 MHz with market values for bands on which Ofcom imposes an ALF. There are relatively few examples of such auctions but recent examples in the EU include Ireland and the Netherlands. This information could allow Ofcom to assess the degree to which UK auction prices are a good relative indicator of the market value of ALF spectrum, taking account of the impact of auction rules in each jurisdiction. The relative values of spectrum in different bands drawn from the recent Irish Auction is illustrated in **Figure 8** below.

Figure 8. Relative prices of bands in the 2012 auction in Ireland

Source: Vodafone analysis of publicly available information

4.4 Decomposing market values into annual fees

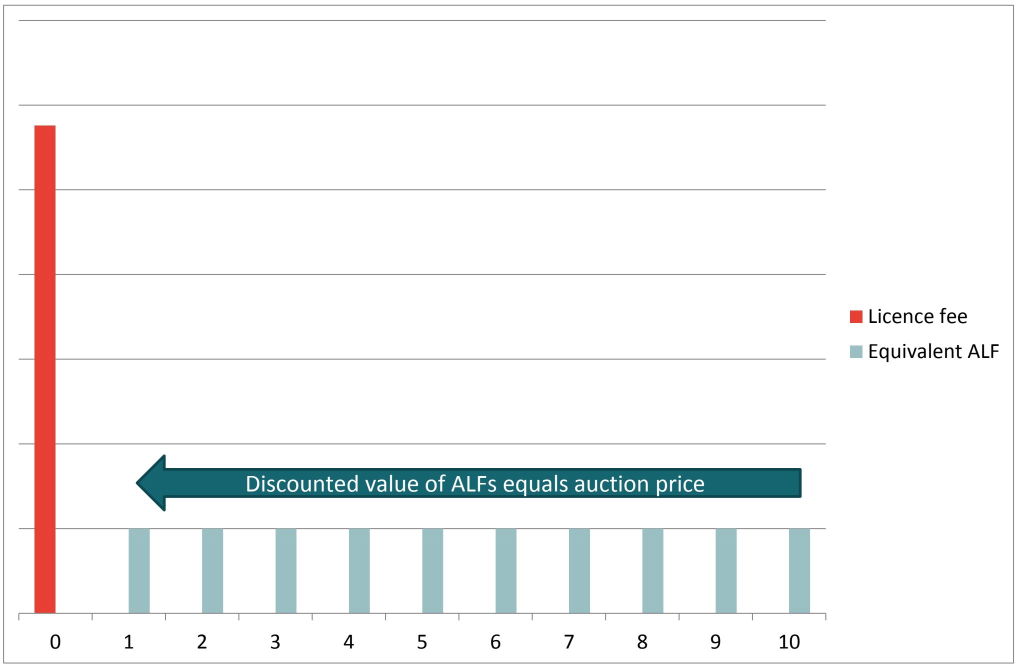
The rights to spectrum allocated through auctions typically extend for a number of years, and may also include pre-emption rights at the end of any fixed term. Auction bids generally consist of a single value for a licence paid, with a pre-determined payment schedule and other approaches, such as DCF modelling, will also result in a single valuation. For the purpose of deriving ALFs from market values, an equivalent annual fee must be estimated using the appropriate discount rate.

In the absence of uncertainty[27], a market value based licence bid should be equal to the discounted value of the series of annual fees over the life of the licence,

27 Where there is uncertainty over the value of the licence over time, this may create real options which, in theory, would need to be considered when converting auction bids into a stream of annual payments (for example the option to return the spectrum under an ALF regime would need to be considered).

plus any terminal value associated with the licence[28]. The simplest assumption would be that the annual licence fee remains constant in real terms. This allows the annual value of the licence to be calculated using a simply annuity, as illustrated below.

