CRITIQUE OF OFCOM'S INTERNATIONAL BENCHMARKING ANALYSIS

A REPORT PREPARED FOR VODAFONE

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Contents

Contents

1 Executive Summary

In its proposal for revising 900 MHz and 1800 MHz licence fees[1] Ofcom relies on international benchmarking by using spectrum auction prices from other European countries as a source of estimates for UK market values. Frontier has been asked to consider Ofcom's international benchmarking approach and to assess its appropriateness for deriving reliable estimates of the market value of 900 MHz and 1800 MHz spectrum in the UK.

The degree of variation in international benchmarks of auction outcomes means that using the benchmarks to inform the valuation of spectrum in the UK is not a straightforward task. The large variations in prices between different countries means that estimates of UK market values derived from other jurisdictions without an analysis and understanding of such variations are unlikely to be accurate. Nevertheless, international benchmarking can be a useful complement to information about the market value of 900 MHz and 1800 MHz spectrum in the UK, derived from the results of the recent UK auction and other sources of information, if the information is appropriately analysed and assessed.

After a detailed consideration of the benchmarking evidence that Ofcom has relied on, we identify a number of deficiencies in Ofcom's approach which imply that its estimates of UK market values are inappropriate. Correcting for the main deficiencies in Ofcom's benchmarking approach, and taking into account the appropriate estimates of the market value of 800 MHz spectrum from the UK auction, results in a range of estimates of market values for 900 MHz spectrum of between **£12 and £15.9m per MHz**. This range of estimates is robust to a number of sensitivities and modifications to the benchmarking sample used.

1.1.1 Summary of Ofcom's approach to benchmarking

Ofcom uses two approaches to translate auction prices from other European countries into an estimate of the market value of 900 MHz and 1800 MHz spectrum in the UK.

- First, it scales absolute (i.e. actual) spectrum prices from 900 MHz and 1800 MHz auctions to a 20 year period, adjusting for purchasing power and population.
- Second, it calculates relative spectrum values by looking at the ratios from 900 MHz to 800 MHz, 1800 MHz to 800 MHz (or 2.6 GHz) auction prices

[1] Annual licence fees for 900 MHz and 1800 MHz spectrum, Ofcom, October 2013 (hereinafter 'The Consultation')

in jurisdictions where spectrum in the two relevant bands has been auctioned. It then applies these ratios to the estimated values of 800 MHz (and 2.6 GHz) spectrum from the UK 4G auction to estimate UK market values of 900 MHz and 1800 MHz spectrum.

In both cases, Ofcom evaluates whether auction outcomes in each country are likely to reflect market value in the UK, and distinguishes between auction outcomes that are more likely to be useful benchmarks for the UK (labelled "more important evidence") and those that Ofcom considers to be less reliable benchmarks (labelled "less important evidence").

Based information from both approaches Ofcom proposed that the appropriate estimate of the ALF of 900 MHz spectrum is £25m per MHz, and of 1800 MHz spectrum £15m per MHz, for a 20 year licence.

1.1.2 Ofcom's approach to benchmarking is unreliable

There are five major weaknesses in Ofcom's approach to the derivation of market value based on benchmarking which imply that its ALF estimates are unreliable.

- **Ofcom treats auction outcomes in a biased and internally inconsistent way putting too much weight on evidence that is not informative of the market value of spectrum in the UK.** Ofcom's approach in relation to estimating the 900 MHz market value is inconsistent with its approach in relation to estimating the 1800 MHz market value. When estimating the 1800 MHz market value, it put less weight on those outcomes that are *below* what Ofcom considers to be the lower-bound of the market value in the UK, i.e. the value of 2600 MHz spectrum derived from the recent UK auction. When looking at European auctions of 900 MHz spectrum, Ofcom's sample consists of seven observations which it considers to be 'more important' evidence. However, three of these observations are *above* what Ofcom's considers to be the upper bound of the market value of 900 MHz spectrum in the UK, namely the market value of 800 MHz spectrum derived from the recent UK auction. Therefore, these observations are at best of very limited value as relevant evidence for the purposes of deriving 900 MHz ALF estimates.

- **Ofcom relies on an incorrect estimate of the market value of 800 MHz in the UK, which leads to inflated estimates of the market value of 900 MHz spectrum.** Ofcom incorrectly estimates the market value of 800 MHz spectrum from the recent UK auction to be £29.9m per MHz. As explained

in Frontier's separate report[2], the appropriate market clearing value to use from the UK is likely to be much lower, in the range £17.9m to £21.4m per MHz, with a realistic 900 MHz upper-bound at around £22.7m per MHz.[3] This means that Ofcom incorrectly treats some absolute benchmarking auction results that are below £29.9m but above the more realistic upper bound of £22.7mn as relevant or 'more important' evidence. In addition, Ofcom uses the same incorrect UK market value for 800 MHz spectrum when calculating the equivalent value of 900 MHz spectrum using benchmarks of relative prices, inflating the resulting 900 MHz estimates.

- **Ofcom misinterprets information that auction outcomes provide about market value in a number of benchmark countries where auctions cleared at the reserve price**. Ofcom incorrectly concludes that auction prices underestimate market value for auctions in which spectrum cleared at or close to the reserve price by assuming that this was the result of "limited competition". Market value in the current context should reflect the opportunity cost for the use of a marginal (incremental) block of spectrum by the excluded bidder (when demand equals supply). We show in the main body of the report that, given the way reserve prices were set and the fact that these auctions cleared at the reserve price, the market value can be expected to be below the reserve prices paid.

- **Ofcom does not appropriately control for country- and auction-specific factors that could make auction outcomes in benchmark countries less comparable to the UK**. Ofcom takes into account certain expected drivers of spectrum value, and adjusts auction outcomes accordingly. However, it fails to consider many other important factors, such as market profitability, and the extent to which these might affect auction prices relative to UK values.

- **Ofcom relies on a small sample of observations, which increases the risk of setting ALFs above true market value.** Ofcom's benchmarking analysis relies on a relatively small number of 'more important evidence' observations, with a high degree of variation between countries. When working with such a small sample, Ofcom needs to be cautious when estimating true market value of spectrum and setting ALFs. This is because,

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2 Frontier Economics: Deriving Market Clearing Prices for 800 MHz Spectrum from the UK 800MHz/2600GHz Auction, January 2014 (hereinafter 'UK Auction Report')

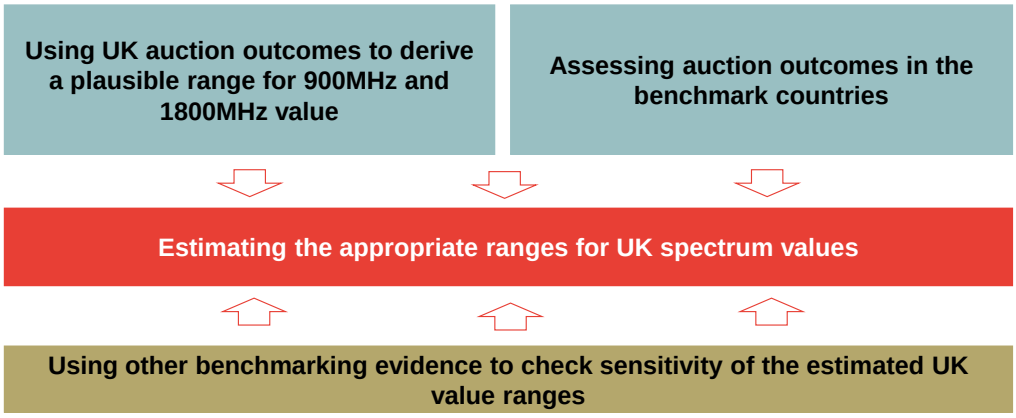
3 The upper bound calculated as a mid-point of the appropriate UK 800 MHz value of £19.7m per MHz plus the estimated co-existence costs of approximately £3m per MHz.

as explained in Frontier's separate report[4], the potential welfare losses resulting from inadvertently setting ALFs too high (i.e. above true market value) are likely to be more significant than any losses that might arise from setting ALFs below market value.

1.1.3 Developing an appropriate benchmarking framework

We have developed an alternative approach to benchmarking that addresses the key limitations of Ofcom's approach. The two key steps to deriving appropriate ranges for the market values of 900 MHz and 1800 MHz spectrum in the UK are as follows.

Figure 1. Overview of our benchmarking approach



Source: Frontier Economics

Using appropriate estimates of the value of 800 MHz spectrum in the UK

We use as a starting point the range of appropriate estimates of the market value of 800 MHz spectrum in the UK, £17.9m to £21.4m, derived from the recent 4G auction. We use the mid-point of this range, £19.7m, as the point estimate for the UK 800 MHz value. In order to derive the appropriate upper bound for 900 MHz spectrum, we add the estimated cost of co-existence of £3m per MHz to get an upper bound of value of 900 MHz in the UK of approximately £22.7m per MHz.[5]

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4 Frontier Economics: Revising Annual Licence Fees, May 2013 (hereinafter 'ALF Asymmetry Report')

5 This is because estimated 800 MHz value from the UK auction is based on bidder valuations after deducting all essential costs of operating 800 MHz network, including the co-existence costs. To the extent that such co-existence costs are not as significant in relation to 900 MHz spectrum, it is

Similarly, we treat estimates of the market value of 2600 MHz in the UK, also derived from the recent 4G auction, as a lower bound for the market value of 1800 MHz spectrum in the UK - and implicitly also for the market value of 900 MHz spectrum, as 900 MHz spectrum is unlikely to be less valuable than 1800 MHz spectrum in the UK. Any outcomes from international auctions that are above the appropriately estimated market value of 800 MHz spectrum in the UK (our upper bound) or below the market value of 2600 MHz spectrum in the UK (our lower bound) are considered in our basic approach[6] as uninformative of UK market value for 900 MHz and 1800 MHz spectrum.

This removes the inconsistency in Ofcom's approach of considering as important evidence values of 900 MHz spectrum from international benchmarking evidence that *exceed* the estimated market value of 800 MHz spectrum in the UK derived from the recent UK auction (in contrast to its approach when deriving the value of 1800MHz spectrum).

Assessing the auction outcomes in the benchmark countries

The second step involves an assessment of the robustness and relevance of all auctions in the international benchmarking sample, to assess their appropriateness for informing the market value of 900 MHz and 1800 MHz spectrum in the UK. To interpret auction outcomes correctly, we answer two questions for each of the benchmark countries in Ofcom's sample. We have extended Ofcom's sample to include auctions in Austria and Norway, as the results of these auctions became available since Ofcom's consultation was published.

- **Do the auction outcomes reveal market clearing values for the benchmark countries?** To answer this question, we look at the key elements of each auction in Ofcom's sample and analyse whether the resulting auction outcomes can be considered to provide reliable estimates of market value in the relevant countries.

- **Is this market value reflective of spectrum value in the UK?** We identify the drivers of spectrum value, and assess the extent to which the drivers of spectrum value in the benchmark countries are comparable to the corresponding drivers in the UK.

Based on the answers to these two questions, we assess whether the benchmarking evidence can be expected to provide reliable information to derive

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appropriate to increase the estimated upper bound of 900 MHz by adding these costs, see The Consultation, para 4.25

6 Such estimates are however taken into account in our sensitivity analysis.

the market value of 900 MHz (and 1800 MHz) spectrum in the UK. A full presentation of this assessment is included in the main report (and Annexe 2).

In summary, our conclusions are that international benchmarking evidence about the *absolute* value of 900 MHz and 1800 MHz spectrum alone cannot in general be confidently relied upon to inform the true market value of 900 MHz and 1800 MHz spectrum in the UK. This is because the benchmark values depict significant variation, reflecting country specific factors which cannot be fully controlled for. By contrast, international benchmarking evidence on the *relative* valuation of 800 MHz and 900 MHz spectrum provides a more reliable basis for deriving a range for the market value of 900 MHz and 1800 MHz spectrum in the UK, and should be given greater weight.

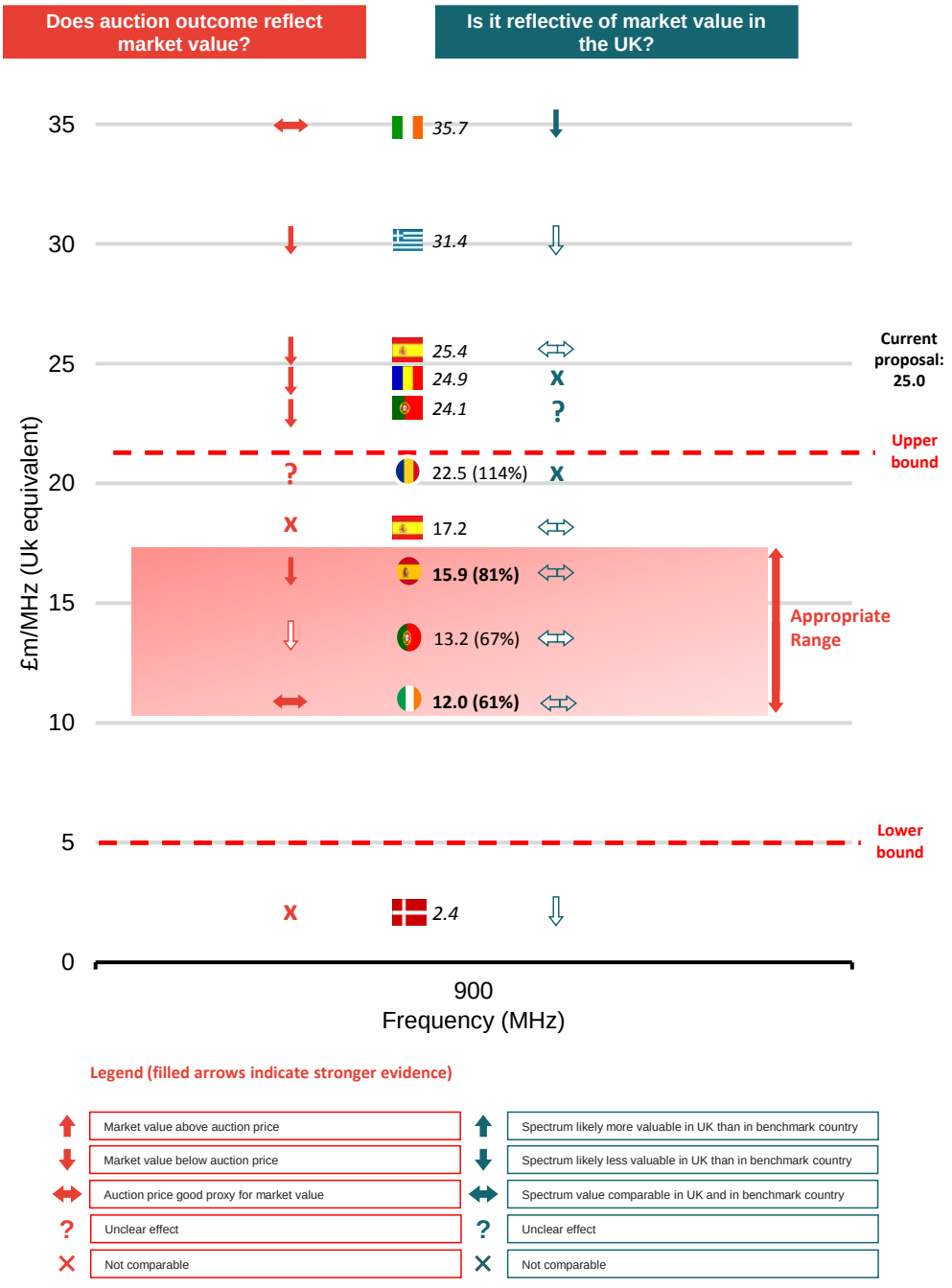
1.1.4 Applying the appropriate framework to derive market values of 900 MHz and 1800 MHz spectrum in the UK

By implementing the above two steps we derive a range of market values for 900 MHz and 1800 MHz spectrum in the UK. We find that the deficiencies in Ofcom's approach to benchmarking lead to a *material overestimate* of the market value of spectrum in the UK. This is the case for both 900 MHz and 1800 MHz spectrum.

Figure 2 below summarises the benchmarking evidence that we have used for estimating the market value of 900 MHz spectrum. Our sample consists of 11 observations. Five of these observations are above the upper bound for the market value of 900 MHz spectrum in the UK, based on the results of the UK 4G auction. In addition, one observation, based on the absolute valuation from Denmark, is below the lower-bound for the market value of 2600 MHz spectrum in the UK, as estimated by Ofcom. This also implies that it is below the lower-bound for the market value of 900 MHz spectrum in the UK. Therefore, we treat these six observations as less relevant evidence and we do not consider them when deriving the appropriate range of market values for 900 MHz spectrum in the UK under our base case.[7]

[7] The 'less relevant' evidence is considered in our sensitivity analysis, where we attach less weight to these observations.

Figure 2. Value of 900 MHz spectrum based on international benchmarks



Note: In line with Ofcom's approach, squared markers refer to absolute (£m per MHz) values, round markers refer to relative value. More important evidence in **bold**, less relevant evidence in *italics*.

Source: Frontier Economics

There are five observations that lie within the plausible range: absolute valuation from the Spanish beauty contest and the relative valuations based on the auctions in Romania, Spain, Portugal and Ireland.

As explained in the main report the outcome of the Spanish beauty contest is unlikely to reflect the true market value of 900 MHz spectrum in Spain and we consider this observation to be less important evidence for deriving the value of 900 MHz spectrum in the UK. Similarly, in Portugal and Romania, all sold spectrum went at the reserve price, which implies that the relative valuations could not be expected to be reflective of relative market value[8]. At the same time, in Portugal, operators chose the significantly more expensive 800 MHz over 900 MHz, with some 900 MHz spectrum left unsold, which would suggest that the relative value of 900 MHz to 800 MHz as reflected in the reserve prices can be seen as potentially overestimating the true value of 900 MHz in Portugal. The auction results in Romania are likely to be further distorted by country specific factors and provide only limited information about the true market value of spectrum in the UK. We therefore treat Portugal and Romania as less important evidence and we do not consider these observations when deriving the appropriate range for the UK 900 MHz value under our base case.

Two observations based on **relative values,** derived from the auctions in **Spain** and **Ireland**, lie between the upper- and lower bounds for the market value of 900 MHz spectrum in the UK. Our analysis suggests that the relative prices in these two countries are likely to provide the most reliable indicators to inform the appropriate range for the market value of 900 MHz spectrum in the UK. As 900 MHz spectrum was sold at the reserve price in Spain, this is likely overestimating the market value of 900 MHz spectrum, whereas 800 MHz spectrum sold above the reserve price and could therefore be expected to be reflective of market value of this spectrum. This implies that the application of the relative value of 900/800 MHz from Spain to the UK would overestimate the market value of 900 MHz spectrum in the UK. In Ireland, 800 MHz and 900 MHz spectrum cleared above the reserve price, so the auction outcomes can be expected in general to be reflective of relative market value.[9]

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8 We note nevertheless that the estimated ratio of 900 MHz to 800 MHz value in Portugal is consistent with the ratios observed in Spain and Portugal, and lies between these ratios: taking therefore Portugal into account in the basic approach to derive the market value of 900 MHz spectrum in the UK would not be expected to affect the results of our analysis.

9 Our analysis actually suggests that demand for 2G spectrum is likely to be higher in Ireland, which, all else the same, would imply that the ratio of the market value of 900 MHz to 800 MHz in Ireland may be higher than the corresponding ratio in the UK. This could lead to an over-estimation of the value of 900 MHz spectrum in the UK.

Using these relative valuations for 900 MHz spectrum[10], together with the mid-point of the estimated value of 800 MHz spectrum in the UK, we find that the appropriate range for the market value of 900 MHz spectrum in the UK is between **£12m and £15.9m per MHz.**

Using a similar approach, we find that the appropriate range for the market value of 1800 MHz spectrum in the UK is between **£6.3m and £12.5m per MHz**. This is based on relative 1800/800 MHz valuations from Sweden and Ireland.

1.1.5 Sensitivity checks of the estimated ranges of market values

The estimated ranges described above are based on a relatively small sample of auctions. Therefore, we have also undertaken a sensitivity analysis in which we take into account all available international evidence, after carefully assessing the comparability of such evidence with the UK.

To undertake the sensitivity analysis, we have estimated approximate per MHz prices from the auctions in Switzerland, Norway, Netherlands and Austria using a simple decomposition approach[11], which increases our sample to 15 observations. We have attached weights on observations that were considered to be of less relevant evidence, including observations that lie outside the plausible range of 900 MHz market value in the UK. We then calculated a weighted average, attaching 100% weight to the 'more important' evidence observations, 75% weight to the observations that are within the plausible range but which are considered to be 'less important' evidence, and 50% weight to 'less relevant' observations outside the plausible range of 900 MHz market value.

We first undertake this exercise taking into account 11 auction outcomes from Ofcom's benchmarking sample. We then replicate the exercise using a larger sample of 13 observations, which includes estimates of 900 MHz prices from auctions in Switzerland and Norway, but excludes 'outlier observations' from 900 MHz auctions in Netherlands and Austria[12]. Finally, we consider the full sample of 15 observations.

Figure 3 shows that the estimated weighted average value of 900 MHz spectrum across the alternative samples of observations is broadly similar. Whilst we recognise that international evidence needs to be treated cautiously, because of the limitations in comparability to the UK, the results of our sensitivity analysis

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10 These relative valuations are the same as the ones used by Ofcom in its analysis.

11 See Annexe 1 for more details.

12 We identify Austria and Netherlands (where the price paid was relatively high) as outlier observations using three different approaches proposed by DotEcon: International benchmarking of 900 MHz and 1800 MHz spectrum value - September 2013, page 11-13. We note that our main conclusions hold even if we consider Denmark (where the price paid was relatively low) as an outlier observation.

are consistent with the estimated range for the market value of 900 MHz spectrum in the UK, as described above.

Figure 3. Results of sensitivity analysis 900 MHz estimates

£m/MHz (UK equivalent)	Price	900MHz	Frontier's more important evidence	Auctions considered by Ofcom	All observations (no outliers)	All observations
Netherlands (2012)	Absolute	[✂]				50%
Austria (2013)	Absolute	[✂]				50%
Ireland (2012)	Absolute	35.7		50%	50%	50%
Greece (2011)	Absolute	31.4		50%	50%	50%
Spain (2011)	Absolute	25.4		50%	50%	50%
Romania (2012)	Absolute	24.9		50%	50%	50%
Portugal (2011)	Absolute	24.1		50%	50%	50%
Romania (2012)	Relative (114%)	22.5		75%	75%	75%
Spain (May 2011)	Absolute	17.2		75%	75%	75%
Spain (2011)	**Relative (81%)**	**15.9**	**100%**	**100%**	**100%**	**100%**
Norway (2013)	Absolute	[✂]			75%	75%
Switzerland (2012)	Absolute	[✂]			75%	75%
Portugal (2011)	Relative (67%)	13.2		75%	75%	75%
Ireland (2012)	**Relative (61%)**	**12.0**	**100%**	**100%**	**100%**	**100%**
Denmark (2010)	Absolute	2.4		50%	50%	50%
Max			*15.9*	*35.7*	*35.7*	*59.0*
Min			*12.0*	*2.4*	*2.4*	*2.4*
Average			**14.0**	**12.7**	**12.4**	**14.6**

Note: Plausible range highlighted in blue. More important evidence highlighted in **bold**.

