NERA
ECONOMIC CONSULTING

Review of country benchmarks used for setting lump sum values for UK 900 MHz and 1800 MHz

– A Response to Ofcom's Further Consultation

Prepared by NERA Economic Consulting for Telefónica UK

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1. Introduction

NERA Economic Consulting (NERA) has been asked by Telefónica UK to undertake a statistical analysis of the country benchmark data that is being used by Ofcom to derive lump sum values of UK 900 MHz and 1800 MHz spectrum. Telefónica told us that they broadly support the revised methodology adopted by Ofcom to estimate UK values based on a qualitative analysis of benchmarks from other European countries.[1] However, they are concerned that the Ofcom analysis places undue weight on potential high price outliers to the sample, while (correctly) putting little weight on low price outliers. In Telefónica's view, this approach leads Ofcom to over-estimate the value of 900 MHz and 1800 MHz spectrum in the UK.

In this paper, we set out a "top-down" econometric approach to test for probable outliers in Ofcom's sample of country data points. Having identified the potential outliers using a purely statistical approach, we then undertake a "bottom up" qualitative analysis of these country data points to determine if the evidence supports the conclusion that they are outliers. For the quantitative analysis, we run an econometric model using two alternative samples: one using data supplied by Ofcom; and one that uses the same sample but with a limited number of adjustments proposed by Telefónica.[2] For the qualitative analysis, we draw on Ofcom's own published analysis, stakeholder responses to Ofcom's consultations and our own knowledge of recent European spectrum auctions.[3]

The debate between Ofcom and stakeholders over the merits of including particular country data points in the benchmarking exercise has, for some countries, been highly contentious. For example, in its 2013 consultation document, Ofcom placed significant weight on Romanian price data as a benchmark for the UK. Several respondents to this consultation, including Telefónica, put forward multiple reasons why Romania was a poor benchmark for the UK, and Ofcom subsequently downgraded Romania in its analysis. In its new consultation, Ofcom places great weight on price data from the 2013 Austrian multiband auction. Previously, in response to an Ofcom update in May 2014, respondents, including Telefónica, presented qualitative evidence why the Austrian auction data may be unreliable as a benchmark for the UK, but Ofcom argued that this evidence was inconclusive.

We believe that our approach of first using a "top down" econometric evaluation to screen for potential outliers and only then turning to "bottom up" qualitative reasoning for an explanation provides a framework for concluding this debate. The underlying premise of Ofcom's benchmarking exercise is that their country benchmarks for each spectrum band are estimates, perhaps noisy ones, of *the same thing*. A direct implication of this is that we can use an econometric test to determine a confidence interval (e.g. 98%) for the expected value

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1 For a description of Ofcom's approach, see: Ofcom, Annual Licence fees for 900 MHz and 1800 MHz spectrum, Further consultation, 1 August 2014 (hereafter, the "August 2014 Consultation"), Section 3.

2 It was not within the scope of the study to consider whether the Ofcom data is accurate.

3 NERA's spectrum auctions team, led by Richard Marsden, one of the report authors, actively tracks spectrum auctions worldwide. We advised Telefónica group companies in the recent Spanish, Irish, UK, Czech and Slovak multi-band spectrum auctions, and supported bidders in a number of other awards in Ofcom's benchmark set. We also assisted the BIPT with the design and implementation of the 2013 Belgium 800 MHz auction.

of country benchmarks by band, while allowing for country-specific variations. When data is *within* this confidence interval, a fair assumption is that the benchmark is good unless demonstrated otherwise by qualitative analysis. By contrast, where data is *outside* the confidence interval, a fair assumption is that the data is suspect, and little weight should be attached to such benchmarks unless there are sound qualitative reasons not to dismiss the data.

Our econometric test confirms that **Austria is a high price outlier amongst both the 900 MHz and 1800 MHz benchmarks**. There is also a plausible narrative to explain why Austria is an outlier based on alleged strategic bidding behaviour driving up prices in general and distorting price ratios across bands. The absence of published bid data means that it is not possible to verify allegations of strategic bidding. Equally, it is not possible to prove the counter-factual that price ratios were not distorted. Given the statistical evidence that Austrian benchmarks are outliers, the reasonable approach is to presume that Austrian bid data is suspect, and for Ofcom to downgrade it from a Tier 1 (stronger) to Tier 3 (weaker) evidence point.

We also propose some other more modest changes to Ofcom's assessment based on the results of our model and supporting qualitative analysis. These involve:

- taking a fresh look at the Danish benchmarks, based on alternative bid data proposed by Telefónica which produce more plausible values for 900 MHz and 1800 MHz than the Ofcom data;

- downgrading Ireland 1800 MHz from Tier 1 to Tier 2, owing to concerns about the impact of the (somewhat arbitrary) level of the 2600 MHz proxy; and

- acknowledging the risk that Sweden 1800 MHz is likely to overstate value.