Figure 9. Decomposing auction prices into equivalent ALFs



Source: Frontier Economics

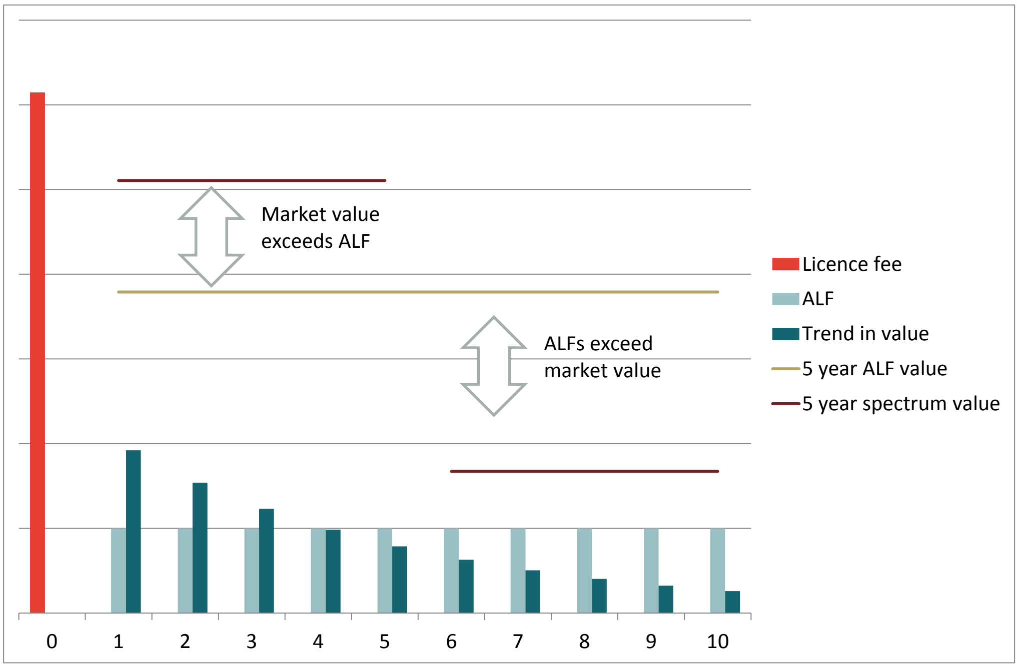
However, if the value of spectrum to a user were to change over time, then such a simple decomposition may result in a sub-optimal allocation. Known factors that might be expected to change the valuation of a given band of spectrum over time may include technological developments (including the likely availability of a new technology in a band or in other bands) and the expectation of further spectrum becoming available.

For example, if the market value of a given block of spectrum were to decrease over time, then such a simple de-composition would underestimate the value in the initial part of the period and then over-estimate the value in the second part. As a result the ALF price would be 'wrong' in both parts of the period. In the simple example of equipment with 5 year lifetime and a 10 year licence, a suboptimal operator could then take advantage of the under-pricing of spectrum

28 This may be due to explicit pre-emption rights associated with the licence or due to expected value, such as that associated with the customer base, which is expected to endure after the end of the fixed term.

in the first half of the period. In the second part of the period, the value may exceed the value of any operator, in which case spectrum could be returned to the government at the beginning of the second half of the period whether the current user was optimal or not. Due to the asymmetry in outcomes with setting the wrong ALF price, the potential loss in welfare is much greater in the second half of the period.

Figure 10. Sub-optimal allocation if ALFs do not reflect changes in value



Source: Frontier Economics

While the annual licence values do not necessarily need to take account of short term fluctuations in value, as sunk costs mean that operators will take a medium term view of value, if ALFs are out of line with market values for a significant number of years, then sub-optimal allocations can occur.

In conclusion a simple constant ALF may not provide the optimal disaggregation of market value. Ofcom should seek to understand the likely changes in value over the lifetime of a licence when setting ALFs.

If Ofcom, for reasons of predictability, wishes to set ALFs that are constant in the long term then the level will need to reflect the fact that future values may be lower than present values – leading to lower overall levels to avoid future inefficiencies arising from unused spectrum.

4.5 Analysis of the recent UK auction as a benchmark

In this section, we examine the factors that Ofcom should take into account when using the results of the recent UK auction of 800 MHz and 2.6 GHz spectrum to estimate market value based ALFs for the 900 MHz and 1800 MHz bands.