Source: Frontier Economics

2 Description of Ofcom's approach

In December 2010, the Government issued a Direction which required Ofcom to revise the fees for licences in 900 MHz and 1800 MHz bands in a way that they would reflect the full market value. The consultation paper "*Annual licence fees for 900 MHz and 1800 MHz spectrum*" from 10 October 2013 sets out Ofcom's proposal for revising the annual license fees. The report derives proposals for new annual licence fees (ALF) in two steps:

- assessment of lump-sum values; and
- deriving ALF from the lump-sum values.

The estimation of the base lump-sum value of spectrum in 900 MHz and 1800 MHz bands is based upon three different sources:

- UK 4G Auction: As required by the Direction, Ofcom incorporated the results of the UK multi-band 4G auction in their assessment. Ofcom commissioned DotEcon to analyse the bids and derive values for 800 MHz and 2600 MHz spectrum bands.

- International benchmarks: Ofcom also commissioned DotEcon to provide a report with international benchmarks and comments on auction awards. The international benchmark includes auction data from 800 MHz, 900 MHz, 1800 MHz, 2100 MHz and 2600 MHz spectrum bands.

- Technical evidence: In addition, Ofcom took into account the different technical and commercial characteristics of spectrum bands and their implication on market value, as well as the technical modelling and policy conclusion prior the UK 4G auction and publicly available results from technical models of network costs.

With regards to the international benchmarks, Ofcom assessed whether the data is likely to be informative for the valuation of 900 MHz and 1800 MHz spectrum in the UK, because the evidence consists of data from different markets. Ofcom puts more weight on evidence that it considers to reflect the market value and to be of relevance for the value of 900 MHz and 1800 MHz spectrum in the UK.

Ofcom focuses on 4G auctions in European countries from 2010 onwards. It considers auction outcomes in absolute and relative terms, and it categorises these as either more important or less important evidence.

- **Absolute measures** of spectrum value are derived from prices paid in spectrum awards of 900 MHz and 1800 MHz auctions from different countries. In order to make these values comparable to the circumstances in the UK, they were transformed into an equivalent 20 year lump-sum fee,

converted into the same currency using PPP exchange rates and adjusted for population. Among these measures, evidence from the UK 4G auction and selected European auctions that were considered to be likely to be informative was put more weight on, see **Table 1** below. Ofcom concludes that the UK 4G auction awards for 800 MHz (£29.9m per MHz) and 2600 MHz (£5m per MHz) is an upper limit for the 900 MHz value and a lower bound for the value of 1800 MHz respectively.

Table 1 Overview of auctions considered by Ofcom (absolute values)

£m/MHz (UK equivalent)	800 MHz	900 MHz	1800 MHz	2.G GHz
Austria (2010)				*1.8*
Belgium (2011)				*4.5*
Denmark (2010)	*10.1*	*2.4*	*1.0*	*9.5*
France (2011)	*34.3*			*5.2*
Germany (2010)	*50.1*		*1.8*	*1.5*
Greece (2011)		**31.4**	**13.9**	
Ireland (2012)	*58.6*	**35.7**	**23.1**	
Italy (2011)	*48.3*		**15.5**	*3.5*
Netherlands (2012)		Not known		
Portugal (2011)	*36.1*	*24.1*	*3.1*	*2.4*
Romania (2012)	*21.8*	**25.4**	**6.2**	*2.5*
Spain (2011)		*17.2*	*2.9*	
Spain (2011)	*31.4*	**24.9**		*3.1*
Sweden (2011)	*14.3*		**9.1**	*9.7*
Switzerland (2012)		Not known		
UK (2013)	**29.85**			**4.95**

Source: Ofcom, more important evidence shown in bold, less important evidence in Italics

- **Relative measures** are values derived from observations which included one or both bands auctioned in the UK 4G auction (800 or 2600 MHz), and

Description of Ofcom's approach

one or both bands subject to evaluation (900 or 1800 MHz). The ratio between the values of 800 MHz/900 MHz and 2600 MHz/1800 MHz, is then used to estimate a value for the 900 MHz and/or 1800 MHz using the estimated absolute values of 800 MHz and 2600 MHz from the UK 4G auction. Ofcom calculates relative values only for countries where absolute values are considered to be more important evidence, see **Table 2** below.[13]

13 Ofcom further calculated a simple average of 800 MHz and 2600 MHz values from the UK auction as additional evidence point for the 1800 MHz value. The value was considered to be informative and received more weight in the estimation.

Table 2 Overview of auctions considered by Ofcom (relative values)

	900 MHz	1800 MHz	1800 MHz
Ratios to other bands (%)	**/800 MHz**	**/800 MHz**	**/2.G GHz**
Ireland	61%	39%	
Italy		32%	455%
Romania	114%	33%	
Spain[14]	81%		
Sweden		64%	
Implied values in the UK (£m per MHz)			
Ireland	**18.2**	**11.7**	
Italy		**9.6**	**21.9**
Romania	**34.1**	**8.5**	
Spain	**24.2**		
Sweden		**19**[15]	

Source: Ofcom, more important evidence shown in bold, less important evidence in Italics

In total, Ofcom relies on seven observations (both absolute and relative auction outcomes) from four benchmark countries for the value of 900 MHz spectrum; and ten observations from five benchmark countries for the value for 1800 MHz spectrum. Based on the available evidence, Ofcom estimates the 20 years lump-sum value for 900 MHz spectrum to be £25m per MHz and for 1800 MHz

14 Results for Spain based on Ofcom's corrected figures available at http://stakeholders.ofcom.org.uk/binaries/consultations/900-1800-mhz-fees/summary/Correction_Slip.pdf?utm_source=updates&utm_medium=email&utm_campaign=minor-corrections

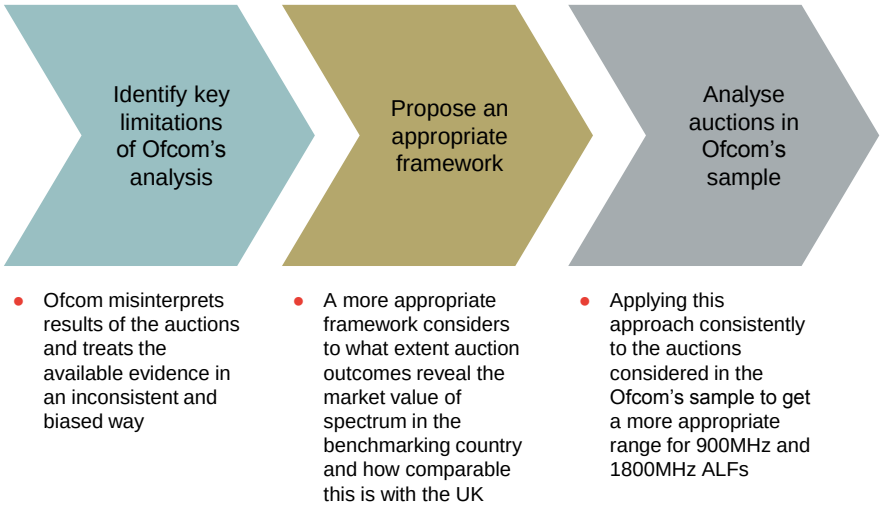
15 Corrected value calculated as the relative ratio of 64% multiplied by Ofcom's estimate of the value of 800 MHz of £29.9m per MHz

Description of Ofcom's approach

spectrum £15m per MHz (after adjusting for Purchasing Power Parity in the exchange rates[16]).

We start by reviewing the Ofcom analysis and identifying a number of limitations, which imply that the conclusions Ofcom has drawn from the international evidence about the value of 900 MHz and 1800 MHz spectrum in the UK are unreliable. We then consider the appropriate approach to the assessment of the international benchmarking evidence and conclude that Ofcom's approach contains a significant risk of materially over-estimating the true market value of the 900 and 1800 MHz spectrum in the UK. We then use the available information on international benchmarks, to derive a range of values for 900 MHz and 1800 MHz spectrum in the UK that reflects more appropriately the characteristics of the auctions from which these values were derived, and their comparability to the UK. Our approach is summarised in **Figure 4** below.

Figure 4. Overview of our approach



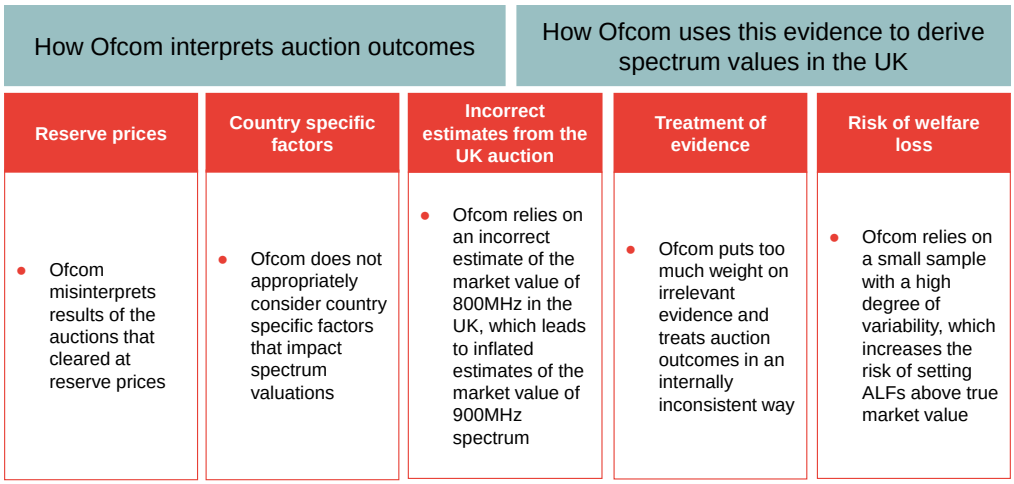
Source: Frontier Economics

16 It seems, however, that Ofcom's estimates of UK equivalent auction prices uses the same PPP adjustment for all Euro countries, i.e. it assumes the same purchasing power in Germany and Greece. This could potentially lead to overestimating spectrum value in Euro countries with price levels below the EU average, such as Greece. In our analysis, we use more appropriate PPP adjustments factors that take into account purchasing power differences within countries using the same currency.

3 Key limitations of Ofcom analysis

Using international benchmarks of auction outcomes to inform the valuation of spectrum in the UK is an inherently complex task. However, there are a number of significant weaknesses in Ofcom's approach that need to be addressed to achieve more reliable ALF estimates, as illustrated in **Figure 5** below.

Figure 5. Main weaknesses of Ofcom's approach



Source: Frontier Economics

- **Ofcom treats auction outcomes in a biased and internally inconsistent way putting too much weight on evidence that is not informative of the market value of spectrum in the UK.** Ofcom's approach in relation to estimating the 900 MHz market value is inconsistent with its approach in relation to estimating the 1800 MHz market value. When estimating the 1800 MHz market value, it put less weight on those outcomes that are *below* what Ofcom considers to be the lower-bound of the market value in the UK, i.e. the value of 2600 MHz spectrum derived from the recent UK auction. When looking at European auctions of 900 MHz spectrum, Ofcom's sample consists of seven observations which it considers to be 'more important' evidence. However, three of these observations are *above* what Ofcom's considers to be the upper bound of the market value of 900 MHz spectrum in the UK, namely the market value of 800 MHz spectrum derived from the recent UK auction. Therefore, these observations are at best of very limited value as relevant evidence for the purposes of deriving 900 MHz ALF estimates.

- **Ofcom relies on an incorrect estimate of the market value of 800 MHz in the UK, which leads to inflated estimates of the market value of 900 MHz spectrum.** Ofcom incorrectly estimates the market value of 800 MHz spectrum from the recent UK auction to be £29.9m per MHz. As explained in Frontier's UK Auction Report, the appropriate market clearing value to use from the UK auction is value is likely to be much lower, in the range £17.9m to £21.4m per MHz, with the realistic 900 MHz upper-bound at around £22.7m per MHz.[17] This means that Ofcom incorrectly treats absolute benchmarking auction results that are below £29.9m but above the more realistic upper bound of £22.7m as relevant, or 'more important', evidence. In addition, Ofcom uses the same inflated UK market value for 800 MHz spectrum when calculating the equivalent value of 900 MHz spectrum using benchmarks of relative prices.

- **Ofcom misinterprets information that auction outcomes provide about market value in a number of benchmark countries where auctions cleared at the reserve price**. Ofcom incorrectly concludes that auction prices underestimate market value for auctions in which spectrum cleared at or close to the reserve price by assuming that this was the result of "limited competition". Market value in the current context should reflect the opportunity cost for the use of a marginal (incremental) block of spectrum by the excluded bidder (when demand equals supply). We show in the main body of the report that, given the way reserve prices were set and the fact that these auctions cleared at the reserve price, the market value can be expected to be below the reserve prices paid.

- **Ofcom does not appropriately control for country- and auction-specific factors that could make auction outcomes in benchmark countries less comparable to the UK**. Ofcom takes into account certain expected drivers of spectrum value, and adjusts auction outcomes accordingly. However, it fails to consider many other important factors, such as market profitability, and the extent to which these might affect auction prices relative to UK values.

- **Ofcom relies on a small sample of observations, which increases the risk of setting ALFs above true market value.** Ofcom's benchmarking analysis relies on a few observations, with a high degree of variation between countries. When working with such a small sample, it is appropriate to be cautious when estimating true market value of spectrum and setting ALFs.

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17 The upper bound calculated as a mid-point of the appropriate UK 800 MHz value of £19.7m per MHz plus the estimated co-existence costs of approximately £3m per MHz.

This is because, as explained in Frontier's ALF Asymmetry Report, the potential welfare losses resulting from inadvertently setting ALFs too high (i.e. above true market value) are likely to be more significant than any losses that might arise from setting ALFs below market value.

We discuss some of these points in more detail below. First, we explain how Ofcom misinterprets the results of the auctions that cleared at reserve prices. Then we show that Ofcom does not appropriately consider country specific factors that drive spectrum value. We also show that Ofcom puts too much weight on irrelevant evidence and that it relies on a small sample, which increases the risk of setting ALF value above the true market value of spectrum.

3.1 Ofcom misinterprets results of the auctions that cleared at reserve prices

A number of auctions in Ofcom's benchmarking sample cleared at or close to the reserve prices (e.g. Greece, Spain and Romania). Ofcom concludes that "*there is a significant risk that this may have been symptomatic of limited competition in these auctions, as in a competitive auction bidding would tend to drive prices above any reserve price which was set below market value, while a reserve price set above market value would lead to unsold spectrum*"[18]. The justification for this statement is unclear, and Ofcom does not provide any other information or analysis to support it.

Below we show that a more careful consideration of Ofcom's assertion indicates that this assumption is unlikely to hold.

- First we show that, under various assumptions that are reflective of the auctions where spectrum sold at (or close to) the reserve price, prices paid in such auctions are more likely to *overestimate* the true market value of spectrum.[19]
- Second, the way reserve prices are calculated suggests that they are unlikely to reflect the market value of the spectrum in the benchmark countries.
- Third, we explain the implications for Ofcom's analysis.

18 The Consultation, para 4.33

19 The reason is that potential bidders that would have a lower private value than the reserve price of the auctioned spectrum will not participate in the auction. Given that (i) the private value of the participating bidders in such auctions may well exceed the reserve price, and (ii) effective demand for the spectrum may equal supply (often as a direct result of spectrum caps), all spectrum offered will sell at the reserve price, and yet the 'true' market value will be below the reserve price paid.

Key limitations of Ofcom analysis

3.1.1 Market value of spectrum in auctions that clear at reserve price

As discussed in more detail below, in the auctions where spectrum **clears at or close to reserve price,** prices paid are likely to be above the true market value, i.e. **prices are likely to be overestimating the market value of spectrum**[20].

We explain this by setting out some examples that illustrate, under reasonable assumptions about auction design and bidders' valuations, how spectrum sold at the reserve price would likely over-estimate the 'true' market value of such spectrum:

- First we consider a scenario when total demand for spectrum is higher than the amount of spectrum available. We also assume that there are a limited number of bidders competing for the spectrum, and no spectrum caps imposed on the auction participants. We show that, under a second price rule, an auction clearing at the reserve price is expected to overestimate the market value of the spectrum auctioned.

- Second, we consider a scenario with excess demand for spectrum, this time introducing spectrum caps and thus limiting the amount of spectrum auction participants can acquire. We show again that, under a second price rule, if an auction clears at the reserve price, the outcome is likely to overstate again the market value of spectrum.

- Last, we briefly discuss a situation in which demand is equal or lower than the supply of spectrum in the auction. Similarly to above, we conclude that any non-zero reserve price would lead to auction outcomes likely overestimating the market value of spectrum.

Excess demand (no spectrum caps)

Let's assume there are two bidders *A* and *B* competing for two identical lots of spectrum. Their private valuations for available lots, i.e. the maximum they are willing to pay per lot, are shown in **Table 3** below[21].

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20 We generally interpret market value as the opportunity cost of spectrum, which is the private value of a marginal/incremental block of spectrum to the 'excluded' bidder (actual or potential), when demand equals supply.

21 The main results are not affected by the difference in the private value of the spectrum between the two bidders – the assumed difference is used for illustration purposes.

Table 3. Illustrative example – spectrum valuations

	Intrinsic demand (lots)	Willingness to pay (per lot)
Bidder A	2	100
Bidder B	2	50

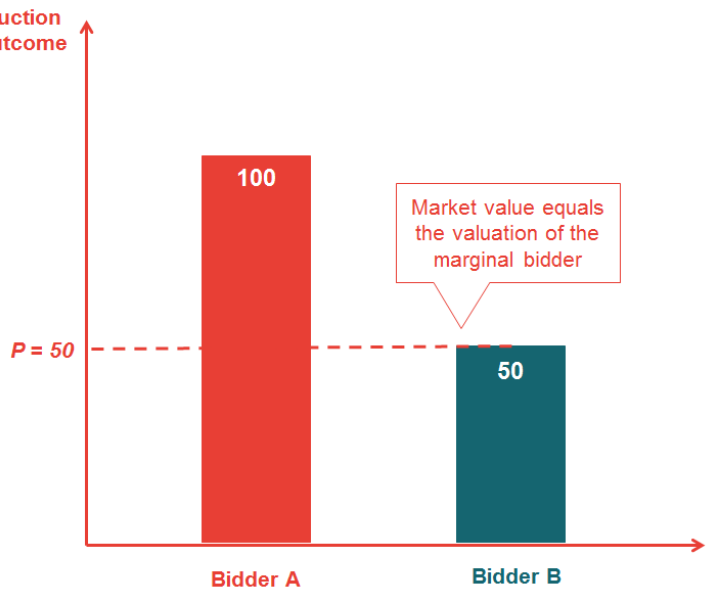
Source: Frontier Economics

Now assume that there is a market mechanism, such as a second price auction, used to allocate these two spectrum lots.[22] There would be an excess demand in the auction as each of the bidders wants two lots (i.e. total demand of four lots), but there are only two lots available in total. In the absence of reserve prices, the auction would clear at or slightly above the price at which supply of spectrum equals demand. In this case, the clearing price will be (slightly above) the private valuation of the marginal bidder, in this case *Bidder B*. *Bidder A* would acquire two lots at the price *P* slightly above 50, which reflect the true market value of spectrum in this simplified example. The spectrum is efficiently allocated to the bidder with the highest private value. This is illustrated in the figure below. This price would reflect the market value of the spectrum.

22 Our conclusions generally hold in any type of second-price auction, irrespective of the auction format (e.g. CCA, SMRA or sealed bid).

Key limitations of Ofcom analysis

Figure 6. Illustrative example - auction outcomes without reserve prices (no spectrum caps)



Source: Frontier Economics

Now assume there is a reserve price *R* introduced in the auction. There are three possible scenarios.

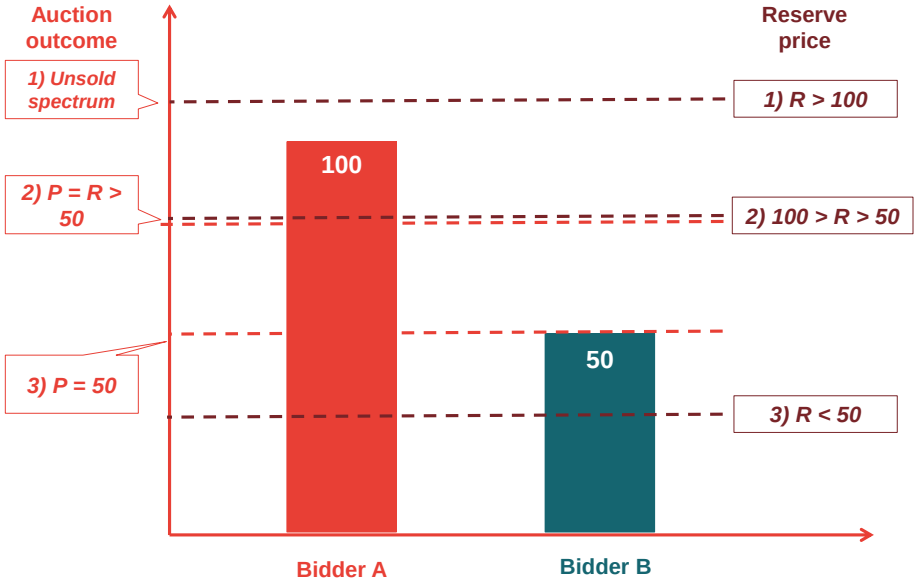
- Scenario 1): The reserve price is above the willingness to pay of the bidder with the highest private valuation, in this case *Bidder A* with 100. In this scenario, the two lots of spectrum are left unsold as the bidders valuations are below R.

- Scenario 2): The reserve price is somewhere between the private valuation of *Bidder A* (100) and *Bidder B* (50). In this case, *Bidder A* acquires the spectrum, but at the reserve price. As the reserve prices is above *Bidder B*'s valuation this is at or above the market value.

- Scenario 3): The reserve price is below the private valuation of the 'marginal' bidder, *Bidder B* (<50). In this case, the auction mechanism would lead to spectrum being acquired by *Bidder A* at the price slightly above the willingness to pay of *Bidder B*, which is an identical outcome to the case where there was no reserve price set.

The three scenarios of different reserve prices are illustrated in the figure below.

Figure 7. Illustrative example - auction outcomes with reserve prices



Source: Frontier Economics

This example illustrates that in a (second price) auction, in which there is an excess demand for spectrum, and which clears at the reserve price, the price paid can be expected to represent **an upper bound of market value**, rather than a lower bound, as suggested by Ofcom.[23]

Excess demand (with spectrum caps)

We next consider a scenario with two bidders *A* and *B,* and only two bidders, competing for two lots of spectrum. Their private valuations for available lots remain the same, 100 and 50 respectively. The difference is that there are now binding spectrum caps, preventing each bidder from acquiring more than one lot. The starting position under this scenario is shown in **Table 4** below.

[23] This would also be the case in the above example, if the marginal value of an additional block of spectrum for say *Bidder A* was below the reserve price; and the reserve price was set below the private value for the 1st block of spectrum of the marginal bidder. In such a case, each bidder would obtain one block of spectrum at the reserve price. The market value however would be lower, as *Bidder B* would only have to outbid the marginal value of *Bidder A* for the second block of spectrum, to obtain the one block of spectrum.