This paper is divided into three further sections. In Section 2, we describe our econometric evaluation for identifying outliers and explain the results. In Section 3, we provide a qualitative analysis of the outlying data points to determine if there is evidence to support the results of the econometric evaluation. Section 4 provides some brief conclusions. In Appendix 1, we report our sample data.

2. Econometric test to screen for outliers

In this section, we describe our proposed "top down" approach to screen for outliers in the dataset of European country benchmarks: Section 2.1 describes our benchmark data sets; Section 2.2. describes our methodology; Section 2.3 provides our results; and Section 2.4 discusses the implications of these results.

2.1. Benchmark datasets

We run our model using two distinct sets of benchmark data:

- Sample 1: Ofcom's data set.
- Sample 2: Ofcom's data set but with some adjustments proposed by Telefónica.

Sample 1 uses the benchmark numbers provided to Telefónica by Ofcom. These include both the absolute benchmarks for each of the four spectrum bands (800, 900, 1800 and 2600 MHz), and also the two benchmark ratio prices that Ofcom reports (the 900/800 MHz ratio price and the 1800 MHz distance method price). Specifically, we use price data from a spreadsheet called the "Benchmarking Model" prepared by DotEcon for Ofcom, and provided to Telefónica and its advisors for the purposes of responding to the August 2014 Consultation.[4] We understand that this is the source data for Ofcom's proposals.

Sample 2 uses the same data as Sample 1 except for the following adjustments, as proposed by Telefónica in its response to the August Consultation:

- *Denmark.* The 800 MHz value is based on the reserve price for the B lot, inclusive of annual fees. The 2600 MHz value is based on the reserve price, inclusive of annual fees. The 800 MHz ratio benchmark, based on the 900/800 ratio, has been updated accordingly, and – with the revised data – it is possible to add an 1800 MHz ratio benchmark, based on the distance method.
- Estonia. An absolute price benchmark for 800 MHz has been added to the sample, based on prices in 2nd and 3rd awards (which were competitive auctions) but not the 1st award (which was a beauty contest). This is calculated using Ofcom's methodology.
- *France*. Absolute price benchmarks for 800 MHz and 2600 MHz have been added to the sample. These are calculated using Ofcom's methodology.
- *Ireland*. The 1800 MHz ratio benchmark has been recalculating using Ofcom's methodology but with Telefónica's proposed estimate of the 2600 MHz proxy price.
- *Sweden.* The 1800 MHz ratio benchmark has been recalculating using Ofcom's methodology but with Telefónica's proposed estimate of the 2600 MHz proxy price.

[4] Ofcom, ALF 900-1800 MHz: Final benchmarking dataset.

We understand that there are many factors that could in principle affect the value of spectrum licences within each country and thus the relative level of benchmarks for UK prices. For example, it is standard practice when comparing spectrum auction revenues across countries to adjust for population size and the amount of spectrum sold to produce per MHz per pop price. Ofcom makes further adjustments to its benchmarks, for example to account for: differences in licence duration; the discounted value of future spectrum fees; changes in underlying price levels between award dates; and differences in purchasing power parity. Stakeholders have queried some of these adjustments and also suggested other factors that may affect relative prices, such as market profitability, urbanisation and 3G penetration, which Ofcom has rejected.[5] This study does not seek to influence this debate. We make no comment on the validity of the original DotEcon / Ofcom data and the changes proposed by Telefónica, except to the extent they impact our econometric results. Rather, we offer conclusions on specific datasets based on the untested assumption that the underlying data is valid.

Accordingly, our model is based on the reported benchmark prices and does not attempt to decompose them to account for adjustments made by Ofcom. As we explain below, the model does attempt to identify country-specific effects that may cause variations in the level of benchmark prices. However, in general, we do not attempt to decompose these country effects, with the partial exception that we do include population size as a potential distinct explanatory variable. Given the limited and noisy sample size available, we do not see any value in attempting to build a more complex model.

The full datasets for each sample are reported in Appendix 1.

2.2. Methodology

The underlying premise of any benchmarking exercise is that the data which go into the benchmark are estimates, perhaps noisy ones, of *the same thing*. This premise gives rise to a potential econometric test: take the underlying data and test whether or not they plausibly come from some distribution of possible values of that thing. Individual estimates which fall outside of likely membership in the given distribution are called *outliers*. In this subsection, we will describe a process for econometrically uncovering probable outliers. In the next subsection we will discuss the results of the methodology applied to the data in this case.

In the simplest example, we have n observations in a dataset which purport to be n measurements of the same thing and we want to see if any of these observations are outliers. The standard method would be to specify a family of distributions from which the observations came, use the data to estimate the specific member of that family from which the data arose, and then choose thresholds from that distribution which correspond to boundary values beyond which any observation outside that threshold is unlikely.

To make this concrete, a typical analysis might:

- posit that the underlying distribution was normal;

[5] Ofcom, August 2014 Consultation, Annex 7, p.64-70.