4.5.1 Summary of the auction results

The auction allocated 2 x 30 MHz of 800 MHZ spectrum and 2 x 70 MHz paired and 50 MHz unpaired 2.6 GHz spectrum. Five of the seven auction participants were allocated spectrum, including all four of the mobile network operators ('MNOs'), as summarised below:

Table 3. Allocation of spectrum (MHz)

Bidder	800 MHz (paired)	2.6 GHz paired	2.6 GHz unpaired
EE	5	35	
H3G	5		
BT ("Niche")		15	25
Telefónica	10		
Vodafone	10	20	25

Source: Ofcom

When assessing the current market value of the 900 MHz or 1800 MHz spectrum, it is necessary to consider the forward-looking value for the spectrum, given the operators' current spectrum holdings post auction. The successful outcome of the auction is likely to have reduced the market value of spectrum by:

- significantly increasing the supply of spectrum available across the market;
- allowing all operators to significantly increase their spectrum holdings overall; and
- allowing all operators to gain low frequency spectrum.

The certainty over post-auction spectrum allocations will also have reduced the option value attached to existing spectrum, pre-auction.

800 MHz allocation

The allocation of 800 MHz spectrum, and the bidding behaviour in the auction, suggests a relatively high valuation of 2 x 10 MHz by Telefónica and Vodafone, and a relatively low valuation of a marginal 2 x 5 MHz block of 800 MHz spectrum by EE and H3G.

It seems reasonable to conclude that the high average valuation of Telefónica and Vodafone reflects the fact that a minimum of 2 x 10MHz of 800 MHz provides them with the capability to offer LTE services, which was not available from their existing spectrum holdings. The lower marginal valuations of EE and 3G compared to Telefónica and Vodafone's' average valuation indicate that the additional capability and/or network cost savings of marginal blocks of spectrum are relatively low.

2.6GHz allocation

The 2.6 GHz spectrum is a complement to lower frequency spectrum used to roll out a coverage network. Additional spectrum will allow for higher capacity to be served or lower costs in urban environments.

Estimates of market values

Given that the basic payments[29] for the supplementary round were based on second prices, the basic payments can be decomposed to provide an estimate of the market clearing prices for the bands in the auction, as shown in the table below.

Table 4. Approximate disaggregated prices

	Price per 5 MHz block
800 MHz	£280,000,000
2.6 GHz (paired)	£45,000,000
2.6 GHz (unpaired)	£10,000,000

Source: Frontier Economics analysis of Auction results

This shows, as expected, a lower marginal value for higher frequency spectrum.

29 Which determined the volume of spectrum allocated, but not additional payments which determined the actual blocks allocated.

4.5.2 Application to 1800 MHz Spectrum

In this section, we compare the 1800 MHz band with the two auction bands in terms of the technology availability, physical characteristics and potential users.

Technology

Due to the actual or planned roll out of LTE networks in 1800 MHz by a number of large operators[30], the 1800 MHz band is now well supported by network equipment and terminal manufacturers for the provision of LTE services. Terminal availability is likely to be similar to that for the 800 MHz and 2.6 GHz bands.

1800 MHz spectrum will still be used for legacy GSM support by existing holders, but this is unlikely drive the value of the spectrum at the margin.

Physical characteristics

While the 2.6 GHz spectrum will be most suitable for adding capacity in urban areas where the density of cell sites is high, 1800 MHz spectrum can be, and has been, used to roll out coverage networks across the whole country. However 800 MHz spectrum will provide some advantages over 1800 MHz spectrum in terms of:

- lower cost of coverage in rural areas, due to higher effective cell radii for coverage cells; and
- potentially better coverage, for example in building, in areas nominally covered per MHz of spectrum deployed.

The physical characteristics of the 1800 MHz band lie between that of the auctioned 800 MHz spectrum and the 2.6 GHz spectrum.

Potential users

All four mobile operators currently hold 1800 MHz spectrum and would likely seek to acquire additional spectrum were it to become available, in order to provide additional LTE capacity. In the case of EE and H3G, the additional spectrum would allow them to provide additional capacity on their existing LTE networks using 1800 MHz. For Telefónica and Vodafone, additional spectrum would provide the capability to launch LTE at 1800 MHz.

30 Including EE and H3G in the UK.

Implications for benchmarking against auction results

It is reasonable to assume that the market value of 1800 MHz spectrum will fall between that of 800 MHz spectrum and that of the paired 2.6 GHz spectrum, with the difference in value largely reflecting differences in physical characteristics.

The relationship between market value and frequency is unlikely to be linear, except co-incidentally. A more accurate estimation of the relationship should be possible through network cost modelling of the potential incremental cost savings for deploying LTE networks given incremental blocks of 800 MHz, 1800 MHz and 2.6 GHz spectrum and under varying demand. Given that this modelling would only need to provide relative valuations, such an approach could be reasonably robust.