Key limitations of Ofcom analysis

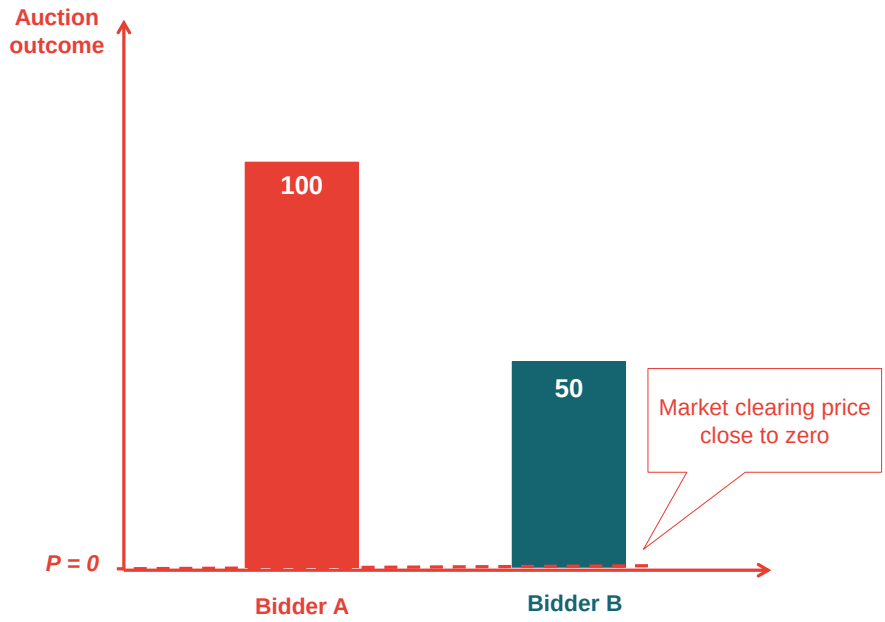
Table 4. Illustrative example – spectrum valuations (with spectrum caps)

	Intrinsic demand (lots)	Implied demand (lots)	Willingness to pay (per lot)
Bidder A	2	1	100
Bidder B	2	1	50

Source: Frontier Economics

While the intrinsic demand of each bidder is two lots, the spectrum caps imposed mean that the implied demand is one lot per bidder. Therefore, the auction can be expected to lead to a lower price at which supply of spectrum will equal to demand. In this particular case, and absent a reserve price and an additional bidder, this price would be close to zero, because spectrum caps effectively restrict the demand for the available spectrum to equal supply - see **Figure 8** below.

Figure 8. Illustrative example - auction outcomes without reserve prices (with spectrum caps)



Source: Frontier Economics

This simplified example assumes that the spectrum cannot be put to an alternative use and has no option value. The opportunity cost of allocating the

spectrum in the auction, expressed in this case by the willingness to pay of an absent marginal bidder, is therefore close to zero.[24].

If we now assume there is a reserve price *R* introduced in the auction, there are again three possible scenarios.

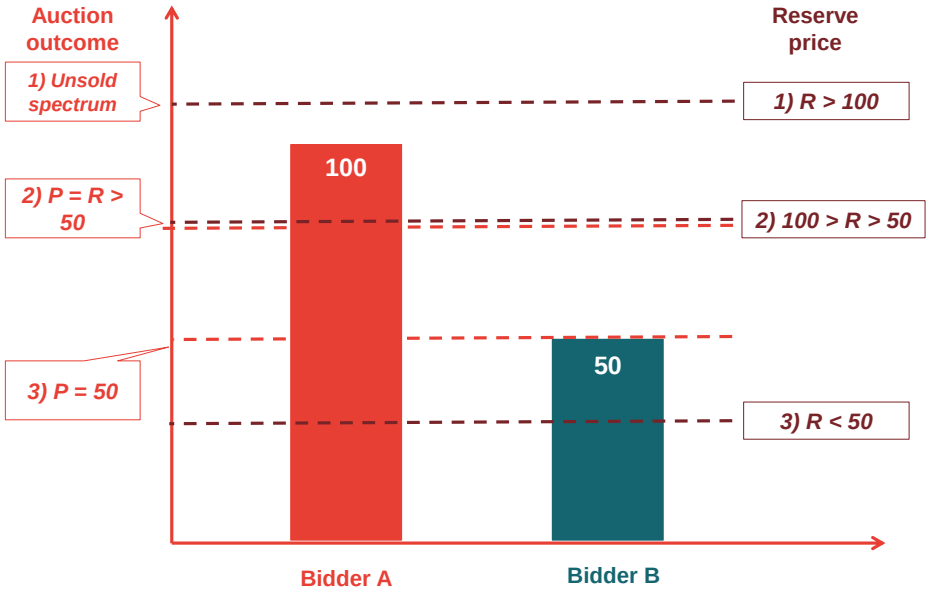
- Scenario 1): The reserve price is above the willingness to pay of the bidder with the highest private valuation, in this case *Bidder A* with 100. The two lots of spectrum are left unsold.

- Scenario 2): The reserve price is somewhere between the private valuation of *Bidder A* (100) and *Bidder B* (50). In this case, *Bidder A* acquires one lot (as it is restricted by spectrum caps) but at the reserve price which is at or above the true market value. One lot of spectrum is left unsold.

- Scenario 3): The reserve price is below the private valuation of the marginal *Bidder B* (<50) but above zero. In this case, the auction mechanism would lead to each bidder acquiring one lot at the reserve price. This would be above the 'market value' of spectrum, if the opportunity cost of the spectrum was lower than the reserve price set.

This is illustrated in the figure below.

Figure 9. Illustrative example - auction outcomes with reserve prices (with spectrum caps)



Note: We assume the opportunity cost of spectrum is equal to zero

Source: Frontier Economics,

This example shows that the imposition of spectrum caps can lead to spectrum being sold at the reserve price set, even if there is 'intrinsically' excess demand for the spectrum being sold. Even in auctions in which spectrum caps imply that competition within an auction may be limited, and which clear at the reserve price, the price paid by bidders is likely to represent **an upper bound of market value**, rather than a lower bound, as suggested by Ofcom.

No excess demand

If demand is equal to or lower than the supply of spectrum in the auction, then either i) the outcome would be identical to the one described in the previous example, where spectrum caps implied supply was equal to demand, or (ii) the supply of spectrum exceeds demand, and the auction clears at a price close to zero, but some spectrum is left unsold. In such cases, a positive reserve price would likely lead to auction outcomes that overestimated the market value of spectrum.

This shows again that, where spectrum in an auction is sold at (or close) to the reserve price, this can be expected to represent an *overestimate* of the market value (or 'opportunity cost') of spectrum, unless if the reserve price is set to reflect the

true opportunity cost of allocating spectrum within the auction. We turn to this question next.

3.1.2 Reserve prices should not be expected in general to reflect the market value (or opportunity cost) of spectrum in auctions where spectrum is sold at the reserve price

As explained above, the reserve prices in auctions where spectrum sells at the reserve price, could be indicative of market value if they reflect the true opportunity cost of allocating the spectrum within the auction. This would be the case if reserve prices were set in a way that reflected the opportunity cost of allocating the spectrum in an auction where demand is expected to equal supply.

The opportunity cost in such auctions would in general be expected to reflect either:

- the option value of retaining the spectrum for later use within the mobile sector,
- the value of putting spectrum to an alternative use (e.g. broadcasting),
- the private valuation of alternative (non-incumbent) bidders that chose not to enter the auction[25], and
- the private valuation of auction participants for the marginal block of spectrum on offer.

As discussed in more detail below, there seem to be two main approaches taken by regulators (NRAs) when setting reserve prices in their respective auctions:

- NRAs often look at reserve prices and auction outcomes in other countries (benchmarking approach); and/or
- they use some form of cash-flow modelling to derive the value of spectrum for the mobile industry (modelling approach), which is then typically adjusted downwards to reduce the risk of over-estimating the value of the spectrum leading to spectrum being left unsold.

These methods are unlikely to offer reliable estimate of the opportunity cost of spectrum as set out above.

We consider each of the approaches below.

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25 These would be bidders with positive valuations of spectrum that would likely have participated in the auction if the reserve price was zero, or very low.

Reserve prices set using a benchmarking approach

The benchmarking approach typically relies on auction outcomes and/or reserve prices set in other countries, harmonised to reflect the amount of spectrum on sale, the length of the licences, the size of the population and, on some occasions, the levels of income (GDP per capita). To the extent that the auction outcomes reflect prices from auctions that cleared above the reserve price, they are unlikely to provide a reliable indication of the opportunity cost of the spectrum in a country where demand equals supply. This is primarily because:

- the option value of retaining the spectrum for later use is likely to be less than the market value of similar spectrum sold in other countries;
- the opportunity cost of an alternative use of the spectrum is likely to be significantly lower than the market value of the spectrum for mobile operators in the benchmark countries;
- the private valuation of non-participating bidders is likely to be below reserve prices, otherwise such bidders would participate in the auction in the benchmarking countries; and
- the private valuation of participating bidder for the marginal block can be significantly below the (reserve) price paid for the spectrum acquired in the auction.

- With regards to non-participating bidders or new entrants, their private valuation can be well below the willingness to pay of participating incumbents. For instance, in the Netherlands, where spectrum was reserved for new entrants and two operators competed for it, the prices paid were significantly below the (estimated) prices paid by the incumbents for similar spectrum. Tele 2 acquired 2x10 MHz of 800 MHz spectrum for EUR161 million (ca. £27.7m per MHz). Based on confidential information from Vodafone, the estimated price paid for similar spectrum but the two successful incumbent operators, KPN and Vodafone, was [✂] times higher.

- With respect to participating bidders, it is possible that their valuation for a marginal block is the best approximation for the market value of the spectrum. This would be the case in auctions where all spectrum is sold at reserve price, but one or more bidders does not acquire all spectrum it could, given the spectrum caps imposed in the auction. This implies that the valuation of the unsuccessful bidder for the marginal block it did not acquire was below the reserve price. How much below it would depend on circumstances, but it is plausible that the willingness to pay for the additional block could be significantly lower than the reserve price paid for the acquired spectrum. For instance, the results of German 4G auction suggests

that E-Plus was willing to pay approximately 70% less for the second 2x5MHz block of 800 MHz spectrum, compared to the first block.[26]

The above illustrates that reserve prices set on the basis of international benchmarking are likely to have only limited ability to provide information about the true opportunity cost of spectrum. Also, there is likely to be an element of circularity as reserve prices in one market inform reserve prices in others: unless the reserve prices in all of the benchmark countries that are used are set to reflect the opportunity cost in those countries if there is limited (or no) excess demand for spectrum, the use of the benchmarks will not provide reliable information.

Reserve prices set using a modelling approach

This approach uses typically some form of cash-flow modelling (or modelling of cost savings from additional spectrum) to derive the value of spectrum on which reserve prices are then based.

When there is likely to be excess demand for spectrum in the auction and the model considers cash-flow that could be generated by a marginal bidder in the auction, i.e. estimating the marginal value of the spectrum to mobile industry, this could, in theory, lead to reserve prices that provide an indication of the market value of spectrum.

Nevertheless, in practice, business modelling typically focuses on operators overall willingness to pay for packages of spectrum and performs poorly when assessing the marginal valuation of spectrum – Ofcom's own modelling demonstrates this. Thus, business modelling can provide useful information to ensure that reserve prices are not set above the level where operators would not be willing to pay for packages of spectrum. The modelling is much less accurate in determining the market value of the spectrum by determining the optimal allocation of spectrum and the opportunity cost resulting from this optimal allocation.

In addition, in auctions where there is no excess demand however, this approach could lead to reserve prices overestimating the market value in a given country. This is because the modelling approach looking at the private value of spectrum to the marginal bidder could over-estimate, potentially significantly, the true opportunity cost of the spectrum, reflecting either of the options outlined above, i.e. the option value of retaining the spectrum, the value of putting spectrum to an alternative use and/or the private valuation of non-participating bidders.

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26 DotEcon's analysis suggests that E-Plus likely dropped their bid from 2x15MHz to 2x10 MHz at a price of £0.211 per MHz per capita, and then further from 2x5MHz to zero at a price £0.671 per MHz per capita, see Spectrum value of 800 MHz, 1800 MHz and 2.6GHz, July 2012, para 52.

Key limitations of Ofcom analysis

Evidence from countries where spectrum cleared at reserve price

The available evidence suggests that reserve prices in countries where auctions cleared at reserve price were unlikely to have been set in a way that would reflect the market value of spectrum. This is in line with Ofcom's own conclusion that '*It is possible that reserve prices happened to be set close to market value in those countries, but there is no basis for assuming this to be the case*'.[27]

- **Greece:** the Greek regulator EETT set reserve prices based on the interim results of a benchmarking study carried out by DotEcon for the Irish regulator ComReg.[28] DotEcon's interim results were published before January 2011 and relied on the outcomes of past 2G and 3G auctions, considering 900 MHz, 1800 MHz as well 2100 MHz bands.[29] The interim results suggest the range of prices from €0.546m to €0.8m per MHz/pop. This equals approximately £34.1m - £50m per MHz in the UK equivalent terms[30]. These are relatively high values, most likely driven by high prices paid for 2100 MHz spectrum in the 3G auctions considered in DotEcon's benchmarking sample. The average price paid for 900 MHz spectrum across recent 4G auctions, according to more recent DotEcon's report, was between £22.1m and £29m per MHz[31]. This is clearly well below the range considered by the Greek regulator. Therefore, the reserve price in Greece, despite being set below the lower bound of the £34.1m - £50m per MHz range, is unlikely to reflect the true market value of 900 MHz spectrum in Greece.

- **Romania:** According to DotEcon's report, Romanian regulator ANCOM *"considered outcomes from other spectrum auctions, spectrum demand and the physical characteristics of the various bands amongst other factors when setting reserve prices"*. At

27 The Consultation, para 4.33

28 See Page 5: http://www.eett.gr/opencms/export/sites/default/admin/downloads/Consultations/RadioCommunications/dikaiomata_xrisis_radiosyxnotiton/900-1800 MHz_Consultation_ENG.pdf

29 We are only aware of one 4G spectrum auction in Europe (Denmark) which took place before this date.

30 We use the same adjustment factors as DotEcon, as provided by Ofcom, to convert all values in PPP and inflation adjusted current prices in GBP. We assume UK population of 63.1 million.

31 See Table 1 of DotEcon's International benchmarking of 900 MHz and 1800 MHz spectrum value, September 2013. We convert 900 MHz benchmarks of £0.35 - £0.46 per MHz/pop assuming UK population of 63.1 million.

the same time, DotEcon concludes that "*there was however, no specific reference to reserve prices reflecting market value*"[32]

- **Portugal and Spain:** the information from public sources and regulatory documents provides only limited insight into how reserve prices were set in Spain and Portugal.[33] Nevertheless, according to DotEcon "*there is no indication that reserve prices were set to reflect market value*".[34] DotEcon also notes that reserve prices in Spain and Portugal were similar to those in Ireland, where reserve prices were set to reflect market value. Auctions in these three countries also took place in the same year. These similarities, however, do not imply that reserve prices in Spain and Portugal actually reflect market value. This is because market value is likely to differ, potentially significantly, across countries for the reasons discussed in the next chapter.

- **Italy:** there is no indication that reserve prices for 1800 MHz in Italy were set to reflect the market value. The 1800 MHz reserve price was among the highest set in Europe and above the upper bound of DotEcon's benchmarking range for the value of renewed 1800 MHz spectrum [35]. There is also some indication that the reserve prices were set to extract the private value of the auction participants.[36] Therefore, we conclude the reserve price in Italy is unlikely to reflect the market value of spectrum.

3.1.3 Implications for Ofcom's benchmarking analysis

We explained above why any auction clearing at or close to reserve price is likely to overestimate the true market value of spectrum in the benchmarking country. This has significant implications for the results of Ofcom's 900 MHz benchmarking analysis, because in 3 out of the 4 countries (**Greece**, **Spain, Romania**), which Ofcom considers to be 'more important' evidence for deriving absolute values of 900 MHz spectrum, auctions cleared at the reserve price. It

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32 DotEcon's International benchmarking of 900 MHz and 1800 MHz spectrum value, September 2013. para 67.

33 One of the responses from the public consultation in Portugal suggests that the regulator ANACOM considered auction outcomes in other EU countries, without even making adjustments for difference in population size and income levels (PPP).

34 DotEcon's International benchmarking of 900 MHz and 1800 MHz spectrum value, September 2013. para 67.

35 See Table 1 of DotEcon's International benchmarking of 900 MHz and 1800 MHz spectrum value, September 2013. We convert 1800 MHz renewal benchmarks of £0.12 - £0.25 per MHz/pop assuming UK population of 63.1 million.

36 There is a reference to this possibility in "*The Impact of Bidding Eligibility Conditions on Spectrum Auction Revenues*", Martyn Roetter, Alan Pearce, February 2013, available at http://www.ccianet.org/wp-content/uploads/library/IAE%20Report%20-%20Final.pdf

also has implications for **Portugal**, where the 900 MHz auction also cleared at reserve prices, but which Ofcom considers to be 'less important' evidence.

Ofcom concluded that these outcomes represent a 'lower bound' of market value of spectrum, in contrast to our earlier analysis that indicates the reverse. As shown in **Table 5** below, the prices paid for 900 MHz spectrum in these auctions range from £24m in Portugal to £31m in Greece. Based on our analysis above, and before considering additional evidence, these results are therefore expected to overestimate the market value of 900 MHz in the benchmarking countries.

Table 5. Auction results (900 MHz) in countries where auctions cleared at reserve prices

Country	Price paid (£m per MHz) – absolute	Relation to market value in the benchmark country	Comment
Portugal	24.1	Overestimating	Reserve prices an indicator of an upper bound of the market value of spectrum
Romania	24.9	Overestimating	
Spain	25.2	Overestimating	
Greece	31.4	Overestimating	

Source: Frontier Economics

With regards to 1800 MHz auctions, in **Italy** this spectrum was sold very close to reserve price. Our understanding from Vodafone is that there was effectively no competition for 1800 MHz spectrum in the Italian auction and the clearing price slightly above the reserve price was an outcome of the specifics of the auction design. Ofcom treats Italy as more important evidence for deriving ALFs of 1800 MHz spectrum. Based on the above, these results should also be expected to overestimate the market value of 1800 MHz in Italy.

3.2 Ofcom does not appropriately consider country specific factors that impact spectrum valuations

There are a number of factors that affect auction outcomes that can be summarised under two broad categories:

Market structure and conditions: the value of spectrum to mobile operators will depend on various factors that are specific to the benchmark country and likely to be related to the structure of the mobile market in the benchmark country. On the supply side, these factors are, for instance:

- the number of players in the market and the intensity of competition;

- distribution of current spectrum holdings, the intensity of their use and the amount of spectrum expected to become available in the future; and
- the socio-economic and geographic factors affecting the cost of network deployment, such as population density and dispersion.

On the demand side, these are, among others:

- the current and expected levels of mobile penetration;
- the current and expected levels of usage of different mobile services; and

  income levels and the willingness to pay for mobile services measured by the level of average revenue or margin per user.

Auction design: the extent to which the true market value of spectrum is revealed in the auction will also depend on the specifics of the auction design and conditions. The factors that are likely to play an important role on whether the auction reveals any useful information about the true value of spectrum in the benchmark country, as well as whether these values are likely to be comparable with the outcomes expected in the UK are, among others:

- the auction format;
- the type and amount of spectrum offered in the auction;
- the existence of spectrum caps and other limitations on the level of competition within the auction;[37]
- the strategic importance of the auctioned spectrum to each operator's current spectrum portfolio and future operations;
- the duration of licences and potential limitations on the technology that can be adopted in terms of licensed use;
- the reservation of spectrum for new entrants and/or any additional measures to promote new entry;
- the level of reserve prices across different bands; and
- the timing of the auction[38].

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37 While spectrum caps might limit excess demand and competition within the auction, their purpose is to make sure that the outcomes of the auction do not lead to concentrations or distributions of spectrum that could potentially lead to a dampening of competition post-auction. Comparison of auction outcomes in different countries need to therefore consider the implications of spectrum caps on auction results.

Key limitations of Ofcom analysis

These factors tend to vary across countries and auctions, therefore making any international benchmarking inherently difficult. Ofcom seems to recognize this and in its analysis tries to control for some of the factors to make the outcomes of individual auctions more comparable.

Nevertheless, as shown below, the adjustments Ofcom relies on in its benchmarking analysis are not sufficiently robust. In addition, these adjustments, even when done properly, are not in general sufficient to allow a reliable direct comparison of auction outcomes across countries.

3.2.1 Ofcom's adjustments of auction outcomes in the benchmark countries are not sufficiently robust

First, Ofcom relies on DotEcon's benchmarking analysis, which adjusts the auction outcomes by controlling for:

- the licence duration;
- inflation;
- difference in income levels through PPP adjustments[39]; and
- size of the potential market (through population adjustments).

These adjustments, however, are unlikely to be sufficient to fully capture differences across countries that are driving the spectrum value.

In particular, the adjustments made by DotEcon do not capture the differences in profitability of mobile services in different countries, and this would be expected to have a significant impact on the spectrum value and prices paid in the auction, all else the same. This is consistent with a significant variation in average margin per user across the EU countries, even after adjusting for purchasing power differences, see **Figure 10** below.[40]

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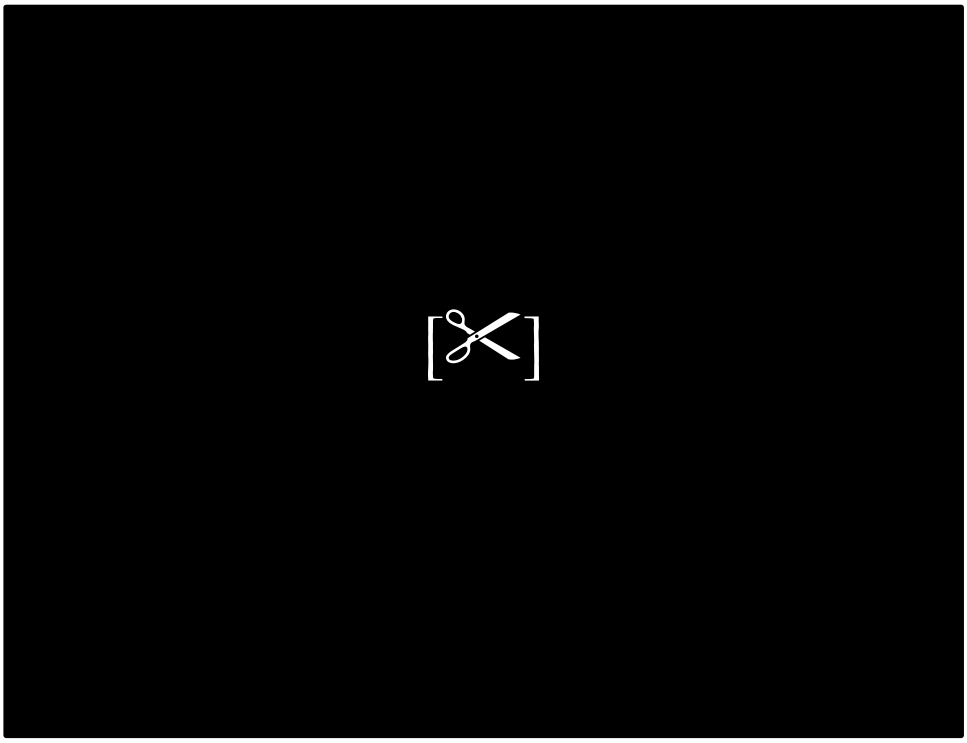
38 The more recent auctions are likely to provide more relevant information about the spectrum value in the UK, to the extent that global economic conditions might have impacted on operator's spectrum valuations across the benchmarking sample. At the same time, results of more recent auctions could still be significantly influenced by specific conditions of supply and demand for spectrum in the benchmark country at the time of the auction.