Information from auctions in other jurisdictions which included 1800 MHz spectrum in addition to 800 MHz and/or 2.6 GHz spectrum could be used to validate the results.

4.5.3 Application to 900 MHz spectrum

In this section, we compare the 900 MHz band with the two auction bands in terms of the technology availability, physical characteristics and potential users.

Technology

Whilst the spectrum is standardised for LTE services, most European operators are not planning to roll out LTE in 900 MHz in the short term, but instead use the band to deliver 3G services. As a result, a lack of suitable handsets and equipment may mean that in the short term roll-out of LTE in this band is not commercially viable.[31] This partially explains the relatively high price paid by the existing 900 MHz spectrum holders to gain access to 800 MHz spectrum.

900 MHz spectrum in the UK is currently used for GSM services and is being re-farmed by the current holders to also be used for 3G services. Providing 3G services is likely to be the highest value use in the next few years.

Over the longer term, the difference in availability of LTE equipment may reduce, and the 900 MHz and 800 MHz spectrum will likely become substitutable. A recent report for Ofcom by Analysys Mason considered that 900 MHz spectrum would be available for use for LTE in 2022 (whereas the 700 MHz spectrum would be available two years earlier in 2020)[32].

---

31 http://stakeholders.ofcom.org.uk/binaries/consultations/award-800mhz/statement/RW-lte.pdf

32 Ofcom (2013) Final Report for Ofcom. Opportunity cost of the spectrum used by the digital terrestrial TV and digital audio broadcasting. Pages 83 and 88.

Physical characteristics

The physical characteristics of the 900 MHz spectrum are close to that of 800 MHz spectrum. In both cases the band allows an operator to roll out a coverage network with lower cost than higher frequency spectrum. Where operators have existing grids based on lower frequency spectrum (i.e. Vodafone and Telefónica), 900 MHz spectrum would allow them to roll out services at lower cost than a higher frequency band.

Potential users

In the short term, the value of 900 MHz spectrum to H3G and EE is likely to be limited. This is because:

- they would not seek to launch GSM in these bands; and
- the incremental benefit to them of using the band to extend coverage of WCDMA on their grids optimised for high frequency is relatively low, and the investment required would be high.

The highest value users at the moment are likely to be the two current holders of 900 MHz spectrum, as their current network grids are optimised for low frequency spectrum. Both Telefónica and Vodafone could use incremental spectrum in the short run to add 3G capacity at lower cost. In the longer run, they could use the spectrum to add additional LTE capacity.

The value of incremental 900 MHz spectrum to Telefónica and Vodafone is likely to be relatively low given the significant existing holdings, which allow them to re-farm existing spectrum to WCDMA, while maintaining a coverage network for GSM users.

Implications for benchmarking against auction results

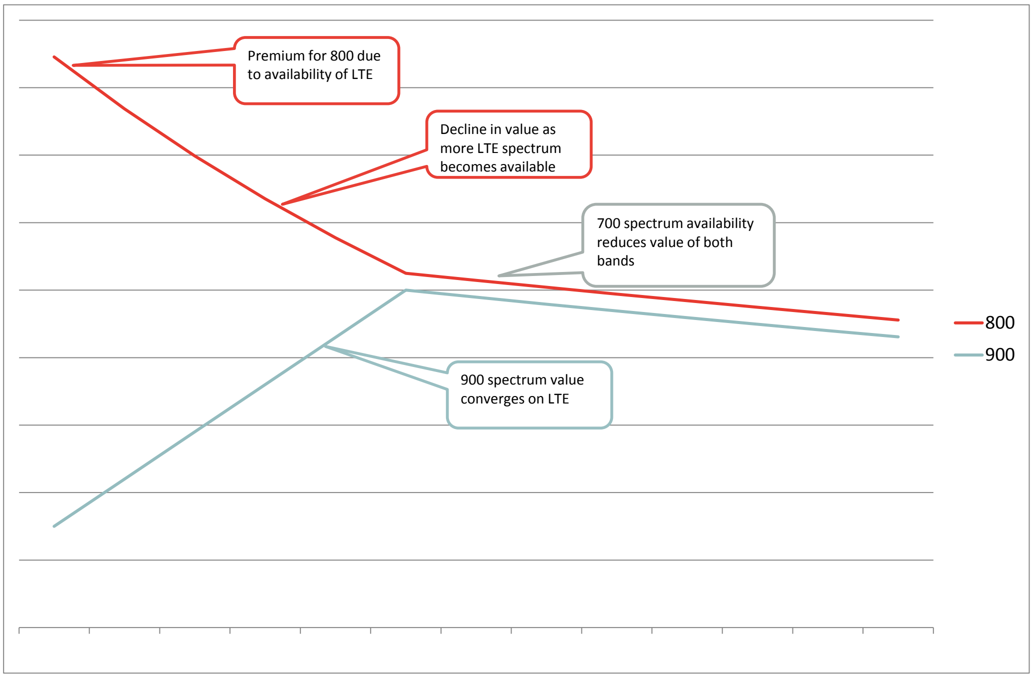
The lack of commercial viability for LTE in the 900 MHz band in the medium term provides evidence that the value of 900 MHz spectrum will be significantly lower than 800 MHz spectrum in the short run. This result appears to be borne out by recent auction results in jurisdictions where both 800 MHz and 900 MHz spectrum were auctioned.

Network modelling may provide some indication of relative value of additional 900 MHz spectrum to Telefónica and Vodafone compared to the value of additional 800 MHz spectrum to EE and H3G (as the second price bidders for the 800 MHz spectrum). However, the different demand characteristics of LTE and 3G traffic going forwards mean that it may be difficult to produce a true like-for-like comparison.

In the longer term, if LTE-900 MHz devices become widely available, then the market value of 800 MHz and 900 MHz spectrum is likely to converge. This is likely to reduce the current premium on 800 MHz spectrum, as it will no longer offer unique capabilities to operators - with 900 MHz spectrum being a close substitute. Over a similar timeframe, 700 MHz spectrum and additional spectrum in other bands will become available, which will further lower the value of all spectrum, in particular low frequency spectrum, as no single band of spectrum will be essential for roll-out or operation of a coverage network designed for low frequency spectrum.

In addition, the introduction of LTE-Advanced will allow aggregation of non-contiguous frequency which would increase the fungibility of blocks of spectrum for capacity purposes, including between low and high frequency bands. These changes are illustrated below.

Figure 11. Illustration of future market values of 800 MHz and 900 MHz spectrum



Source: Frontier Economics

Given this context, a conservative current valuation of 900 MHz spectrum is likely to reflect a significant discount from the UK auction valuation of 800 MHz spectrum. The level of discount may be informed by results from recent auctions where both 800 and 900 MHz spectrum were allocated.

The decomposition of the resulting valuation into a series of ALFs will also need to reflect the likely erosion over time in the premia attached to low frequency spectrum, due to increased supply.

4.6 Conclusion

In this report we have shown that the determinants of private spectrum value are complex (Section 2). We have also shown that if ALFs do not accurately reflect market values, then an ALF regime can result in mis-allocations of spectrum, and that the resulting welfare losses are asymmetric with respect to the direction of measurement error (Section 3). Moreover, as mobile networks are supported by long term sunk investments which are dependent on spectrum availability, it is important for dynamic efficiency that an ALF regime does not expropriate the value of operators' existing sunk investments, and provides predictability and certainty for the level of payments over time.

We have examined the alternative potential methods for estimating market values, and have explained that each has certain weaknesses, meaning that it would be unsound to rely on one approach alone (Section 4). Benchmarking against auctions within jurisdiction may offer valuable information alongside other approaches such as network cost modelling, but considerable caution should be exercised when making inferences about the market value of either 900 or 1800 MHz spectrum on the basis of the recent UK auction. In particular, evidence suggests that 800 MHz spectrum is likely to have a considerably higher valuation than 900 MHz spectrum in the next few years. The market value of 1800 MHz spectrum is likely to lie somewhere between the market value of 800 MHz and the 2.6 GHz spectrum, but the relationship between spectrum bands and value is unlikely to be linear.

FRONTIER ECONOMICS EUROPE
BRUSSELS | COLOGNE | LONDON | MADRID

Frontier Economics Ltd 71 High Holborn London WC1V 6DA
Tel. +44 (0)20 7031 7000 Fax. +44 (0)20 7031 7001 www.frontier-economics.com