39 It seems, that Ofcom's estimates of UK equivalent auction prices uses the same PPP adjustment for all Euro countries, i.e. it assumes the same purchasing power in Germany and Greece. This could potentially lead to overestimating spectrum value in Euro countries with price levels below the EU average, such as Greece.

40 Similarly, while the size of the country, measured by population, might provide some indication about the future cost and earnings, it is unlikely to fully capture other significant cost and revenue drivers captured by measures such as population density and dispersion, or by levels of urbanisation.

Figure 10. Average margin per user in $PPP (2011)



Note: we calculate average margin per user as EBITDA divided by a number of unique subscribers[41]

Source: Frontier Economics based on Bank of America Merrill Lynch, GSMA, Annual Reports

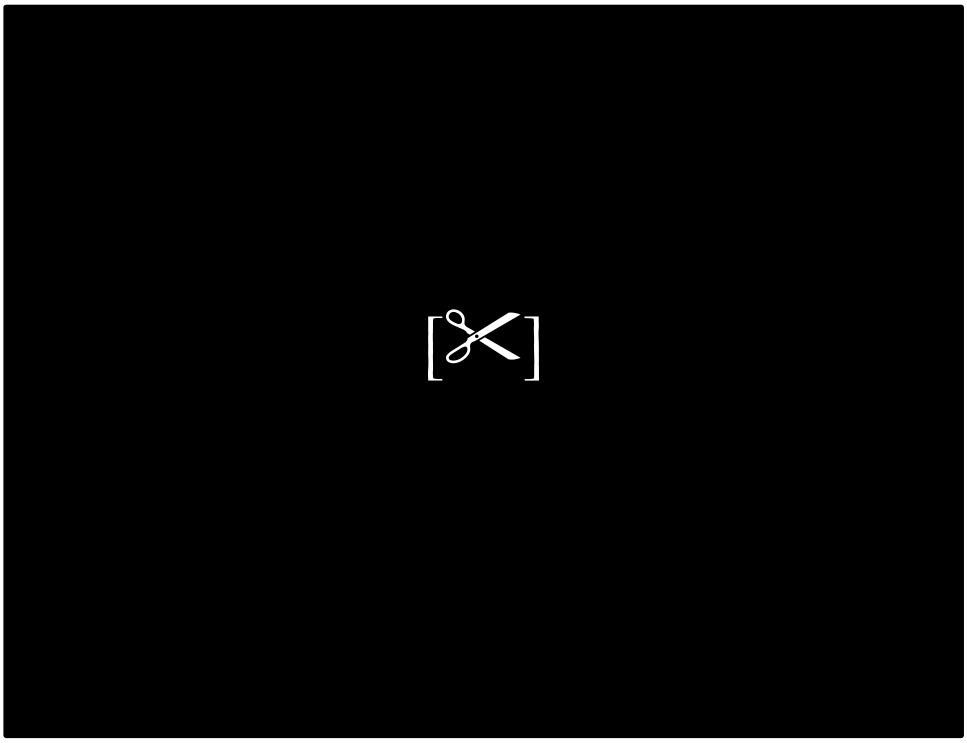
As discussed in more detail below, mobile markets in **Italy and Portugal** are characterised by significantly higher margins per user than what we observe in the UK. As shown in **Figure 10**, average margins in Italy and Portugal were almost [✂] the UK value in 2012. Other things being equal, this would suggest operators might be willing to pay more for spectrum as their ability to recover their investment is higher in a more profitable market.

Ofcom also considers it appropriate to place more weight on evidence from 4G auctions in EU countries from 2010 onwards. Whilst these auctions may be more appropriate benchmarks for the UK than other auctions considered in DotEcon's analysis, there are still significant differences between mobile markets in the selected benchmark countries and in the UK. For instance, **Figure 11** shows the variation in 2G penetration across EU countries – all of the benchmarks selected by Ofcom are from the EU.

41 We recognise that there are other possible measures of market profitability, such as return on capital employed (ROCE) or net earnings per MHz, which might in some cases be more appropriate for cross-country comparisons, but where data availability is more limited.

Key limitations of Ofcom analysis

Figure 11. 2G penetration in the EU countries (2012)

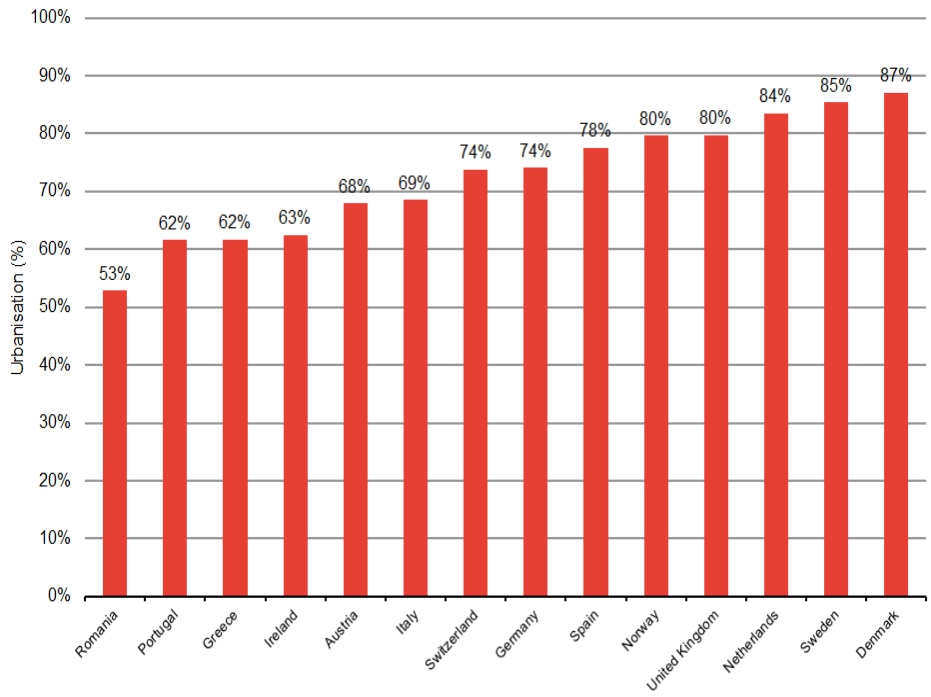


Source: Frontier Economics based on GSMA

It is reasonable to assume that, all else the same, operators with a significantly larger share of 2G subscribers are likely to value spectrum bands suitable for provision of 2G services (i.e. 900 MHz and 1800 MHz) more than operators where a majority of customers is using 3G and 4G enabled devices and the focus of operators is on the future provision of LTE services. The market value of 900 MHz and 1800 MHz, all else the same, is therefore likely to be higher in **Romania** and **Greece** than in the UK, because of the significantly higher demand for 2G services.

Furthermore, there are significant differences in urbanisation levels across the EU countries, see **Figure 12** below. It is reasonable to assume that the level of urbanisation will be negatively correlated with the cost of network rollout, i.e. it is likely to be more costly to roll out networks in rural and less densely populated areas. As a result, one would expect sub-1GHz spectrum to be more valuable in less urbanised countries such as **Romania, Greece, Portugal or Ireland** than in the UK.

Figure 12. Urbanisation in the EU countries (2012)



Source: Frontier Economics based on World Bank

Ofcom seems to appreciate that each auction is a unique event and its design and outcomes need to be analysed carefully to derive some useful indication about the market value of spectrum in the UK. While Ofcom provides key descriptive information about the auctions in individual countries, it has not considered fully the impact that specific features of the auction design might have on the auction outcomes and implied spectrum valuations.

3.2.2 Implications for Ofcom's benchmarking analysis

As shown above, there are number of factors that could potentially affect the value of spectrum in the benchmark countries. Therefore, Ofcom would need to carefully asses these market and country specific factors when considering how the spectrum value might differ across the benchmarking sample and more importantly how this might compare with the spectrum value in the UK.

In addition, when considering auction outcomes from benchmark countries where there are significant differences between the UK and the benchmark country across a wide range of these factors, Ofcom should consider to what extent relative valuations might be less affected by different factors (such as higher profitability). As shown in our own analysis below, relative values can be

Key limitations of Ofcom analysis

expected to be more reflective of market value of spectrum in the UK as they tend to be less distorted by country and market specific factors.

3.3 Ofcom treats auction outcomes in a biased and internally inconsistent way, putting too much weight on evidence that is not informative of the market value of spectrum in the UK

Our analysis suggests that Ofcom treats the available evidence in an inconsistent way, overestimating the true value of 900 MHz spectrum in the UK. When looking at the auctions of 900 MHz spectrum, Ofcom's sample consists of seven observations of absolute value from international auctions, out of which Ofcom puts more weight on the auction results from four countries. These are combined with three *relative* valuations of 900 MHz spectrum, to derive a sample of seven auction outcomes which Ofcom considers as 'more important' evidence.

Three of these seven observations are however above Ofcom's estimate of the market value of 800 MHz in the UK. And yet, Ofcom considers the market value of 800 MHz in the UK to be a likely upper bound of 900 MHz value in the UK.

> *"On this basis, we consider on balance that 900 MHz is unlikely to have a higher value than 800 MHz spectrum in the UK, i.e. the value of the 800 MHz spectrum in the UK is likely to set an upper limit on the value of 900 MHz in the UK."*[42]

Based on the results from the UK auction, Ofcom estimates the market value of 800 MHz to be £29.9m per MHz. Following Ofcom's own approach, any auction outcomes from the international benchmarking suggesting 900 MHz value is above £29.9m should be given no, or very limited, weight. This implies that the relevant range of 900 MHz benchmark values, even by Ofcom's own analysis, should be £18.2m to £24.9m.[43] Therefore, Ofcom's proposal for the ALF of 900 MHz is *above the upper bound* of the range Ofcom should consider as more important evidence[44].

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42 The Consultation, para 4.42.

43 This is in contrast with para 4.40 of The Consultation, where it effectively states that the appropriate range for 900 MHz values goes from £18.2m to £36m.

44 Ofcom seems to be arguing (paragraph 4.57) that because the reserve prices of 900 MHz in Greece and Romania could be expected to under-estimate the market value in these countries, it is appropriate to rely on these data points even though they exceed Ofcom's estimated value of 800 MHz in the UK. If the value of 800 MHz in the UK is an upper bound for the value of 900 MHz in the UK, consistency would require that any international evidence that suggests otherwise cannot inform reliably the value of 900 MHz in the UK. We also note that, for the reasons explained earlier, the reserve prices in Romania and Greece are likely to over-estimate the true market value in these countries.

Ofcom's approach to setting the ALF for 900 MHz is also inconsistent with Ofcom's approach to setting the ALF for 1800 MHz, based on the assessment of auction outcomes in relation to 1800 MHz spectrum. For the 1800 MHz auctions in Germany and Portugal Ofcom states "*the results imply a UK value for 1800 MHz below the UK LRP for 2.G GHz spectrum, which we do not consider plausible.*"[45] When setting the ALF for 1800 MHz spectrum, not only does Ofcom consider such observations as 'less important' evidence, but it effectively ignores them completely.

3.3.1 Implications for Ofcom's benchmarking analysis

The consequence of the above, is that when deriving 900 MHz benchmark values Ofcom has to take a consistent approach and disregard (or place very limited weight on) any auction outcomes that suggest 900 MHz value is above the upper bound of market value in the UK, based on the appropriately derived value of 800 MHz from the UK auction.

45 The Consultation, para 4.32

3.4 Ofcom relies on an incorrect estimate of the market value of 800 MHz in the UK, which leads to inflated estimates of the market value of 900 MHz spectrum

Ofcom incorrectly estimates the market value of 800 MHz spectrum from the recent UK auction to be £29.9m per MHz. As explained in Frontier's UK Auction Report, this number is overstated. The appropriate 800 MHz market value to use from the UK auction is estimated to be much lower, in the range £17.9m to £21.4 m per MHz.

We use the mid-point of the value range from the UK auction (£19.7m) as a point estimate of UK 800 MHz value. We use this mid-point of 800 MHz value as a starting point for deriving the appropriate upper bound for 900 MHz spectrum. We then add the estimated cost of co-existence of £3m per MHz to get the appropriate upper bound of value of 900 MHz spectrum in the UK, of approximately £22.7m per MHz.[46] We use this value in our own analysis below.

In addition, Ofcom uses an inappropriate estimate of UK market value for 800 MHz spectrum when deriving the equivalent value of 900 MHz, spectrum using benchmarks of relative prices. Ofcom's estimate of the UK market value of 800 MHz spectrum is includes co-existence costs. We understand from Vodafone however, that co-existence costs were anticipated in multiple European markets, including Ireland, Spain and Sweden. As such, the co-existence costs would have been incorporated in bidders' valuation of 800 MHz spectrum in these auctions. Accordingly, to use international comparisons on a like-for-like basis, the 900/800 MHz ratios derived from the international benchmarks need to be applied to the estimated 800 MHz value from the UK auction *without* the inclusion of any co-existence costs, to arrive at a comparable market value estimate for 900 MHz spectrum in UK.

Therefore, as the relevant 800 MHz benchmarks from other jurisdictions are net of co-existence costs, the appropriate UK 800 MHz benchmark to apply is the UK 800 MHz estimated market value, net of such costs.

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46 This is because the estimated 800 MHz value from the UK auction is based on bidder valuations after deducting all essential costs of operating 800 MHz network, including the co-existence costs. To the extent that co-existence costs are not as significant in relation to 900 MHz spectrum, it is appropriate to increase the estimated upper bound of 900 MHz by adding these costs. This estimate is likely to overestimate the upper bound of 900 MHz, as it does not take into account the cost of LTE re-farming, which would lead to lower value of 900 MHz spectrum.

3.4.1 Implications for Ofcom's benchmarking analysis

When deriving the appropriate range of 900 MHz value in the UK, Ofcom should rely on the correct estimates of UK 800 MHz value, which is in the range £17.9m to £21.4m per MHz. This implies that any auction outcomes that are above the appropriately derived upper bound of 900 MHz value at £22.7m should be considered as less relevant evidence. In addition, when deriving the implied value of 900 MHz and 1800 MHz spectrum in the UK using relative valuations from the benchmarking sample, we have used as a starting point of UK 800 MHz value the midpoint of the estimated range of the 800 MHz value from the UK auction, i.e. £19.7m per MHz.

3.5 Ofcom relies on a small sample of observations with a high degree of variability, which increases the risk of setting ALFs above true market value

In its analysis Ofcom relies on a relatively small sample of observations with a high degree of variability when deriving ALF prices. For instance, when looking at the auctions of 900 MHz spectrum, Ofcom's sample consists of seven 'more important evidence' observations with spectrum prices ranging from £18.2m per MHz to £35.7m.

This requires a careful assessment of all available spectrum outcomes against the range of market and country specific factors, to develop an informed view about how the prices paid for spectrum in other auctions might differ across the benchmarking sample and, more importantly, how this might compare with the spectrum value in the UK.

In addition, when facing such significant variation in the estimated market values of 900 MHz and 1800 MHz spectrum in the UK, it would be appropriate for Ofcom to take a cautious approach when setting ALFs.[47] This is because, as explained in Frontier's ALF Asymmetry report, the welfare loss from setting ALF too high, i.e. above true market value, are likely to be more significant than from setting ALF below market value.

3.5.1 Implications for Ofcom's benchmarking analysis

Ofcom relies on a relatively small sample of benchmarking outcomes. Moreover, there is significant variation in the data in the benchmarking sample, and uncertainty about how these results result reflect the true market value of

47 This would be consistent with the approach Ofcom adopted when setting prices based on the AIP method to reflect the asymmetry of risks, where the estimated spectrum value based on cost modelling was halved, to reflect such risks.

spectrum in the UK. For these reasons, it is desirable for a cautious approach to be adopted when setting the ALFs.

3.6 Main implications for Ofcom's benchmarking analysis

Based on the analysis of Ofcom's key shortcomings, we summarise the main implications for Ofcom's revised benchmarking analysis.

- When considering auctions that cleared at reserve price, these must be interpreted as an upper bound of the market value in the benchmarking country.

- Market and country specific factors that can be expected to have potentially a significant impact on spectrum value, need to be assessed carefully, when considering how spectrum value might differ between the benchmarking sample and the UK.

- Ofcom needs to treat the available benchmarking evidence in an appropriate and consistent way. If certain auction outcomes are above what Ofcom believes is the upper bound of market value of spectrum in the UK, these outcomes on their own should be considered as largely irrelevant for purposes of deriving ALF value in the UK.

- The appropriate estimates of UK 800 MHz value need to be used, which have been estimated by Frontier to be much lower than Ofcom's estimates, in the range £17.9m to £21.4m per MHz.

- Working with a relatively small sample with a high degree of variability and uncertainty around the comparability of the data in the benchmarking sample to the UK, it is appropriate to take a conservative and cautious approach when setting ALFs.

We now turn to considering an approach that corrects for the weaknesses in Ofcom's approach, and the implications of this approach for the market value of 900 MHz and 1800 MHz in the UK.

4 Appropriate framework for an international benchmarking analysis

As explained above, the available evidence from international benchmarking needs to be considered carefully, as each auction is a unique and complex process.

In order to derive any useful information about the value of spectrum in the UK on the basis of benchmarks, two key questions need to be addressed:

- Does the auction outcome reveal true market value of spectrum in the benchmark country?
- Is this market value reflective of spectrum value in the UK?

After the assessment of each one of the auctions (Sections 4.2– 4.4), we estimate the appropriate range for 900 MHz and 1800 MHz value in the UK (Section 5), taking into account the following factors:

  - the appropriate estimates of the value of 800 MHz spectrum in the UK, which impacts both the upper bound for the 900 MHz value, as well as 900 MHz estimates derived based on relative valuations from other countries; and
  - applying a consistent approach by putting less weight on the auctions outcomes outside a plausible range of auction values for the UK, i.e. outcomes higher than the UK value of 800 MHz (upper bound) or lower than the 2600 MHz (lower bound), appropriately derived from the UK auction results.

We discuss the two key questions used to evaluate individual auctions in more detail below.

Does the auction outcome reveal true market value of spectrum in the benchmark country?

With regards to this question, we carefully consider for each of the auctions in Ofcom's sample, the key elements of the auctions as set out above, such as auction format, type and amount of spectrum offered, spectrum caps and other potential restrictions of the completion in the auction. We then analyse the auction outcomes in each individual band to come to a conclusion as to the extent to which these reflect the market value of spectrum.

In general, we conclude that if there is excess demand in the auction and all spectrum gets sold at significantly above the reserve price, the auction outcomes likely indicate market value in the benchmarking country. Nevertheless, this does

not automatically imply that this outcome is a good proxy for the spectrum value in the UK for the same band.

Is this market value reflective of spectrum value in the UK?

With respect to this question, we consider various factors that can be expected to drive spectrum value and that may materially differ in the benchmark country compared to the UK. We look at a wide range of indicators related to these factors to assess how comparable the benchmark country is with the UK.

Where we find significant differences that are likely to impact spectrum valuations, we assess the materiality of these factors, based on a qualitative assessment that categorises the different factors according to their importance.

The three factors considered the most important drivers of the value of 900 MHz and 1800 MHz spectrum, based on an analysis of the likely significance of the drivers of future mobile profitability, the technical properties of different spectrum bands, and discussions with Vodafone experts, are:

- **Market profitability:** other things being equal, operators could be expected to be willing to pay more for spectrum in markets characterised by higher profitability per subscriber, as the impact on profitability of marginal traffic enabled by increased spectrum is likely to be higher. In our analysis, we look at the PPP adjusted average margin per subscriber (AMPU) as a main proxy for market profitability. We also consider evolution of margins over time and the distribution of profits among operators within the benchmarking country.

- **Demand for 2G spectrum:** in lower income markets the trade-off between handset affordability and spectral efficiency is such that there is a large proportion of traffic on 2G networks. In these jurisdictions, it is reasonable to assume that, all else the same, operators are likely to value spectrum bands suitable for provision of 2G services higher relative to those which can only provide 3G or 4G services. As direct information about 2G traffic volumes are not generally available, we consider the 2G penetration measure, in combination with voice usage per subscriber, as a proxy for the overall demand for 2G spectrum. We therefore assume that 900 MHz/1800 MHz would be more valuable in a country with a higher penetration of 2G subscribers, other things equal, including the levels of voice usage per customer.

- **Level of urbanisation:** it is reasonable to assume that a higher proportion of the network is coverage constrained rather than traffic constrained in less densely populated rural areas. In these countries the additional cost of coverage with high frequency spectrum is likely to be more significant than in densely populated countries and most operators will have built macro-cell

grids based on low frequency spectrum. As a result, one would expect sub-1GHz spectrum, including 900 MHz, to be relatively more valuable in less urbanised countries than higher frequency spectrum.

Other important drivers that we consider in our analysis are listed below.

- **Uncertainty about future spectrum availability**: we take into consideration the current and future supply of spectrum in the benchmarking country. We assume that operators might place more value on the auctioned spectrum in countries where there is larger uncertainty about the timing and the scope of additional spectrum becoming available for mobile services, compared to countries where there is clearer expectation about the current and future availability of spectrum. We note that Ofcom is generally at the forefront of spectrum planning and there is likely to be more certainty about future spectrum supply in the UK compared to the situation in some of the benchmarking countries prior to the auction.

- **Timing of the existing licences' expiration:** where possible, based on the publicly available data, we take into account the expiration date of the spectrum licences renewed in the auction. We consider that operators' willingness to pay for the renewed spectrum is likely to be higher the closer the spectrum expiration is to the auction date. This is because the operators are likely to depend on their current spectrum holdings to meet the existing demands. Therefore, not renewing these licences in the auction might have significant negative implication for their business if they do not have enough time to re-direct their existing traffic through alternative channels (e.g. using different spectrum bands).

- **Demand for mobile services in general and mobile data services in particular**: we assume that in countries where there is a higher demand for mobile services and mobile data services operators might be willing to pay more for spectrum suitable for capacity on mobile data networks as existing networks may be capacity constrained. We use different measures to proxy demand for mobile data services, such as smartphone penetration or a share of mobile broadband devices (i.e. 'dongles').

- **Coverage obligations and other restrictions of spectrum use**: when looking at the market value of spectrum in the benchmarking country, we also take into account different restrictions (e.g. spectrum emissions rules) and obligations (e.g. coverage obligations) on spectrum use attached to the licences. We consider the likely impact of such licence conditions on the absolute and relative valuations of spectrum in the benchmarking country. Other things being equal, one would expect these restrictions to have a negative impact on the value operators put on the spectrum.

Appropriate framework for an international benchmarking analysis

Finally, drivers that we do consider in our analysis, but where the impact on the spectrum value may in general be expected to be less significant, include:

- distribution of spectrum holdings prior to the auction, e.g. how much different spectrum each operator holds;
- the wide scale availability of LTE services from multiple operators prior to the auction; and
- the auction format and specific rules that might have impacted spectrum valuations in the benchmarking country.

Taking into account all these factors we provide an overall assessment as to how the auction outcome in the benchmark country can be expected to compare to spectrum values in the UK, where possible.

We note that as a matter of principle, **absolute valuations of spectrum** from other countries can be expected to have more limitations in terms of informing the value of 900 MHz and 1800 MHz spectrum in the UK, due to the difficulty of adequately controlling for the wide range of country specific factors that can affect the absolute value of spectrum between countries. Appropriately selected **relative valuations of 900 MHz/1800 MHz and 800 MHz spectrum** however, can be expected to provide a more useful benchmark[48], as some of the key drivers of spectrum value could in general be expected to impact in a similar way the value of different bands of spectrum in the same country:

- First, with regards to market profitability, we would expect variations in profitability to lead to variations in absolute spectrum valuations across different countries. The impact of such variations on the relative valuation between different spectrum bands in the same country, in particular when it comes to sub 1GHz spectrum, would however be expected to be limited. Therefore, we would expect 900/800 MHz, and to some extent 1800/800 MHz, relative valuations to be largely unaffected by variations in market profitability between the benchmark country and the UK.

48 It should be noted that one of the possible weaknesses of relative valuations of 900 (and 1800) MHz spectrum from other jurisdictions is that this spectrum is commonly auctioned in 2x5MHz blocks, which limits comparability with the UK ALF where spectrum could in principle be traded at smaller increments. As marginal valuation can be expected to be lower than average, the prices paid for spectrum are less likely to reflect the incremental value of spectrum. Therefore, the relative valuation of 900 (and 1800) MHz spectrum in countries where spectrum was made available in 2x5 MHz blocks (e.g. Spain, Ireland) would likely overestimate the market value of 900 MHz spectrum in the UK, all else equal.

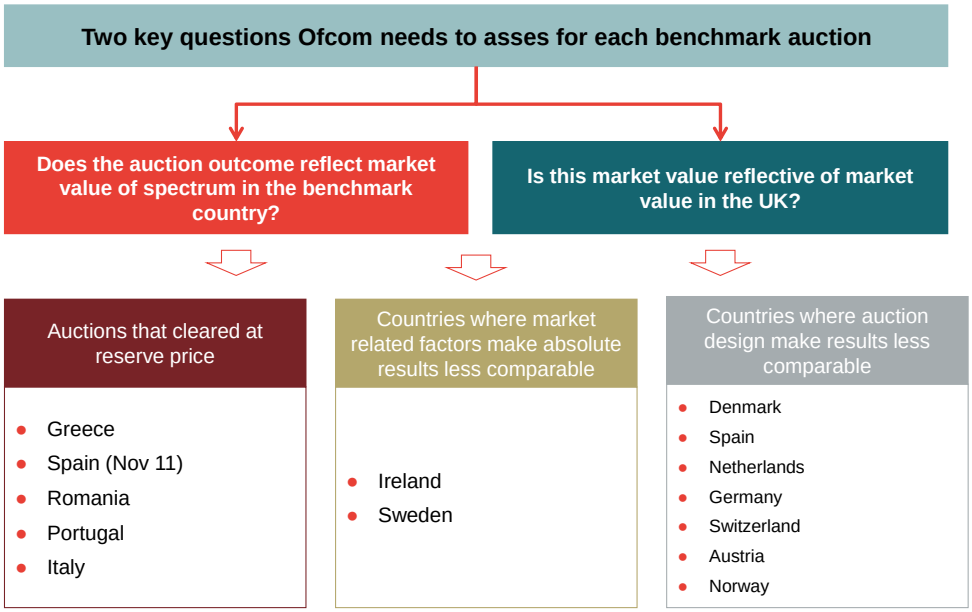
- Second, with regards to urbanisation levels, we explain above why one would expect sub-1GHz spectrum, i.e. both 800 MHz and 900 MHz to be more valuable in less urbanised countries. Therefore, we would expect that relative valuation of 900/800 MHz would be well suited to control for this effect in the benchmark country and would therefore be a good indicator of the market value in the UK.

We note however that there are also factors that can be expected to affect relative valuations, in particular demand for services using relatively more 2G spectrum. We explained above why this is likely to lead to potentially higher valuations of 900 MHz and 1800 MHz spectrum. Assuming higher demand for 2G spectrum has only limited impact on the valuation of 800 MHz spectrum, this would inflate the relative valuations of 900/800 MHz and 1800/800 MHz and could potentially overestimate the market value of 900 MHz and 1800 MHz spectrum in the UK, other things equal.

Figure 13 below summarises the framework we use when analysing in detail the auctions from the sample of countries Ofcom considers in their benchmarking analysis.

Appropriate framework for an international benchmarking analysis

Figure 13. Appropriate benchmarking framework



Source: Frontier Economics

We group the benchmark countries[49] in three broad categories:

- countries where auctions cleared at or close to reserve prices (**Spain – November 2011, Greece, Romania**, **Portugal** and **Italy**);
- countries where market related factors make the absolute results less comparable with the UK, but where relative valuations could provide useful benchmark (**Ireland and Sweden**); and
- countries where the auction design make the results less comparable or non-comparable to the UK (**Denmark, Spain – July/October 2011, Netherlands, Germany, Austria – 2013, Switzerland and Norway 2013**).[50] [51]

49 We do not explicitly consider auctions from Ofcom's sample where either 900 MHz or 1800 MHz was not auctioned, as these are unlikely to provide any information about the value of 900/1800 MHz spectrum in the UK. In particular, these are Austria (2010), Belgium (2011) and France (2011).

50 We consider the recent 4G spectrum auctions in Austria and Norway as a potential benchmark. Ofcom does not include the latter in its analysis, as the results were not available at the time Ofcom published its consultation document.

51 The 4G spectrum auction in the Czech Republic was completed after the publication of Ofcom's consultation document. The auction design in the Czech Republic included significant measures to promote new entry. Furthermore, the auction was undertaken twice, as the first auction got cancelled in March 2013, on the basis that prices were too high. The second auction in November

We first provide a brief overview of the auction and summarise the main outcomes. We also summarise Ofcom's view of the usefulness of the benchmark.

After the assessment of each one of the auctions, we summarise our findings and then provide our estimate of the market value of 900 MHz and 1800 MHz in the UK, based on the results of international benchmarking.

4.2 Auctions that cleared at reserve price

In this section, we focus on countries where auctions cleared at or close to reserve prices, this is Spain (November 2011), Greece, Romania and Portugal.

Ofcom treats outcomes of the Greek, Spanish and Romanian auction as more important evidence for 900 MHz, while it considers Portugal as less important evidence. Ofcom also considers Italy as a more important evidence for 1800 MHz benchmarks. Ofcom also states that the fact spectrum sold at reserve price means prices paid in the auction likely underestimate true market valuations.

As explained in Section 3.1, the auction clearing at reserve prices mean that the prices paid likely **overestimate market value of spectrum in Greece, Spain, Romania, Portugal and Italy**.

At the same time, in auctions that cleared at reserve prices, the significance of the relative value of 900 MHz and 800 MHz spectrum needs to be assessed carefully, before being considered as a useful benchmark for UK spectrum values.

In addition, as we show below, there are factors that make auction outcomes in these countries less comparable with the UK. In particular:

- **Greece:** the prices paid for spectrum in Greece are likely to overestimate the market value in the UK, due to reserve prices likely over-estimating the market value of spectrum. In addition, the key market characteristics, such as lower urbanisation level and higher demand for 2G services, suggest that the market valuation in Greece could be higher than the value of spectrum in the UK. This is particularly true in the 900 MHz band, where the absence of 800 MHz and uncertainty about its future availability means 900 MHz spectrum could be expected to be valued more highly.

- **Spain:** the Spanish market is characterised by higher margins than in the UK, which implies that the absolute market valuation in Spain could be

2013 cleared at reserve prices. Finally, there was speculation that the new entrant bidder in the first auction was bidding strategically to weaken the largest of the three incumbent mobile operators. This new entrant bidder did eventually acquire the largest incumbent mobile operator during the auction process. For these reasons, we do not consider this auction in our analysis as it is expected to provide limited information about the market value of spectrum in the UK.

expected to overestimate the value of spectrum in the UK. On balance, however, we conclude that the overall effect of various market factors on absolute valuations of spectrum in Spain is unclear. At the same time, while difference in profitability and other factors could be expected to impact the absolute valuation of spectrum, it is unlikely to have a significant impact on the relative valuation of sub-1GHz spectrum. Therefore, we consider the relative value of 900 MHz in relation 800 MHz in Spain to be a reliable benchmark for the corresponding relative value in the UK.

- **Romania:** the significant differences in market characteristics between the UK and Romania make any comparison of absolute values very challenging. The available evidence also suggests that the market characteristics, in particular the much higher share of connections accounted for by 2G in Romania and the lack of demand for 4G spectrum in the auction, suggest the results of the auction in Romania are not an appropriate benchmark for the relative market value of 900 MHz and 800 MHz in the UK. The relative price of 900 MHz v 800 MHz spectrum in Romania implies a valuation of 900 MHz spectrum above 800 MHz spectrum, which is inconsistent with what Ofcom considers a plausible upper bound of market value in the UK.

- **Portugal:** Higher profitability, lower urbanisation and higher 2G penetration, suggest that Portuguese operators may value 900 MHz spectrum more than in the UK. At the same time, the restrictions on spectrum use imposed on the incumbent operators would likely imply a relatively lower valuation than in the UK. Since all spectrum sold at the reserve price, absolute valuations are unlikely to be reflective of true market value in Portugal. On balance, we consider that, based on a detailed review of the evidence available, it is unclear to what extent 900 MHz prices paid in Portugal reflects the market value in the UK.

- **Italy:** At the time of the auction, average margin per user in Italy were significantly higher than in the UK. Other things being equal, this would suggest operators might be willing to pay more for 1800 MHz spectrum in Italy than in the UK. With regards to relative 1800/800 valuations, these are likely to overestimate the value of spectrum in the UK, mainly due to a combination of the price paid for 1800 MHz spectrum likely exceeding market value in Italy, as spectrum sold at the reserve price, and restrictive coverage obligations in the 800 MHz band, which likely pushed down the prices paid for 800 MHz spectrum.

Below, we summarise the assessment for each individual country. A more detailed evaluation of each benchmark auction is then provided in an Annexe[52].

52 Frontier Economics: Annexe 2 to Critique of Ofcom's International Benchmarking Analysis: Case Studies, January 2014 (hereinafter 'Annexe 2')

4.2.1 Greece

The multi-band SMRA auction in Greece took place in November 2011, with three existing operators taking part in the auction. All spectrum sold at reserve price, including 2x7.5MHz of 900 MHz pre-allocated to each operator, in order to not disrupt existing services, see **Table 6** below.

Table 6. Outcomes of the November 2011 auction in Greece[53]

Bidder	900 MHz	1800 MHz	Price (EUR)
Cosmote	2 x 10 MHz	2 x 10 MHz	119m
Vodafone	2 x 15 MHz	2 x 10 MHz	169m
Wind Hellas	2 x 10 MHz	None	93m
Unsold spectrum	None	None	

Note: 2x7.5MHz was pre-allocated to each operator and cost them a total EUR182m – this is included in the allocations of 900 MHz spectrum above, but not in the total price paid

Source: Ofcom

Ofcom treats the outcomes of the Greek auction as 'more important' evidence. They also state that the fact spectrum sold at reserve price means prices paid in the auction likely underestimate true market valuations.

As indicated above, reserve prices in the absence of excess demand are likely to **overestimate market value** in Greece. In addition, the market characteristics suggest the market valuation in Greece, could potentially **overestimates the value of spectrum in the UK**. This is particularly true in the 900 MHz band, as the absence of 800 MHz in Greece means 900 MHz spectrum could be expected to be valued more highly. We explain this below.

Table 7 summarises our views on the overall quality of different types of benchmarks based on the Greek auction.

53 For the purposes of our analysis and easier comparison, we present only outcomes related to FDD spectrum in this report, although we recognise these was TDD spectrum sold in some auctions in our benchmarking sample.

Table 7. The quality of benchmark – Greece

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MH)	900 MHz	31.4m	Likely overestimating	Potentially overestimating
	1800 MHz	13.9m	Likely overestimating	Unclear

Source: Frontier Economics

Do auction outcomes reflect market value?

In the Greek auction there were no restrictive spectrum caps and all spectrum sold at the reserve price. This is consistent with our earlier analysis, indicating that the prices paid likely overestimate the market value of 900 MHz and 1800 MHz spectrum in Greece.

Are these outcomes reflective of market value in the UK?

As discussed in more detail in Annexe 2, there are number of differences between Greece and the UK. These differences indicate that prices paid in the Greek auction, even if reflective of market value, would likely overestimate the market value of 900 MHz spectrum in the UK.

Greece's profit margins were [✂] higher than in the UK prior to the auction, which indicates, all other things equal, that the value of spectrum in Greece auction prices would be likely to overestimate market value in the UK. 2G penetration in Greece was [✂], significantly higher than the UK pre-auction value of [✂]. Also in 2011 an average mobile user in Greece consumed [✂] more voice minutes per month compared to his UK counterpart. This implies that market values of 900 MHz and 1800 MHz spectrum in Greece would be likely to overestimate the UK value (all else the same). Furthermore Greece has relatively low levels of urbanisation 61% (compared to the UK value of 80%), and has a large number of islands, potentially increasing the worth of low frequency spectrum. Therefore, all else equal, 900 MHz spectrum could be valued more highly in Greece than in the UK.

In addition, in Greece 800 MHz spectrum has not yet been freed up for use by mobile sector, so the only sub 1GHz spectrum available is 900 MHz spectrum. Due to its good propagation and coverage, sub-1GHz spectrum is generally seen as more valuable than higher frequency spectrum. Therefore, this could further lead to the value of 900 MHz spectrum in Greece overestimating the UK's.

Appropriate framework for an international benchmarking analysis

Therefore, we consider that prices paid for 900 MHz spectrum in Greece are likely to overestimate the market value in the UK.

At the same time, we consider that the effect of these factors on the absolute valuation of 1800 MHz spectrum is less clear. In particular, we find that the impact of the lack of availability of 800MHz and 2.6GHz spectrum on the level of demand for 1800MHz spectrum is unclear. On balance, we therefore conclude that it is unclear whether the market value of this spectrum in Greece is reflective of market value in the UK, although higher profitability and 2G demand imply 1800 MHz might be more valuable in Greece than in the UK, all else equal.

4.2.2 Spain (July/November 2011)

The July auction was a multiband SMRA auction, in which three operators participated.[54] 2x5MHz of 900 MHz spectrum went unsold, due to spectrum caps. This spectrum was then re-auctioned in November, with spectrum caps lifted.

Table 8. Outcomes of the July/November 2011 auctions in Spain

Bidder	800 MHz	900 MHz	2600 MHz	Price (EUR)
Movistar	2 x 10 MHz	2 x 10 MHz	2 x 20 MHz	668m
Vodafone	2 x 10 MHz	None	2 x 20 MHz	518m
Orange	2 x 10 MHz	None	2 x 20 MHz	437m
Regional Wholesalers	None	None	2 x 10 MHz	-
Unsold spectrum	None	None	None at national level	-

Source: Ofcom

Ofcom treats both absolute and relative outcomes of the Spanish auction as 'more important evidence'. They also state that the fact spectrum sold at reserve price means prices paid in the auction underestimate true market valuations.

As already mentioned, our analysis of auctions that cleared at a reserve price suggests that the absolute auction outcomes in Spain likely **overestimate the market value of 900 MHz spectrum**. In addition, the Spanish market is characterised by higher margins than in the UK, which implies that the absolute

[54] Yoigo, the fourth MNO in the market did not participate in the auction.

market valuation in Spain could be further overestimating the value of spectrum in the UK. There are, however, other factors in which Spanish and the UK market differs significantly, such as the level of demand for 2G services and mobile data services (see Annexe 2), and the overall effect of these factors on absolute valuations of spectrum in Spain is unclear.

In terms of the estimated value of 900 MHz spectrum in the UK based on the **relative value between** 800 MHz and 900 MHz **in Spain, this also over-estimates the likely market value in the UK.** This is because 900 MHz spectrum was sold at the reserve price in Spain, thus likely overestimating the market value of 900 MHz spectrum, whereas 800 MHz spectrum sold above the reserve price. **Table 9** summarises the assessment of the reliability of benchmarks based on the Spanish auction.

Table 9. The quality of benchmark – Spain

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	24.9m	Likely overestimating	Unclear
Relative value (%)	900 MHz	81%	Likely overestimating	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

In the 900 MHz band, the November auction is the best auction to use for estimating the market value of 900 MHz spectrum in Spain.

This is because in the July auction, sub-1GHz spectrum caps meant that, provided the three participants wanted 2x10 MHz of 800 MHz spectrum, only Movistar could obtain 2x5MHz spectrum in the 900 MHz band.

In November with spectrum caps lifted, operators were free to bid for the remaining 2x5MHz of 900 MHz spectrum. The fact that Movistar obtained the spectrum at reserve price indicates that other operators valued the spectrum at below reserve price. Therefore the auction outcome overestimates the market value of 900 MHz spectrum in Spain.

In the 800 MHz band, the July auction was competitive despite there only being three participants. This is because (i) the sub-1GHz spectrum was not binding for Orange and (ii) one of the 800 MHz blocks is subject to interference;

therefore the three participants were competing for the other five blocks of spectrum, pushing up prices above the reserve price. The prices paid for 800 MHz spectrum can be seen as reflective of market value.

Therefore the results of the Spanish auction of 900 MHz spectrum are likely to be significantly affected by the reserve prices. The price paid can be seen as overestimating the value of 900 MHz spectrum in Spain.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, there are differences in the key market indicators between Spain and the UK. The key discrepancy is that Spain did have [✂] higher pre-auction margins than the UK. This could indicate that spectrum is potentially more valuable in Spain. At the same time, 2G penetration level in Spain prior to the auction was relatively low at [✂] (but still higher than the UK at [✂]) while, voice usage per customer was [✂] lower than in the UK (based on 2011 data). The overall impact on spectrum valuation is therefore less clear. Pre-auction urbanisation levels were similar in both countries, while there is some indication that there might be less demand for mobile services in Spain, which would likely have negative impact on the spectrum valuation. Overall, we conclude that the effect of these market characteristics on absolute valuations of spectrum in Spain is unclear.

At the same time, while differences in profitability (and other factors) could impact the absolute valuation of spectrum across bands, it is unlikely to have a large impact on relative valuation of sub-1GHz spectrum. Therefore, we consider the relative value of 900 MHz in relation 800 MHz in Spain, absent the distortion of auction outcomes by high reserve prices, would be a potentially good indicator of the relative market value of spectrum in the UK.

4.2.3 Romania

The multi-band auction in Romania took place in September 2012, with four existing operators taking part in the auction. The outcomes of the auction are described in **Table 10** below.

Table 10. Outcomes of the September 2012 auction in Romania

Bidder	800 MHz	900 MHz	1800 MHz	2600 MHz	Price (EUR)
Cosmote RMT	2 x 5 MHz	2 x 10 MHz	2 x 25 MHz	2 x 10 MHz	180m
Orange	2 x 10 MHz	2 x 10 MHz	2 x 20 MHz	2 x 20 MHz	227m
RCS & RDS	None	2 x 5 MHz	None	None	40m
Vodafone	2 x 10 MHz	2 x 10 MHz	2 x 30 MHz	None	229m
Unsold spectrum	2 x 5 MHz	None	None	2 x 40 MHz	-

Source: Ofcom

The nature of CCA auctions means it is not generally possible to directly observe band specific outcomes. However the total proceedings from the auction were only fractionally higher than the combined reserved price from all the lots, therefore the reserve price can be taken as a reasonable proxy of the price paid for specific bands. We note that the 900 MHz reserve price was set above the 800 MHz reserve price – indicating that the Romanian authorities considered 800 MHz spectrum to be less valuable than 900 MHz spectrum in Romania.

Ofcom treats both absolute and relative outcomes of the Romanian auction as 'more important evidence'. This seems inconsistent with Ofcom's position that it is reasonable to expect the market value of 800 MHz spectrum to be the upper bound for the value of 900 MHz spectrum in the UK. Our more detailed analysis actually finds that the results in Romania need to be treated with caution, as they are likely to be significantly distorted by country specific factors. On balance, we consider that the results of the Romanian auction provide limited information about the true market value of spectrum in the UK.

With regards to absolute values of 900 MHz and 1800 MHz, these are likely to overestimate the market value in Romania, as the auction cleared at

(near) reserve price. At the same time, the significant differences in market characteristics between the UK and Romania make any comparison of absolute values extremely challenging. With regards to **relative values of 900 MHz and 1800 MHz, it is not clear to what extent these are revealing true market value in Romania, given the auction cleared at reserve prices**

Table 11 summarises our views on the overall quality of different types of benchmarks based on the Romanian auction.

Table 11. The quality of benchmark – Romania

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	24.9m	Likely overestimating	Not comparable
	1800 MHz	6.2m	Likely overestimating	Not comparable
Relative value (%)	900 MHz	114%	Unclear	Not comparable
	1800 MHz	28%	Unclear	Not comparable

Source: Frontier Economics

Do auction outcomes reflect market value?

In Romania both 900 MHz and 1800 MHz spectrum was sold, as well as spectrum from the 800 MHz and 2600 MHz bands, which are used for determining relative values. Below, we consider each band individually to see whether auction outcomes reflect market value.

- **900 MHz:** Spectrum sold at reserve price indicating that prices paid are likely to overestimate the value of spectrum in Romania.
- **1800 MHz:** Spectrum sold at reserve price indicating that prices paid are likely to overestimate the value of spectrum in Romania.

Therefore priced paid in the auction are going to overestimate the market valuation of spectrum in Romania.

- **800 MHz:** 2x5MHz went unsold indicating the reserve price was set above the market clearing price. Therefore the prices paid likely overestimate the market valuation of spectrum.

With regards to relative values of 900 MHz and 1800 MHz, it is not clear to what extent these are revealing true market value in Romania, as the auction cleared at reserve prices. The effect of reserve prices on relative valuations in Romania is unclear.

Are these outcomes reflective of market value in the UK?

As well as reserve prices distorting auction outcomes across all bands, there are also large differences in market characteristics between Romania and the UK, making any comparison derived from absolute prices paid challenging.

Romania's pre-auction 2G penetration rate of [✂] is significantly higher than the UK's value of [✂], implying market values for 900 MHz and 1800 MHz in Romania are likely to overestimate market value in the UK. In addition, Romania was only 53% urbanised prior to the auction, indicating prices paid for sub-1 GHz spectrum are likely to overestimate market value in the UK.

The fact that pre-auction AMPU [✂] was so low in Romania, coupled with significantly lower smartphone [✂] and mobile broadband penetration [✂] rates (based on latest available data from 2010) suggest that providing a 4G/LTE network in Romania might not be a particularly attractive investment. So although low AMPU indicates, all else being equal, spectrum is less valuable than in the UK, it also helps explain why 900 MHz sold for more than 800 MHz spectrum.

On balance, the results of the Romanian auction provide only limited information about the true market value of spectrum in the UK. In order to make any sensible comparison with the UK, Ofcom would need to develop projections of key market characteristics to a point in future, when the relative significance of 2G services in Romania could be considered similar to the UK. This would be a demanding and highly uncertain exercise, and absent such analysis, we consider that the auction outcomes in Romania are of very limited use in informing the market value in the UK.

Appropriate framework for an international benchmarking analysis

4.2.4 Portugal

The multi-band SMRA auction in Portugal took place in November 2012, with three existing operators taking part in the auction. All sold spectrum went at reserve prices, although there was unsold spectrum in the 900 MHz, 1800 MHz and 2600 MHz bands, see **Table 12** below.

Table 12. Outcomes of the November 2011 auction in Portugal

Bidder	800 MHz	900 MHz	1800 MHz	2600 MHz	Price Paid (EUR)
Vodafone	2 x 10 MHz	2 x 5 MHz	2 x 14 MHz	2 x 20 MHz	146m
TMN	2 x 10 MHz	None	2 x 14 MHz	2 x 20 MHz	113m
Optimus	2 x 10 MHz	None	2 x 14 MHz	2 x 20 MHz	113m
Unsold spectrum	None	2 x 5 MHz	2 x 15 MHz	2 x 10 MHz	-

Source: Ofcom

Ofcom considers Portugal to be less important evidence for absolute and relative value of 900 MHz and 1800 MHz.

Our analysis suggests that auction outcomes in 900 MHz and 1800 MHz bands, are likely to **overestimate the market value in Portugal, as the auction cleared at reserve prices.**

Higher profitability and lower urbanisation suggest that Portuguese operators may value spectrum more than in the UK. At the same time, restrictions on spectrum use imposed on the incumbent operators likely imply a lower valuation than in the UK. On balance, we consider that it is **unclear to what extent the absolute prices paid for 900 MHz and 1800 MHz spectrum reflect the market value in the UK**.

With regards to the implied value of 900 MHz based on the **relative value** of 900 MHz to 800 MHz, this **may be overestimating the true value of 900 MHz spectrum in the UK**, even after we control for differences in market characteristics by using relative valuations. This is because operators chose the significantly more expensive 800 MHz over 900 MHz in the Portuguese auction, which could potentially imply lower relative value of 900 MHz.

Table 13 summarises our views on the overall quality of different types of benchmarks based on the Portuguese auction.

Table 13. The quality of benchmark – Portugal

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	24.1m	Likely overestimating	Unclear
	1800 MHz	3.1m	Likely overestimating	Unclear
Relative value (%)[55]	900 MHz	67%	Potentially overestimating[56]	Potentially a good indicator
	1800 MHz	9%	Unclear	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

In Portugal both 900 MHz and 1800 MHz spectrum was sold together with spectrum from the 800 MHz and 2600 MHz bands. All sold spectrum went at reserve prices, although there was unsold spectrum in the 900 MHz, 1800 MHz and 2600 MHz bands. This suggests that absolute prices paid in the auction are likely to **overestimate the value of 900 MHz and 1800 MHz spectrum** in Portugal.

With regards to relative values of 900 MHz and 1800 MHz spectrum, it is not clear to what extent these are revealing the relativities of true market value in Portugal, as the auction cleared at reserve prices and these are likely overstating true (absolute) market value. At the same time, there is evidence suggesting that the relative price of 900 MHz **potentially overestimates the market value of**

55 We explicitly consider only relative valuations based on 800 MHz spectrum. The 2600 MHz spectrum is likely to be less reliable benchmark here, given the large amount of unsold spectrum in the auction.

56 The relative value of 900 MHz to 800 MHz can be seen as overestimating the true value of 900 MHz, as operators chose the significantly more expensive 800 MHz over 900 MHz in the Portuguese auction, which would imply lower relative value of 900 MHz.

Appropriate framework for an international benchmarking analysis

900 MHz spectrum in Portugal. All participants had a deferred sub-1GHz spectrum cap of 2x20 MHz, with existing holdings of 2x8MHz in the 900 MHz band. Therefore they could choose if they wanted to obtain 800 MHz or 900 MHz to reach their cap. TMN and Optimus chose 2x10 MHz of 800 MHz spectrum over obtaining 900 MHz spectrum. Although not directly comparable, as they had existing holdings of 900 MHz spectrum, it does show that they prioritised 800 MHz spectrum when they could have got 900 MHz spectrum for 67% of the price. This would therefore suggest that the relative price of 900 MHz likely overestimates the market value of 900 MHz spectrum in Portugal.

Are these outcomes reflective of market value in the UK?

Market characteristics suggest that 900 MHz and 1800 MHz spectrum in Portugal is likely to be more valuable than in the UK. Portugal's pre-auction AMPU was [✂] higher than in the UK. 2G penetration was [✂] prior the auction, compared to the UK level of [✂]. Also urbanisation levels were 19 percentage points (p.p.) below the UK. This suggests operators may have been willing to pay potentially more for 900 MHz and 1800 MHz frequencies in the auction than UK operators would be.

On the other hand, there is the caveat that spectrum caps meant no operator, provided that they obtained 2 x 10 MHz of 800 MHz spectrum, could obtain 900 MHz spectrum for their whole licence term. Vodafone bought a 2 x 5 MHz block but will have to return 2 x 3 MHz worth of spectrum in June 2015. This would likely imply that the valuation of spectrum might be higher in the UK, assuming there are no similar restrictions on spectrum use.

With respect to relative valuations of 900/800 MHz and 1800/800 MHz, we consider that these might be a better indicator of the market value of 900 MHz and 1800 MHz spectrum in the UK as they control for the differences in value drivers that have similar impact across different bands, such as differences in market profitability. Nevertheless, as reserve prices in Portugal are overestimating market values across all bands, this could also be expected to affect the accuracy of the relative valuations. In the absence of these distortions, relative valuations in Portugal would be a potentially good indicator of the market value of 900 MHz and 1800 MHz spectrum in the UK.

4.2.5 Italy

The multi-band auction in Italy took place in September 2011, with four existing operators taking part in the auction. The outcomes of the auction are described in table below.

Table 14. Outcomes of the September 2011 auction in Italy

Bidder	800 MHz	1800 MHz	2600 MHz	Price (EUR)
Telecom Italia	2 x 10 MHz	2 x 5 MHz	2 x 15 MHz	1300m
Vodafone	2 x 10 MHz	2 x 5 MHz	2 x 15 MHz	1300m
Wind	2 x 10 MHz	None	2 x 20 MHz	1100m
3	None	2 x 5 MHz	2 x 10 MHz	305m
Unsold spectrum	None	None	None	-

Source: Ofcom

Ofcom treats both absolute and relative values of 1800 MHz as more important evidence. Our results suggest that results of 1800 MHz auction **potentially overestimate the true market value of spectrum in the UK**. The spectrum sold only slightly above the reserve price, but we understand from Vodafone that there was no real competition for 1800 MHz in the auction and that this outcome was a result of the auction design. Therefore, this suggests that these results could overestimate the true market value of spectrum in Italy.

With regards to relative value of 1800 MHz spectrum based on 1800/800 ratio, our analysis suggests that these are **potentially overestimating the market value of 1800 MHz in the UK.** This is because 1800 MHz spectrum was effectively sold at the reserve price, thus overestimating the market value of 1800 MHz spectrum, whereas 800 MHz spectrum sold above the reserve price. In addition, coverage obligations in 800 MHz band would likely push down the prices paid for 800 MHz spectrum, further inflating 1800/800 ratio and the relative value of 1800 MHz spectrum.

Table 15 summarises the overall quality of different types of benchmarks based on the Italian auction.

Table 15. The quality of benchmark – Italy

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	1800 MHz	15.5m	Potentially overestimating	Likely overestimating
Relative value (%)	1800 MHz	32%	Potentially overestimating	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

In the Italian auction the 1800 MHz spectrum sold only slightly above the reserve price. However, we understand from Vodafone that there was no real competition for 1800 MHz in the auction and that this outcome was a result of the auction design.

[✂]

Therefore, we consider the 1800 MHz spectrum was effectively sold at reserve price and, consistent with our earlier analysis, this is indicating that the absolute prices paid overestimate the market value of 1800 MHz spectrum in Italy.

With regards to the relative value of 1800 MHz in Italy, this potentially overestimates the value of spectrum in the UK. This is because 1800 MHz spectrum was sold at the reserve price, overestimating the true market value of spectrum, whereas 800 MHz spectrum sold above the reserve price. In addition,

in the 800 MHz bands there was a land coverage obligations, which is going to push down the prices paid in the auction.

Are these outcomes reflective of market value in the UK?

Whilst there is some comparability between Italy and the UK, there are also differences that can be expected to have an effect on the extent to which the Italian auction outcomes are reliable indicators of spectrum value in the UK.

At the time of the auction, average margin per user (AMPU) in Italy was [✂] higher than in the UK. 2G penetration was [✂]. higher than the level in the UK, although levels of voice usage per customer are comparable. Other things being equal, this would suggest operators might be willing to pay more for 1800 MHz spectrum.

These factors suggest that 1800 MHz spectrum might be more valuable in Italy than the UK, and the absolute outcomes in Italy, are likely overestimating the value of this spectrum in the UK. In combination with the overestimated absolute value of 1800 MHz, this would likely lead to further overestimating market value in the UK.

With regards to relative valuation of 1800 MHz to 800 MHz in Italy, this is likely to better control for the differences in the market characteristics and, in the absence of price distortions described above, could be considered potentially a good indicator of the UK market value.

Appropriate framework for an international benchmarking analysis

4.3 Auctions where country specific factors are making absolute results less comparable with the UK

Below, we summarise the assessment for each individual country. More detailed evaluation of each benchmark auction is then provided in Annexe 2.

In this section, we focus on countries where country specific factors are making auction outcomes less reflective of the market value of spectrum in the UK: Ireland and Sweden.

Ofcom treats outcomes of the auctions as more important evidence. Nevertheless, Ofcom does not consider the impact of country specific factors on the value of 900 MHz and 1800 MHz spectrum in these countries.

- **Ireland:** the absolute results are likely to overestimate the true market value of spectrum in the UK. In particular, higher margins and greater 2G usage imply that operators could be expected to be willing to pay more for 900 and 1800 MHz spectrum in Ireland than in the UK, whilst lower urbanisation indicates that sub-1 GHz spectrum will be valued higher. The relative value of spectrum in Ireland is likely to be a better indicator of spectrum value in the UK, but it could still overestimate the value of 900 MHz spectrum in the UK, due to higher demand for 2G spectrum in Ireland.

- **Sweden:** the significant differences between key market indicators imply that it is unclear how reflective the absolute outcomes of the market value of spectrum in the UK. At the same time, the relative value of 1800 MHz, as calculated by Ofcom, is likely to overestimate the true market value of spectrum in Sweden.

Below, we summarise the assessment for both countries. A more detailed evaluation of each benchmark auction is then provided in Annexe 2.

4.3.1 Ireland

The multi-band CCA auction in Ireland took place in November 2012, with four existing operators taking part in the auction. The outcomes of the auction are described in **Table 16** below.

Table 16. Outcomes of the November 2012 auction in Ireland

Bidder	800 MHz	900 MHz	1800 MHz	Price (EUR)
H3G	None	2 x 5 MHz	2 x 20 MHz	51m
Meteor	2 x 10 MHz	2 x 10 MHz	2 x 15 MHz	145m
Telefónica	2 x 10 MHz	2 x 10 MHz	2 x 15 MHz	161m
Vodafone	2 x 10 MHz	2 x 10 MHz	2 x 25 MHz	125m
Unsold spectrum	None	None	None	

Source: Ofcom

The nature of a CCA auction means it is not possible to directly observe band-specific prices. However, Ofcom provides an estimate of prices that was derived from Vodafone's decomposition of prices in clock rounds where supply matched demand. These results suggest that the implied prices were above the reserve prices across all bands.

Ofcom treats both absolute and relative outcomes of the Irish auction as more important evidence.

Our results suggest that while results of the auction seem to reflect market value in Ireland, the absolute results are likely to **overestimate the true market value of spectrum in the UK**. In particular, higher margins and greater 2G usage imply that operators might be willing to pay more for 900/1800 MHz spectrum in Ireland than in the UK whilst lower urbanisation indicates that sub-1 GHz spectrum will be valued higher.

At the same time, **the relative value of spectrum in Ireland is potentially a good indicator of spectrum value in the UK,** although it could overestimate it, for reasons we explain below.

Table 17 summarises the assessment of different types of benchmarks based on the Irish auction.

Table 17. The quality of benchmark – Ireland

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	35.7m	Good indicator	Likely overestimating
	1800 MHz	23.1m	Good indicator	Likely overestimating
Relative value (%)	900 MHz	61%	Good indicator	Potentially a good indicator
	1800 MHz	39%	Good indicator	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

As all spectrum was sold above reserve price, this would seem to indicate a competitive auction with prices paid reflecting market value in Ireland.

Are these outcomes reflective of market value in the UK?

Whilst there is some comparability between Ireland and the UK, there are also significant differences that can be expected to have an effect on the extent to which the Irish auction outcomes are reliable indicators of spectrum value in the UK.

In particular, AMPU in Ireland is [✂] higher in the UK, (based on latest available data from 2011) indicating that prices for all blocks would likely overestimate market value in the UK. In addition, pre-auction 2G penetration was [✂] higher in Ireland than in the UK and voice usage per subscriber was [✂] higher, implying prices paid for 900 MHz and 1800 MHz spectrum might overestimate the market value in the UK On balance, there is evidence to suggest that the outcomes from the Irish auction may overestimate the true market value of spectrum in the UK, when looking at absolute values of 900 MHz and 1800 MHz.

On the other hand, *relative* values are a more appropriate benchmark to use as they control for some country specific factors. Although the Irish market appears to be more profitable than the UK market this could be expected to affect proportionately the valuation of 800 MHz and 900 MHz spectrum. Demand for

2G spectrum is likely to be higher in Ireland, which, all else the same, would imply that the ratio of the market value of 900 MHz to 800 MHz in Ireland may be *higher* than the corresponding ratio in the UK. On balance, while we consider the relative values in Ireland to likely be an informative indicator of relative value in the UK, they could still lead to an over-estimation of the value of 900 MHz spectrum in the UK. A similar conclusion holds in relation to 1800 MHz spectrum.[57]

[57] Although we recognise that the link between 2G demand and 1800 MHz spectrum value might be weaker due to the wider use of 4G services in this band, compared to 900 MHz.

Appropriate framework for an international benchmarking analysis

4.3.2 Sweden

Two single band auctions in Sweden took place in March 2011 and October 2011, with four existing operators (two in a joint venture) taking part in the auction. In both auctions, spectrum sold above the reserve price. The outcomes of the auction are described in **Table 18** below.

Table 18. Outcomes of the March/October 2011 auctions in Sweden

Bidder	800 MHz	1800 MHz	Price (SEK)
Teliasonera	2 x 10 MHz	2 x 25 MHz	1774m
Net4Mobility	2 x 10 MHz	2 x 10 MHz	899m
Hi3G	2 x 10 MHz	None	431m
Unsold spectrum	None	None	-

Source: Ofcom

Ofcom treats both absolute and relative values of 1800 MHz as more important evidence. Ofcom states that the Net4Mobility joint venture reduces competition in the market so the absolute price of 1800 MHz spectrum underestimates market value. Ofcom believes the effect of joint venture coupled with spectrum caps makes the 800 MHz auction even less competitive so relative values overestimate the value of 1800 MHz spectrum.

Our findings suggest that the absolute values of 1800 MHz from the Swedish auction can be taken as good indicators of market value in Sweden, but the significant differences between key market indicators implies that it is **unclear how reflective the absolute outcomes of the market value of spectrum in the UK**.

At the same time, the **relative value of 1800 MHz, as calculated by Ofcom, is likely to overestimate the true market value of spectrum** in Sweden, although relative valuation is likely to be a better indicator for the market value in the UK.

Table 19 summarises our views on the overall quality of different types of benchmarks based on the Swedish auctions.

Table 19. The quality of benchmark – Sweden

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	1800 MHz	9.1m	Potentially a good indicator	Unclear
Relative value (%)	1800 MHz	64%	Overestimating	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

As all spectrum sold above reserve price, this would seem to indicate competitive auctions with prices paid reflecting market value.

Ofcom argue that the Net4Mobility joint venture reduces competition in the market therefore prices paid underestimate the true market value. However in the 1800 MHz auction, Hi3G participated but did not win any spectrum. Although the joint venture reduced the number of participants from 4 to 3 it can still be seen as a competitive auction due to Teliasonera wanting and being able to obtain a large amount of 1800 MHz spectrum.

The 800 MHz blocks were highly heterogeneous, which is reflected in the prices. Of the six 2x5MHz blocks on offer, two blocks were subject to DTT interference and one had an extensive rollout/coverage obligation.

In its calculation of relative value of 1800 MHz (in relation to 800 MHz), Ofcom seems to use an average across all six blocks of 800 MHz spectrum. However this ignores the fact that the lowest frequency block is subject to interference from television broadcasting and the highest frequency block has a large rollout obligation. This leads to lower value of 800 MHz than what a comparable value without the coverage obligation would be, thus likely overestimating the relative value of 1800 MHz spectrum.[58]

[58] The appropriate comparator when deriving the implied 1800 MHz in the UK, should be derived based on the average value across the five blocks without the coverage obligation. As our estimated value of UK 800 MHz already includes co-existence costs, it would not be appropriate to exclude these from the calculation of the average 800 MHz price in Sweden.

Appropriate framework for an international benchmarking analysis

Are these outcomes reflective of market value in the UK?

Whilst there is some comparability between Sweden and the UK, there are also significant differences that can be expected to have an effect on the extent to which Swedish auction outcomes are reliable indicators of spectrum value in the UK.

Pre-auction AMPU was [✂] higher in Sweden than in the UK whilst 2G penetration was significantly lower in Sweden at [✂], compared to [✂] in the UK. Therefore it is not immediately obvious how auction outcomes in Sweden correspond to market value in the UK. In addition, mobile broadband ([✂], based on 2010 data) and smartphone penetration ([✂]) were significantly higher in Sweden. This indicates that take-up of 4G services could potentially be strong in Sweden, although the fact that average revenues are [✂] lower indicates that willingness to pay may less than in the UK.

Given these significant differences, we conclude that, on balance it is unclear to what extent the absolute auction outcomes in Sweden are likely to be reflective of market value in the UK. At the same time, we recognise that these differences are likely to less relevant when looking at the relative valuation, so the relative value of 1800 MHz is likely to be a good benchmark for the market value in the UK.

4.4 Auctions where the design of the auction makes results less comparable with the UK

In this section, we focus on countries where auction outcomes are less comparable with the UK due to specifics of the auction design used in the individual benchmarking countries: Spain (May 2011), Denmark, Germany, Austria (2013), Netherlands, Switzerland and Norway (2013).

Ofcom treats outcomes of the auctions in Spain, Denmark, Germany, Netherlands and Switzerland as less important evidence. The outcomes of the auctions in Austria and Norway were not available at the time when Ofcom published its consultation document.

- **Spain:** the auction in had a beauty contest format and only two existing operators were allowed to participate. The main financial outlay from winning the spectrum was an investment program, which makes the prices paid less comparable with the licence fees derived in competitive spectrum auctions.

- **Denmark and Germany:** there seems to be some indication that the competition for spectrum have been restricted in the auction, which led to low resulting prices which are below what Ofcom considers a plausible lower band for the value of spectrum value in the UK.

- **Netherlands, Switzerland, Austria and Norway:** the nature of combinatorial auction implies that it is not possible to directly observe band-specific prices from these auctions. In addition, spectrum caps in Austria and Netherlands implied post-auction market structures that make these outcomes less comparable with the UK. Similarly, the first-price nature of the auction in Norway led to auction outcomes that are unlikely to reflect the market value in the UK, even if it was possible to reliably decompose the band-specific prices.[59]

Below, we summarise the assessment for each individual country. A more detailed evaluation of each benchmark auction is then provided in Annexe 2.

[59] Please note that we derive an approximate average price per MHz in these four auctions using a simple decomposition for the purposes of a sensitivity analysis presented in Section 5 below.

4.4.1 Spain (May 2011)

The multi-band auction in Spain took place in May 2011, with a beauty contest format. Only two existing operators took part in the auction as operators with existing holdings in a particular band were not allowed to bid. Orange obtained 2x5MHz in the 900 MHz band, not only paying for the spectrum licence, but also committing to €433m of investment over the next 3 years. Yoigo, the sole bidder in the 1800 MHz band, obtained 2x15MHz, not only paying for the spectrum licences, but also committing to €300m of Capex.

The outcomes of the auction are described in **Table 20** below.

Table 20. Outcomes of the May 2011 auction in Spain

Bidder	900 MHz	1800 MHz	Price (EUR)
Orange	2 x 5 MHz	None	126m
Yoigo	None	2 x 15 MHz	42m
Unsold spectrum	None	None	-

Source: Ofcom

Ofcom treats absolute values of 900 MHz and 1800 MHz as less important evidence.[60] Our results suggest that results of the auction do not reflect market value in Spain, due to the beauty contest format and restrictions on participation in the auction.

Table 21 summarises our views on the overall quality of different types of benchmarks based on the Spanish auction.

60 Ofcom do not consider relative values as they treat auction outcomes as less important evidence. We find that auction outcomes are not reflective of market value therefore relative valuations are not considered as these too would not be reflective of market value in Spain, let alone the UK.

Table 21. The quality of benchmark – Spain

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	17.2m	Not comparable	Unclear
	1800 MHz	2.9m	Not comparable	Unclear

Frontier Economics

Do auction outcomes reflect market value?

Given that this was a beauty contest, it is unlikely that the auction outcome reflects true market value of spectrum. It appears that two key aims of CMT in hosting this beauty contest were increase competition in the market and ensure large-scale investment in mobile networks. The main financial outlay from winning the spectrum is the investment program, which makes it even less comparable with the licence fees derived in competitive spectrum auctions.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, there are differences in the key market indicators in Spain and in the UK. The key discrepancy is that Spain did have [✂] higher pre-auction margins than the UK. This could indicate that spectrum is potentially more valuable in Spain. At the same time, 2G penetration level in Spain prior to the auction was relatively low at [✂] (but still higher than the UK at [✂]) while, voice usage per customer was [✂] lower than in the UK (based on 2011 data). The overall impact on spectrum valuation is therefore less clear. Pre-auction urbanisation levels were similar in both countries, while there is some indication that there might be less demand for mobile services in Spain, which would likely have negative impact on the spectrum valuation. Overall, we conclude that the effect of these market characteristics on absolute valuations of spectrum in Spain is unclear.

4.4.2 Denmark

The multi-band auction in Denmark took place in September 2010, with one existing operator taking part in the auction. The three largest mobile companies were not allowed to participate in the auction as they had existing spectrum holdings in the 900 MHz and 1800 MHz bands. The outcomes of the auction are described in **Table 22** below.

Table 22. Outcomes of the September 2010 auction in Denmark

Bidder	900 MHz	1800 MHz	Price (DKK)
Hi3G	2 x 5 MHz	2 x 10 MHz	12m
Unsold spectrum	None	None	-

Source: Ofcom

Ofcom treats absolute values of 900 MHz and 1800 MHz as less important evidence.[61] Our results suggest that results of the auction have relatively limited informative value for market value in the UK, due to the auction design. Overall, we consider that if auction outcomes did reveal 'true' market value of spectrum in Denmark, it would potentially overestimate the value of spectrum in the UK, due to higher AMPU and 2G penetration rate.

Table 23 summarises our views on the overall quality of different types of benchmarks based on the Danish auction.

61 Ofcom do not consider relative values as they treat auction outcomes as less important evidence. We find that auction outcomes are not reflective of market value therefore relative valuations are not considered as these too would not be reflective of market value in Denmark, let alone the UK.

Table 23. The quality of benchmark – Denmark

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz) [62]	900 MHz	2.4m	Limited comparability	Potentially overestimating
	1800 MHz	1.0m	Limited comparability	Potentially overestimating

Source: Frontier Economics

Do auction outcomes reflect market value?

There was only one bidder who obtained the spectrum at a nominally low reserve price, as the main purpose of the auction seems to have been to promote competition. Given this, the extent to which the price paid can be interpreted as market value is somewhat unclear.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, the key market indicators suggest that market value in Denmark could be considered to overestimate market value in the UK. The pre-auction AMPU in Denmark was [✂], higher than the pre-auction value of [✂] in the UK**.** This potentially indicates that auction outcomes overestimate market value in the UK In addition, Denmark's 2G penetration rate was [✂], compared to [✂] in the UK, while voice usage levels were [✂] higher in Denmark (based on 2011 UK data). As the 900 MHz and 1800 MHz bands are generally used to deliver 2G services, this implies that auction outcomes in these bands may overestimate market value in the UK.

62 The outcomes of the Danish auction allow for calculating also relative values of 900 MHz and 1800 MHz spectrum. Nevertheless, we consider these to provide only limited information about the true value of spectrum in Denmark, due to absolute prices being distorted by the auction design.

Appropriate framework for an international benchmarking analysis

4.4.3 Germany

The multi-band auction in Germany took place in May 2010, with four existing operators taking part in the auction. The outcomes of the auction are described in **Table 24** below.

Table 24. Outcomes of the May 2010 auction in Germany

Bidder	800 MHz	1800 MHz	2100 MHz	2600 MHz	Price (EUR)
T Mobile	2 x 10 MHz	2 x 15 MHz	None	2 x 20 MHz	1300m
Vodafone	2 x 10 MHz	None	2 x 5 MHz	2 x 20 MHz	1400m
Telefonica	2 x 10 MHz	None	2 x 5 MHz	2 x 20 MHz	1400m
E-Plus	None	2 x 10 MHz	2 x 10 MHz	2 x 10 MHz	284m
Unsold spectrum	None	None	None	None	-

Source: Ofcom

Ofcom considers the auction in Germany as less important evidence. According to Ofcom, there is some evidence of a lack of excess demand for 1800 MHz spectrum and that the resulting price appears implausibly low.[63]

As described in more detail in Annexe 2, the German auction had the SMRA format and 1800 MHz spectrum was sold above the reserve price. Our analysis suggests, however, that the auction in Germany is likely to provide only limited information about the true value of spectrum in the UK.

Table 25 summarises our views on the overall quality of different types of benchmarks based on the German auction.

63 The Consultation, para 4.32

Table 25. The quality of benchmark – Germany

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	1800 MHz	1.8m	Likely a good indicator	Unclear
Relative value (%)	1800 MHz	4%	Likely a good indicator	Unclear

Source: Frontier Economics

Do auction outcomes reflect market value?

All spectrum was sold at above reserve price, which would suggest that there was excess demand in the auction and the resulting prices are likely reflecting the market value in Germany.[64]

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, market indicators suggest that there are differences between market characteristics in Germany and in the UK. The pre-auction AMPU in Germany at [✂] was approximately [✂] higher than the pre-auction value in the UK, implying that spectrum is likely to be more valuable in Germany than in the UK. While Germany's 2G penetration rate was more than double the UK's, the voice usage was [✂] lower than in the UK, with the overall effect on the 2G spectrum valuation unclear.

There seems to be some indication that the competition for 1800 MHz might have been restricted by the specific distribution of the current spectrum holdings.[65] This might have reduced the competition in 1800 MHz band leading to auction outcomes underestimating the market value in the UK. On balance, we conclude that it is unclear if auction outcomes, both in terms of absolute and relative value of 1800 MHz spectrum in Germany, are reflective of market value in the UK.

64 Note that 2100 MHz spectrum was more expensive than 1800 MHz in Germany as that was highly competitive with E-Plus bidding aggressively to try and obtain more 2100 MHz spectrum after failing to obtain 800 MHz spectrum.

65 The Consultation, page 94

Appropriate framework for an international benchmarking analysis

4.4.4 Austria

The multi-band auction in Austria took place in October 2013 with three existing operators taking part in the auction. The outcomes of the auction are described in **Table 26** below.

Table 26. Outcomes of the October 2013 auction in Austria

Bidder	800 MHz	900 MHz	1800 MHz	Price Paid (EUR)
A1 Telekom	2 x 20 MHz	2 x 7.5 MHz	2 x 35 MHz	1030m
T Mobile	2 x 10 MHz	2 x 15 MHz	2 x 20 MHz	654m
3 Austria	None	2 x 5 MHz	2 x 20 MHz	330m
Unsold spectrum	None	None	None	-

Source: https://www.rtr.at/en/tk/multibandauktion_ergebnis

Ofcom does not consider the October 2013 auction in its analysis, as the results of auction were not available at the time Ofcom published its consultation.

We consider the auction outcomes in Austria provide only limited information about market value in the UK. This is because it is not possible to directly observe band-specific prices. Also, spectrum caps in Austria implied very different potential market structure post-auction, which make these outcomes less comparable with the UK.

Table 27 summarises our views on the overall quality of different types of benchmarks based on the Austrian auction.

Table 27. The quality of benchmark – Austria

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	N/A	Potentially a good indicator	Not comparable / Likely overestimating
	1800 MHz	N/A	Potentially a good indicator	Not comparable / Likely overestimating

Source: Frontier Economics

Do auction outcomes reflect market value?

As described in more detail in Annexe 2, the Austrian auction had a CCA format. The nature of a CCA auction means it is not possible to directly observe band-specific prices. However by looking at the overall revenues from the auction it is possible to roughly gauge the absolute prices spectrum was obtained at.[66] It appears that spectrum was sold above reserve price, suggesting the outcomes are likely to reflect the market value of spectrum in Austria, under the specific design of the Austrian auction (see below).

Are these outcomes reflective of market value in the UK?

Pre-auction AMPU in Austria was [✂], higher than the pre-auction value of [✂] in the UK, potentially indicating that auction outcomes overestimate market value in the UK. In addition, 2G penetration was [✂] compared to [✂] in the UK, emphasising the fact that auction outcomes are likely to overestimate market value in the UK.

At the same time, the auction design in Austria implies that the results are likely to provide limited information about the value of spectrum in the UK and if anything, they would likely overestimate the market value of spectrum in the UK.

In particular, the less restrictive spectrum caps meant A1 Telekom bid aggressively in order to take acquire 2x20 MHz of 800 MHz spectrum. The high prices paid in the auction are therefore likely to reflect a strategic value of

66 The format of the auction implies we cannot extract information about relative prices paid across different bands, which is why we do not explicitly discuss relative valuations from combinatorial auctions presented in this report (Austria, Netherlands, Switzerland and Norway).

Appropriate framework for an international benchmarking analysis

preventing competitors to access this spectrum and potentially limiting their ability to compete in the future.

This makes the results of the Austrian auction less useful for estimating market value in the UK, where Ofcom designed the auction in a way to ensure there are four credible wholesale providers arising from the auction. If anything, the outcomes in the Austrian auction are likely to overestimate true market value in the UK.

4.4.5 Netherlands

The multi-band auction in Netherlands took place in October 2012 with three existing operators and two new entrants taking part in the auction. The outcomes of the auction are described in **Table 28** below.

Table 28. Outcomes of the October 2012 auction in Netherlands

Bidder	800 MHz	900 MHz	1800 MHz	2100 MHz	Price Paid (EUR)
T Mobile	None	2 x 15 MHz	2 x 30 MHz	None	911m
Vodafone	2 x 10 MHz	2 x 10 MHz	2 x 20 MHz	2 x 5 MHz	1380m
KPN	2 x 10 MHz	2 x 10 MHz	2 x 20 MHz	2 x 5 MHz	1350m
Tele2	2 x 10 MHz	None	None	None	161m
Unsold spectrum	None	None	None	None	-

Source: Ofcom

Ofcom does not consider Netherlands in its benchmarking analysis, as the nature of a CCA auction means it is not possible to directly observe band-specific prices and Ofcom was not able to reliably estimate these.

We consider the auction outcomes in Netherlands provide only limited information about market value in the UK. This is because it is not possible to directly observe band-specific prices. Also, spectrum caps in Netherlands implied very different market structure post-auction, which make these outcomes less comparable with the UK. If anything, the outcomes of the Dutch auction could overestimate the value in the UK.

Table 29 summarises our views on the overall quality of different types of benchmarks based on the Dutch auction.

Table 29. The quality of benchmark – Netherlands

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	N/A	Potentially a good indicator	Potentially overestimating
	1800 MHz	N/A	Potentially a good indicator	Potentially overestimating

Source: Frontier Economics

Do auction outcomes reflect market value?

As described in more detail in Annexe 2, the Dutch auction had a CCA format. The nature of a CCA auction means it is not possible to directly observe band-specific prices. When considering overall revenues from the auction, it appears that spectrum was sold above reserve price, suggesting the outcomes could reflect the market value in the Netherlands.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, most market indicators suggest that spectrum in Netherlands might be more valuable than in the UK. In particular, pre-auction AMPU was [✂] higher in Netherlands than in the UK. Also 2G penetration was [✂] higher, meaning that prices paid for 900 MHz and 1800 MHz spectrum are likely to overestimate market value in the UK.

The auction design meant that 2x10 MHz of 800 MHz spectrum was reserved for a new entrant. This meant 2x20 MHz of spectrum remained for the three incumbents to compete over, pushing up prices in 800 MHz significantly. This could potentially also drive up prices in other spectrum bands, including 900 MHz and 1800 MHz spectrum.

It is therefore unclear how comparable the auction outcomes in Netherlands would be with the market value of spectrum in the UK. On balance, we consider that spectrum reservation and high market profitability suggest that spectrum value in Netherlands could potentially overestimate the market value in the UK.

4.4.6 Switzerland

The multi-band auction in Switzerland took place in February 2012 with three existing operators taking part in the auction. The outcomes of the auction are described in **Table 30** below.

Table 30. Outcomes of the February 2012 auction in Switzerland

Bidder	800 MHz	900 MHz	1800 MHz	2100 MHz	2600 MHz	Price (EUR)
Orange	2 x 10 MHz	2 x 5 MHz	2 x 25 MHz	2 x 20 MHz	2 x 20 MHz	154.7m
Sunrise	2 x 10 MHz	2 x 15 MHz	2 x 20 MHz	2 x 10 MHz	2 x 25 MHz	481.7m
Swisscom	2 x 10 MHz	2 x 15 MHz	2 x 30 MHz	2 x 30 MHz	2 x 20 MHz	359.8m
Unsold spectrum	None	None	None	None	2 x 5 MHz	-

Source: Ofcom

Ofcom does not consider Switzerland in its benchmarking analysis, as the nature of a CCA auction means it is not possible to directly observe band-specific prices and Ofcom was not able to reliably estimate these. We agree with Ofcom, and consider the auction outcomes in Switzerland provide only limited information about market value in the UK.

Table 31 summarises our views on the overall quality of different types of benchmarks based on the Swiss auction.

Table 31. The quality of benchmark – Switzerland

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	N/A	Potentially a good indicator	Potentially overestimating
	1800 MHz	N/A	Potentially a good indicator	Potentially overestimating

Source: Frontier Economics

Do auction outcomes reflect market value?

As described in more detail in Annexe 2, the Switzerland auction had a CCA format. The nature of a CCA auction means it is not possible to directly observe band-specific prices. As spectrum was however sold above reserve price, this suggests the outcomes likely reflect the market value in Switzerland.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, most market indicators suggest that spectrum in Switzerland might be more valuable than in the UK. In particular, pre-auction AMPU was [✂] higher in Switzerland than in the UK. Pre-auction 2G penetration was [✂] higher in Switzerland, although voice usage was [✂] lower than in the UK (based on 2011 data).

It is therefore unclear how comparable the auction outcomes in Switzerland would be with the market value of spectrum in the UK. On balance, we consider that that the two countries are largely comparable, although significantly higher AMPU in Switzerland suggests that the auction outcomes could potentially overestimate the market value in the UK.

4.4.7 Norway

The multi-band auction in Norway took place in December 2013 with three existing operators and one new entrant taking part in the auction. The outcomes of the auction are described in **Table 32**.

Table 32. Outcomes of the December 2013 Auction in Norway

Bidder	800 MHz	900 MHz	1800 MHz	Price (NOK)
Telco Data	2 x 10 MHz	2 x 5.1 MHz	2 x 20 MHz	1632.5m
TeliaSonera	2 x 10 MHz	2 x 5 MHz	2 x 10 MHz	1289.2m
Telenor	2 x 10 MHz	2 x 5 MHz	2 x 10 MHz	1115.5m
Unsold spectrum	None	None	2 x 15 MHz	-

Note: Price paid include annual spectrum licence usage fees amounting to 927.5m NOK for Telco Data and 662.5m NOK for TeliaSonera and Telenor

Source:
http://eng.npt.no/portal/page/portal/PG_NPT_NO_EN/PAG_NPT_EN_HOME/PAG_NEWS?p_d_i=-121&p_d_c=&p_d_v=142986

Ofcom does not consider the October 2013 auction in its analysis, as the results of auction were not available at the time Ofcom published its consultation.

We believe the auction outcomes in Norway provide only limited information about market value in the UK. This is because it is not possible to directly observe band-specific prices. In addition, the auction was a sealed-bid first-price auction and it is consequently unclear to what extent the prices paid do reflect true market value in Norway. At the same time, we conclude that in terms of key market characteristics the two countries are largely comparable.

Table 33 summarises our views on the overall quality of different types of benchmarks based on the Norwegian auction

Table 33. Quality of benchmark – Norway

	Spectrum	Price	Auction outcomes revealing market value?	Relevance for the UK market value?
Absolute value (GBP/MHz)	900 MHz	N/A	Unclear	Potentially a good indicator
	1800 MHz	N/A	Unclear	Potentially a good indicator

Source: Frontier Economics

Do auction outcomes reflect market value?

As described in more detail in Annexe 2, the Norwegian auction had a first-price combinatorial format. The nature of a combinatorial auction means it is not possible to directly observe band-specific prices.

Crucially, the auction was first-price meaning that it is unclear to what extent the prices paid are likely to reflect market value in Norway.[67] We note that there are considerable differences in prices paid by operators; in spite of the fact all three winners of spectrum obtained similar packages.

Although band-specific prices are not observable, by looking at the overall proceedings of the auction it is possible to roughly gauge the prices spectrum was obtained at, and it appears that spectrum was sold above reserve price.

Are these outcomes reflective of market value in the UK?

As described in more detail in Annexe 2, most market indicators suggest that Norway is potentially a good comparator to the UK. Levels of urbanisation ([✂]) are the same in Norway and the UK. There is some indication that demand for 2G spectrum may be greater in Norway, as pre-auction 2G penetration was [✂] higher than the UK with voice usage [✂] higher (based on 2011 data) suggesting spectrum may be valued higher in Norway. Although AMPU ([✂]) was less than in the UK, indicating that spectrum could in fact be valued lower in Norway. In addition, Norway is similar to the UK across a

67 Ofcom itself recognizes the limitations of the first-price auctions "…*for example use of a first price, "pay-what-you-bid" rule risks an inefficient allocation of spectrum amongst bidders as a result of bidders shading their bids in an attempt to reduce what they will have to pay.",* see Ofcom's consultation from January 2012, para 7.13

Appropriate framework for an international benchmarking analysis

number of other factors, such as mobile broadband penetration, smartphone penetration and ARPU levels.

On balance, we conclude that in terms of market characteristics the two countries are largely comparable, although the fact that Norway's auction was first-price means it is unclear to what extent the auction outcomes would be reflective of market value in the UK.

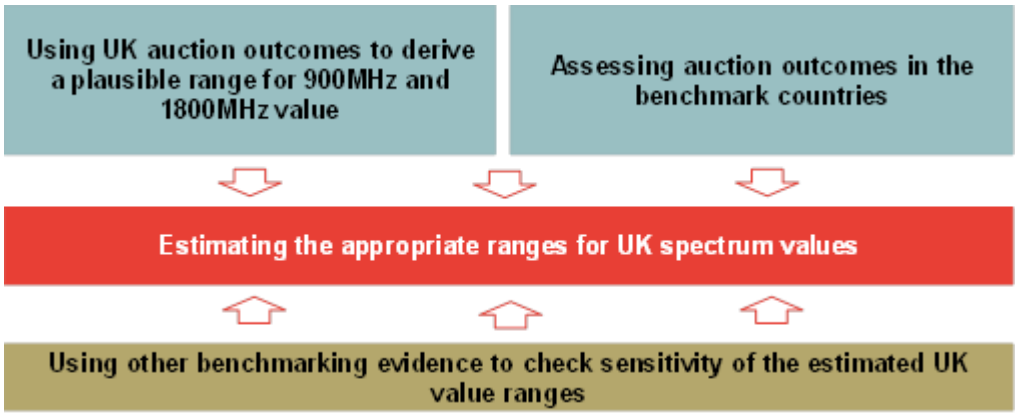
5 Estimating the appropriate range for 900 MHz and 1800 MHz value in the UK

In this Section, based on the assessment of individual auctions, we estimate the appropriate range for 900 MHz and 1800 MHz value in the UK that should be used as a basis for deriving appropriate ALFs.

Correcting for the main deficiencies in Ofcom's benchmarking approach, and taking into account the appropriate estimates of values of 800 MHz spectrum from the UK auction, results in a range of value for 900 MHz spectrum of **£12 and £15.9m per MHz**. Using a similar approach for 1800 MHz spectrum, we find that the appropriate range for 1800 MHz spectrum lies between **£6.3 and £12.5m per MHz.**

The key steps to derive the appropriate ranges of value in the UK are described in **Figure 14** below.

Figure 14. Estimating the appropriate range of 900MHz and 1800MHz market value in the UK



Source: Frontier Economics

As explained below, we take into account the appropriate estimates of the value of 800 MHz spectrum in the UK. This impacts both the upper bound for the 900 MHz value, as well as 900 MHz estimates derived based on relative valuations from other countries.

We then rely on our detailed assessment of auction outcomes in the benchmarking sample to derive the appropriate range for the market value of 900 MHz and 1800 MHz spectrum in the UK.

Finally, we undertake a sensitivity analysis in which we take into account all available international evidence, after carefully assessing the comparability of such evidence with the UK.

We first summarise our results with regards to 900 MHz values. We then discuss 1800 MHz results.

5.1 Applying the appropriate framework to derive market values of 900 MHz spectrum

5.1.1 Using UK auction outcomes to derive a plausible range of 900 MHz market value

We use as a starting point the range of appropriate estimates of the market value of 800 MHz spectrum in the UK, £17.9m to £21.4m, derived from the recent 4G auction. We use the mid-point of this range, £19.7m, as the starting point estimate for the UK 800 MHz value. In order to derive the upper bound for 900 MHz spectrum, we add the estimated cost of co-existence of £3m per MHz to get the upper bound of approximately £22.7m per MHz.[68]

Similarly, we treat estimates of the market value of 2600 MHz in the UK, also derived from the recent 4G auction, as a lower bound for the market value of 1800 MHz spectrum in the UK - and implicitly also for the market value of 900 MHz spectrum, as 900 MHz spectrum is unlikely to be less valuable than 1800 MHz spectrum in the UK.

Any outcomes from international auctions that are above the appropriately estimated market value of 800 MHz spectrum in the UK (our upper bound) or below the market value of 2600 MHz spectrum in the UK (our lower bound) are considered to be irrelevant for deriving the UK market value range for 900 MHz and 1800 MHz spectrum. This removes the inconsistency in Ofcom's approach of taking into account values of 900 MHz spectrum from international benchmarking evidence that *exceed* the estimated market value of 800 MHz spectrum in the UK derived from the recent UK auction.

In addition, the midpoint of the UK 800 MHz value range, £19.7m per MHz, is also used to derive implied value of 900 MHz spectrum in the UK based on relative 900/800 MHz valuations of spectrum from auctions in Romania, Spain, Portugal and Ireland, as described in more detail in Section 0 above.

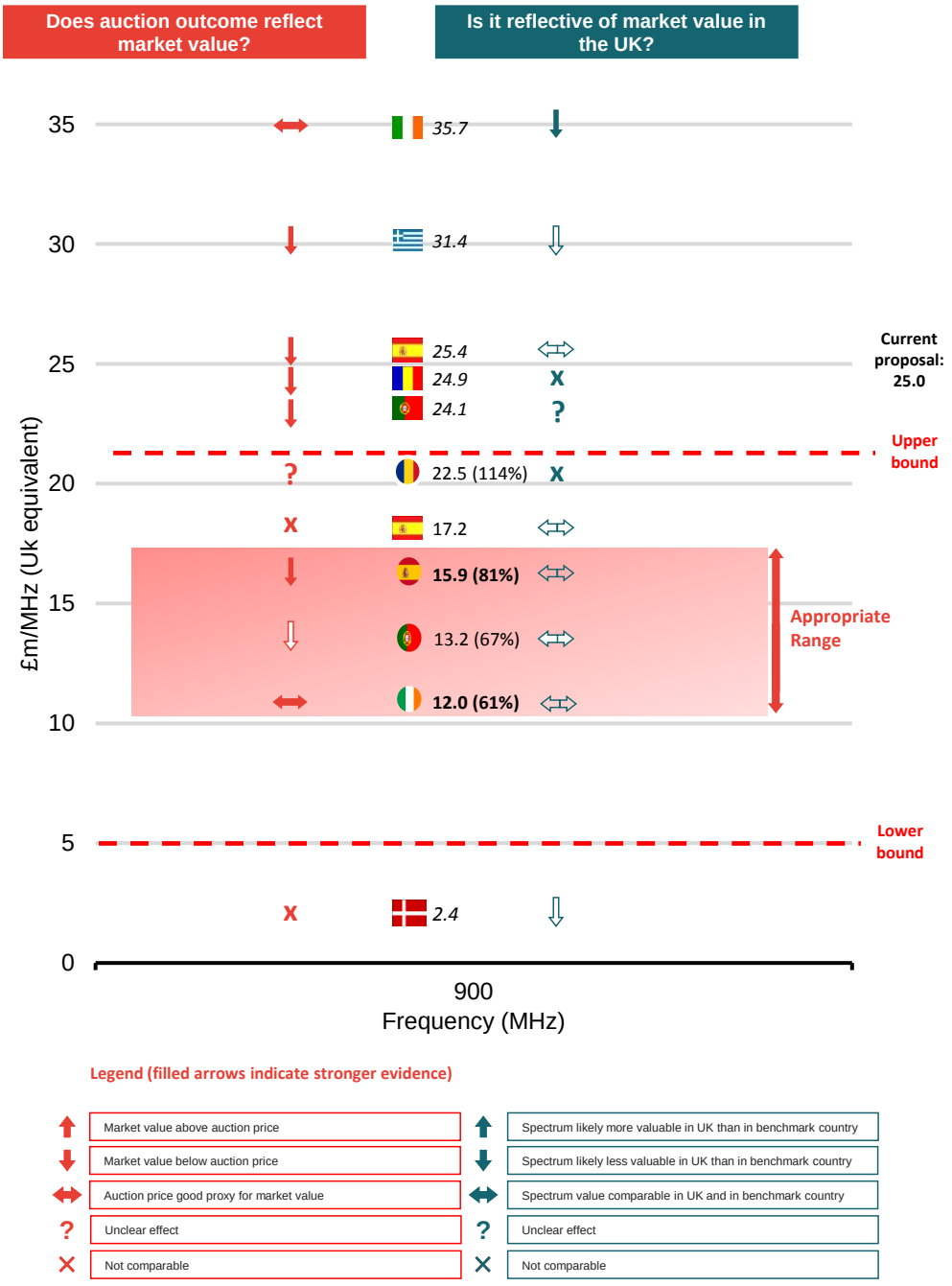
68 This is because estimated 800 MHz value from the UK auction is based bidder valuations after deducting all essential costs of operating 800 MHz network, including the co-existence costs. As the co-existence cost are unlikely to be a significant in relation to 900 MHz spectrum, it is appropriate to increase the estimated upper bound of 900 MHz by adding these costs, The Consultation, para 4.25

5.1.2 Estimating the appropriate range of 900 MHz value based on international benchmarks

Figure 15 below summarises the benchmarking evidence that we have used for estimating the market value of 900 MHz spectrum. Our sample consists of 11 observations. Five of these observations are above the upper bound for the market value of 900 MHz spectrum in the UK, based on the results of the UK 4G auction. In addition, one observation, based on the absolute valuation from Denmark, is below the lower-bound for the market value of 2600 MHz spectrum in the UK, as estimated by Ofcom, and is therefore implicitly below the lower-bound for the market value of 900 MHz spectrum in the UK. Therefore, we consider these six observations to be less relevant evidence for deriving the appropriate range of market values for 900 MHz spectrum in the UK, and as such, they do not enter our estimated range for 900 MHz UK value under our base case.[69]

[69] The 'less relevant' evidence is considered in our sensitivity analysis, where we attach less weight to these observations.

Figure 15. Value of 900 MHz spectrum based on international benchmarks



Note: In line with Ofcom's approach, squared markers refer to absolute (£m per MHz) values, round markers refer to relative value. More important evidence in **bold**, less relevant evidence in *italics*.

Source: Frontier Economics

There are five observations that lie within the plausible range: the absolute valuation from the Spanish beauty contest and the relative valuations based on the auctions in Romania, Spain, Portugal and Ireland.

As explained in Section 4.4.1 above, the outcome of the Spanish beauty contest from May 2011 is unlikely to reflect the true market value of 900 MHz spectrum in Spain and we consider this observation to be less important evidence for deriving the appropriate range of market values for 900 MHz spectrum in the UK. Similarly, in Portugal and Romania all sold spectrum went at the reserve price, which implies that the relative valuations could not be expected to be directly reflective of relative market value.

In Portugal, operators chose the significantly more expensive 800 MHz over 900 MHz, with some 900 MHz spectrum left unsold, which would suggest that the relative value of 900 MHz to 800 MHz as reflected in the reserve prices can be seen as potentially overestimating the true value of 900 MHz in Portugal[70]. The auction results in Romania are likely to be significantly distorted by country specific factors and provide only limited information about the true market value of spectrum in the UK. We therefore treat Portugal and Romania as less important evidence and we do not use these observations when deriving the appropriate range for the UK 900 MHz value under our base case. [71]

The two observations, based on **relative values** derived from the auctions in **Spain (July/November 2011)** and **Ireland**, lie between the upper- and lower-bounds for the market value of 900 MHz spectrum in the UK. Our analysis suggests that the relative prices in these two countries are likely to provide the most reliable indicators to inform the appropriate range for the market value of 900 MHz spectrum in the UK. As 900 MHz spectrum was sold at the reserve price in Spain, this is likely overestimating the market value of 900 MHz spectrum, whereas 800 MHz spectrum sold above the reserve price and is therefore reflective of market value of this spectrum. This implies that the application of the relative value of 800 to 900 from Spain to the UK would overestimate the market value in the UK. In Ireland, 800 MHz and 900 MHz spectrum cleared above the reserve prices and the auction outcomes can therefore be expected to be reflective of relative market value.[72]

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70 We note nevertheless that the estimated ratio of 900 MHz to 800 MHz value in Portugal is consistent with the ratios observed in Spain and Portugal, and lies between these ratios: taking therefore Portugal into account in the basic approach to derive the market value of 900 MHz spectrum in the UK would not be expected to affect the results of our analysis.

71 The 'less important' evidence is considered in our sensitivity analysis, where we attach less weight to these observations.

72 Our analysis suggests that demand for 2G spectrum is likely to be higher in Ireland, which, all else the same, would imply that the ratio of the market value of 900 MHz to 800 MHz in Ireland may be

Using these relative valuations for 900 MHz spectrum[73], together with the mid-point of the estimated value of 800 MHz spectrum in the UK, we find that the appropriate range for the market value of 900 MHz spectrum in the UK is between **£12m and £15.9m per MHz.**

5.1.3 Sensitivity checks of the estimated ranges of market values

The estimated ranges described above are based on a relatively small sample of auctions. Therefore, we have also undertaken a sensitivity analysis in which we take into account all available international evidence, after carefully assessing the comparability of such evidence with the UK.

To undertake the sensitivity analysis, we have estimated approximate per MHz prices from the auctions in Switzerland, Norway, Netherlands and Austria using a simple decomposition approach, which increases our sample to 15 observations. We have attached weights on observations that were considered to be of less relevant evidence, including observations that lie outside the plausible range of 900 MHz market value in the UK. We then calculated a weighted average, attaching 100% weight to the 'more important' evidence observations, 75% weight to the observations that are within the plausible range but which are considered to be 'less important' evidence, and 50% weight to 'less relevant' observations outside the plausible range of 900 MHz market value.

We first undertake this exercise taking into account 11 auction outcomes from Ofcom's benchmarking sample. We then replicate the exercise using a larger sample of 13 observations, which includes estimates of 900 MHz prices from auctions in Switzerland and Norway, but excludes 'outlier observations' from 900 MHz auctions in Netherlands and Austria[74]. Finally, we consider the full sample of 15 observations.

Figure 16 shows that the estimated weighted average value of 900 MHz spectrum across the alternative samples of observations is broadly similar. Whilst we recognise that international evidence needs to be treated cautiously, because of the limitations in comparability to the UK, the results of our sensitivity analysis are consistent with the estimated range for the market value of 900 MHz spectrum in the UK, as described above.

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higher than the corresponding ratio in the UK. This could lead to an over-estimation of the value of 900 MHz spectrum in the UK.

73 These relative valuations are the same as the ones used by Ofcom in its analysis.

74 We identify Austria and Netherlands as outlier observations using three different approaches proposed by DotEcon: International benchmarking of 900 MHz and 1800 MHz spectrum value - September 2013, page 11-13. Please note that our results hold even if we consider Denmark as an outlier observation.

Figure 16. Results of sensitivity analysis 900 MHz estimates

£m/MHz (UK equivalent)	Price	900MHz	Frontier's more important evidence	Auctions considered by Ofcom	All observations (no outliers)	All observations
Netherlands (2012)	Absolute	[✂]				50%
Austria (2013)	Absolute	[✂]				50%
Ireland (2012)	Absolute	35.7		50%	50%	50%
Greece (2011)	Absolute	31.4		50%	50%	50%
Spain (2011)	Absolute	25.4		50%	50%	50%
Romania (2012)	Absolute	24.9		50%	50%	50%
Portugal (2011)	Absolute	24.1		50%	50%	50%
Romania (2012)	Relative (114%)	22.5		75%	75%	75%
Spain (May 2011)	Absolute	17.2		75%	75%	75%
Spain (2011)	**Relative (81%)**	**15.9**	**100%**	**100%**	**100%**	**100%**
Norway (2013)	Absolute	[✂]			75%	75%
Switzerland (2012)	Absolute	[✂]			75%	75%
Portugal (2011)	Relative (67%)	13.2		75%	75%	75%
Ireland (2012)	**Relative (61%)**	**12.0**	**100%**	**100%**	**100%**	**100%**
Denmark (2010)	Absolute	2.4		50%	50%	50%
Max			*15.9*	*35.7*	*35.7*	*59.0*
Min			*12.0*	*2.4*	*2.4*	*2.4*
Average			**14.0**	**12.7**	**12.4**	**14.6**

Note: Plausible range highlighted in blue. More important evidence highlighted in bold.

Source: Frontier Economics

5.2 Applying the appropriate framework to derive market values of 1800 MHz spectrum

5.2.1 Using UK auction outcomes to derive a plausible range of 1800 MHz market value

Again, we rely on the appropriate estimates of the value of 800 MHz spectrum in the UK (including the cost of co-existence), which we treat as the upper bound of the likely market value of 1800 MHz spectrum in the UK[75]. Similarly, we treat 2600 MHz outcomes from the UK auction as a lower bound for the UK 1800 MHz value. This implies that any outcomes from international auctions above the appropriately estimated value of the 800 MHz in the UK (upper bound) or

75 We consider that is reasonable to assume that 900 MHz spectrum is unlikely to be less valuable than 1800 MHz spectrum in the UK.

Estimating the appropriate range for 900 MHz and 1800 MHz value in the UK

below the 2600 MHz UK value (lower bound) are not given any weight in the base case approach to derive the UK market value range for 1800 MHz.

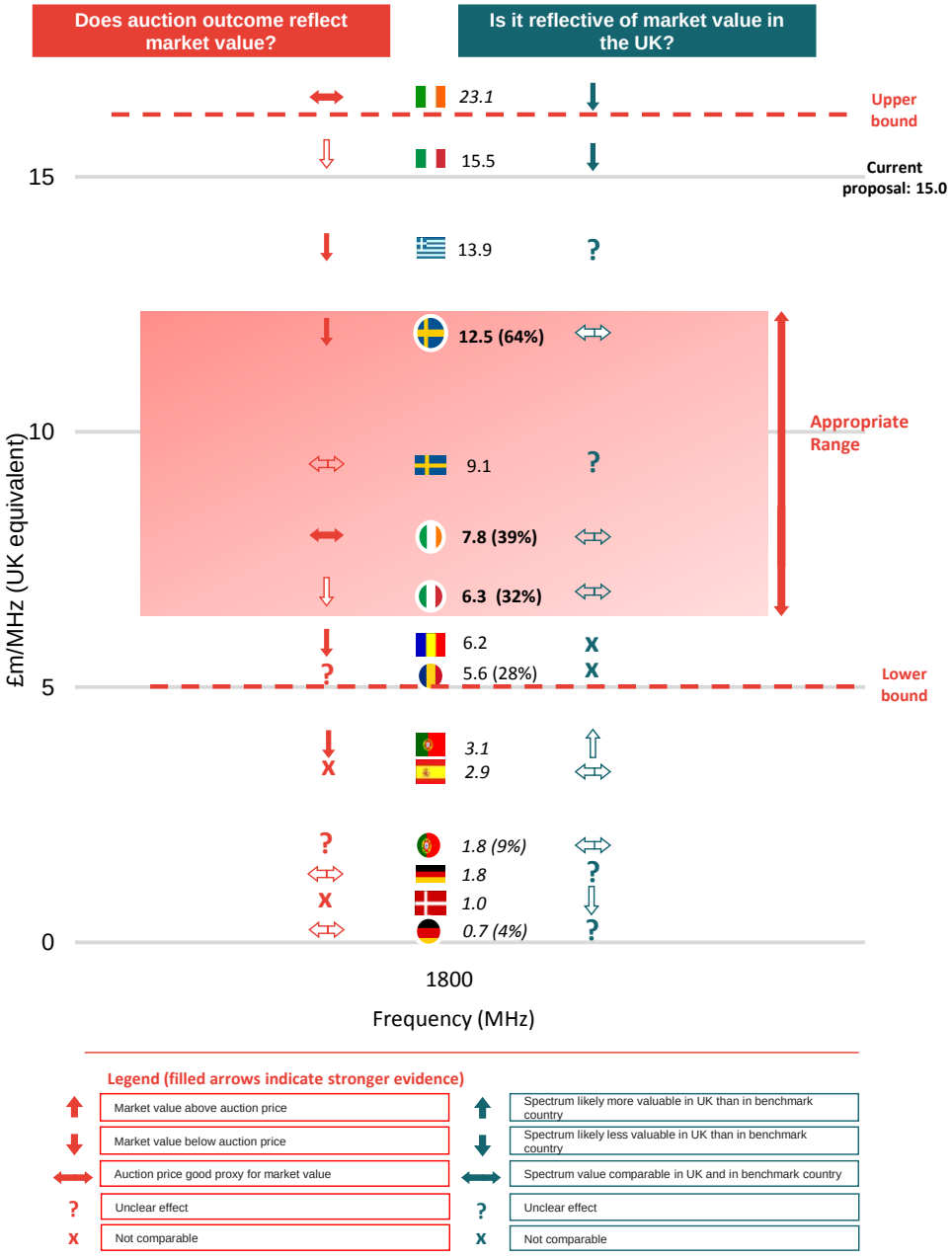
In addition, the appropriate estimate of the value of 800 MHz spectrum in the UK is then used to derive the implied value of 1800 MHz spectrum in the UK based on relative 1800/800 MHz valuations of spectrum from auctions in Sweden, Ireland, Italy, Romania, Portugal and Germany. We consider relative valuations based on 1800/800 MHz ratio as more useful for deriving 1800 MHz value than valuations based on 1800/2600 MHz ratio, as 800 MHz and 1800 MHz are the main bands used for large-scale rollout of 4G networks and 800 MHz auctions in our sample generally cleared above the reserve price and are therefore likely to reflect market value of 800 MHz spectrum. Therefore, our relative estimates for Italy, Romania, Portugal and Sweden are based on 1800/800 MHz ratio. [76]

5.2.2 Estimating the appropriate range of 1800 MHz value based on international benchmarks

Figure 17 below summarises the benchmarking evidence used based on the detail assessment of auction outcomes presented in Section 4. Our sample consists of 15 observations. One observation - based on the absolute valuation from Ireland - is above the upper bound of the 1800 MHz spectrum value, which is based on the appropriately derived value of the 800 MHz spectrum from the UK auction. In addition, six observations, based on absolute and relative valuations of spectrum in Portugal and Germany, and an absolute valuation from Denmark and Spain (May 2011), are below the lower-bound of the 1800 MHz spectrum value. Therefore, we consider these seven observations as less relevant evidence for deriving the appropriate range for 1800 MHz value in the UK.

76 Nevertheless, our results are robust even if we include relative valuations based on 1800/2600 MHz ratio.

Figure 17. Value of 1800 MHz spectrum based on international benchmarks



Note: In line with Ofcom's approach, squared markers refer to absolute (£m per MHz) values, round markers refer to relative value. More important evidence in **bold**, less relevant evidence in *italics*.

Source: Frontier Economics

There are therefore 8 observations in total that lie within the plausible range. Our analysis in Section 4 shows that absolute valuations from Greece and Italy are likely overestimating market value of 1800 MHz spectrum, as spectrum sold at the reserve price. Absolute valuation from Sweden is likely reflecting the market

Estimating the appropriate range for 900 MHz and 1800 MHz value in the UK

value in the benchmark country, but it is unclear how informative is it about the market value in the UK. The auction outcomes from Romania, both absolute and relative, are considered not comparable to the market value in the UK. Therefore, we treat these five observations as less important evidence and we do not consider as part of our base case to derive the appropriate range for 1800 MHz value in the UK

There are, therefore, three observations based on **relative values** derived from the auctions in **Sweden, Ireland** and **Italy** which lie between the upper- and lower-bound and where our analysis suggests that they are likely to provide a good indication about the appropriate range for 1800 MHz value in the UK. Therefore, we consider these three observations as 'more important' evidence.

In Sweden the relative valuation of 1800 MHz is likely to *overestimate* the true market value, due to coverage obligation in 800 MHz that pushes up relative valuation of 1800 MHz.[77] Similarly, the relative valuation of 1800 MHz in Italy is likely to *overestimate* the true market value in the UK, primarily because 1800 MHz sold at reserve price, while the 800 MHz auction outcomes likely reflects true market value.[78] Our analysis suggest that relative valuations from Ireland auction could be considered a potentially good indicator of the market value in the UK, although it is possible that higher 2G demand in Ireland could lead to overestimating the value 1800 MHz based on 1800/800 relativities.

Using these relative valuations for 1800 MHz spectrum, we find that the appropriate range for lump-sum spectrum value in the UK lies between **£6.3 and £12.5m per MHz.**

5.2.3 Sensitivity checks of the estimated 1800 MHz value range

The above estimate range is based on a relatively small sample of auctions. Therefore, we have again also undertaken a sensitivity analysis in which we take into account all available international evidence, after carefully assessing the comparability of such evidence with the UK, in line with the approach described above.

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77 In its calculation of relative value of 1800 MHz (in relation to 800 MHz), Ofcom ignores the fact that the highest 800 MHz block has a large rollout obligation. This leads to lower value of 800 MHz than what a comparable value without the coverage obligation would be, thus likely overestimating the relative market value of 1800 MHz spectrum.

78 The 1800 MHz spectrum was sold at the reserve price, thus likely overestimating the true market value of spectrum (the 800 MHz spectrum sold above the reserve price). In addition, in the 800 MHz band there were land coverage obligations, which could be expected to have pushed down the price paid for 800 MHz spectrum in the auction. In combination with the likely overestimated market value of 1800 MHz, this would lead to further overestimating market value in the UK.

We first undertake this exercise taking into account 15 auction outcomes from Ofcom's benchmarking sample. We then replicate the exercise using a larger sample of 17 observations, which includes estimates of 1800 MHz prices from auctions in Switzerland and Norway, but excludes 'outlier observations' from 1800 MHz auctions in Netherlands and Austria[79]. Finally, we consider the full sample of 19 observations.

Figure 18 shows, again, that the weighted sample average across different groups of observations is lower than the mid-point of the range that we consider to be appropriate for the estimate of the 1800 MHz value in the UK.

79 We identify Austria and Netherlands as outlier observations using three different approaches proposed by DotEcon: International benchmarking of 900 MHz and 1800 MHz spectrum value - September 2013, page 11-13

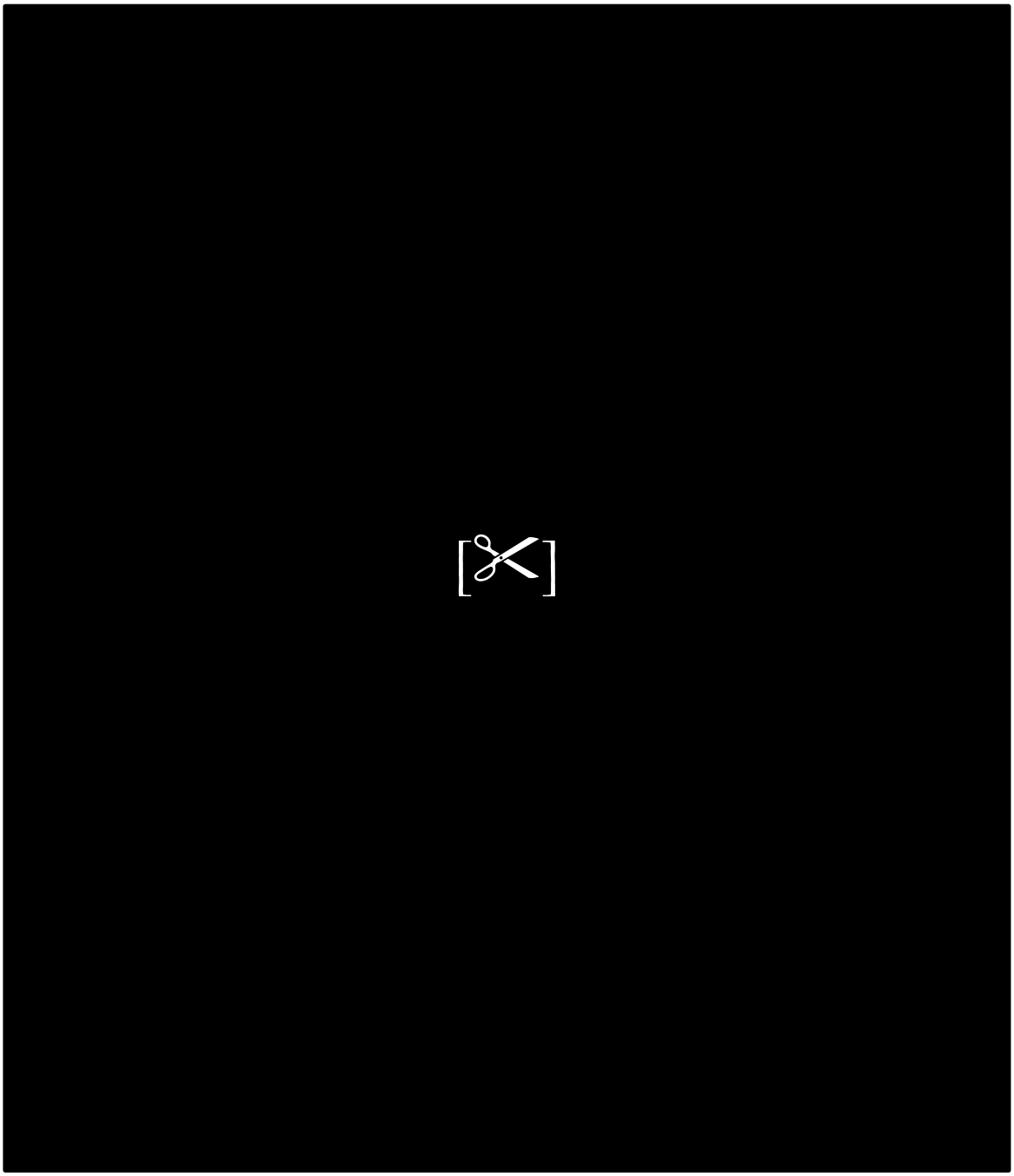
Figure 18. Results of sensitivity analysis 1800 MHz

£m/MHz (UK equivalent)	Price	1800MHz	Frontier's more important evidence	Auctions considered by Ofcom	All observations (no outliers)	All observations
Netherlands (2012)	Absolute	[✂]				50%
Austria (2013)	Absolute	[✂]				50%
Ireland (2012)	Absolute	23.1		50%	50%	50%
Italy (2011)	Absolute	**15.5**		75%	75%	75%
Greece (2011)	Absolute	13.9		75%	75%	75%
Sweden (2011)	**Relative (64%)**	**12.5**	**100%**	**100%**	**100%**	**100%**
Sweden (2011)	Absolute	9.1		75%	75%	75%
Norway (2013)	Absolute	[✂]			75%	75%
Ireland (2012)	**Relative (39%)**	**7.8**	**100%**	**100%**	**100%**	**100%**
Switzerland (2012)	Absolute	[✂]			75%	75%
Italy (2011)	**Relative (32%)**	**6.3**	**100%**	**100%**	**100%**	**100%**
Romania (2012)	Absolute	6.2		75%	75%	75%
Romania (2012)	Relative (28%)	5.6		75%	75%	75%
Portugal (2011)	Absolute	3.1		50%	50%	50%
Spain (May 2011)	Absolute	2.9		50%	50%	50%
Portugal (2011)	Relative (9%)	1.8		50%	50%	50%
Germany (2010)	Absolute	1.8		50%	50%	50%
Denmark (2010)	Absolute	*1*		50%	50%	50%
Germany (2010)	Relative (4%)	*0.7*		50%	50%	50%
Max			***12.5***	***23.1***	***23.1***	***35.4***
Min			***6.3***	***0.7***	***0.7***	***0.7***
Average			**8.9**	**5.4**	**5.6**	**6.8**

Note: Plausible range highlighted in blue. More important evidence highlighted in bold.

Source: Frontier Economics

Annexe 1: Estimating the indicative price paid for spectrum in the auctions in Austria, Netherlands, Switzerland and Norway



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