- use the data to estimate the two parameters (mean and standard deviation) of that normal distribution; and
- identify outliers as observations outside of those expected to occur more than, say, 98 times in 100 hypothetical draws of samples of size n from that distribution (i.e. observations outside a 98% confidence interval).

There are numerous variations to test the robustness of this procedure, including varying the underlying distribution assumed (perhaps to one with fatter tails), varying the calculation of the underlying mean and standard deviation to exclude a particular observation being tested (this is called the "jackknife technique"), and relaxing the thresholds.

From this base, we can then improve outlier estimation if we have useful ancillary information. In this case, useful ancillary information can come from either independent variables which have an effect on the observed values, or from multiple observations which are jointly affected by some common underlying cause. By using a random effects regression model, we can provide tighter bounds on the variation and therefore provide a better sense of whether or not the underlying observations are a measurement of "the same thing."

We do this by creating a model. In this case, the model created is:

$$B_{ic} = \beta X_{ic} + \epsilon_c + \delta_{ic}$$

where B_{ic} is a benchmark for a particular quantity in a particular country; X is a vector of characteristics of the product and/or the country; ε is an error term which is country-specific; and δ is an error term for each benchmark which varies independently.

A key feature of this model is the inclusion of country-specific error term in addition to the standard error term in an econometric analysis. The ancillary information we have is that the process of estimating one benchmark in a particular country may give us information about other benchmarks for that country. In this modelling, the X variable reflects only the population in the country and the particular band. As is typical for benchmarks representing either prices or positive indices, we estimate the logarithm of the benchmark to ensure that predictions will not violate a negativity constraint.

For each sample, we run two sets of regressions: the first estimates the logarithm of benchmark band prices; and the second estimates the logarithm of the two benchmark ratio prices that Ofcom uses in its analysis (i.e. the 900/800 MHz ratio price and the 1800 MHz distance method price).

The band price regression has the form:

$$\log P_{ic} = \beta_1 800MHz + \beta_2 900MHz + \beta_3 1800MHz + \beta_4 2.6GHz + \beta_5 Population + \epsilon_c + \delta_{ic}$$

where the coefficients β_1- β_4 are intercepts for four relevant spectrum bands: 800, 900, 1800 and 2600 MHz.

The ratio regressions have essentially the same form:

$$\log R_{ic} = \beta_1 RatioType1 + \beta_2 RatioType2 + \beta_3 Population + \epsilon_c + \delta_{ic}$$

where RatioType1 is an indicator variable for the 900/800 ratio and RatioType2 is an indicator variable for the distance-based 1800 ratio.

Once we have a model, we can generate a prediction for any given ratio in any particular country and then compare the 98 percent confidence interval (inside which 98% of the underlying observations which actually fit the model should fall) with the actual ratio reported for that country[6].

As a robustness check, we also ran the regressions using the levels of the prices and ratios rather than the logarithms.

The specific coefficients and confidence intervals were estimated using the maximum likelihood random effects estimator in Stata 13, a standard statistical software program.

2.3. Results

The results of the price regressions for the absolute price benchmarks for Sample 1 and Sample 2 are reported in Figure 1 and Figure 2 respectively.

Figure 1: Results of the price regression for absolute price benchmarks (Sample 1)

```
Random-effects ML regression                    Number of obs      =        45
Group variable: c                               Number of groups   =        16

Random effects u_i ~ Gaussian                   Obs per group: min =         1
                                                               avg =       2.8
                                                               max =         4

                                                LR chi2(4)         =     29.45
Log likelihood  = -58.922986                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        logp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        band |
          26 |          0  (base)
         800 |   2.106211   .3068576     6.86   0.000     1.504782    2.707641
         900 |   1.834024   .3683607     4.98   0.000      1.11205    2.555997
        1800 |   .7855341   .3112524     2.52   0.012     .1754906    1.395578
             |
         pop |   4.63e-09   8.98e-09     0.52   0.606    -1.30e-08    2.22e-08
       _cons |   1.079363   .3516946     3.07   0.002     .3900546    1.768672
-------------+----------------------------------------------------------------
     /sigma_u |   .6588224   .2448769                      .3179701    1.365056
     /sigma_e |   .7308713   .1116991                      .5416911    .9861208
          rho |   .4482938   .2310475                      .1012051    .8448919
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=    3.85 Prob>=chibar2 = 0.025
```

[6] To some extent, the confidence level selected is arbitrary. The guiding principle is that the level should not be so low as to consign large fractions of the data to outlier status, nor so high as to accept virtually any estimate. The rough aim should be to be throwing out no more than about (1-c)*n observations, where c is the confidence level and n the number of observations. Where there are very few observations, marking more than one as an outlier is problematic. We have selected 98 percent to avoid marking too many observations as outliers.

Figure 2: Results of the price regression for absolute price benchmarks (Sample 2)

```
Random-effects ML regression                    Number of obs      =        48
Group variable: c                               Number of groups   =        18

Random effects u_i ~ Gaussian                   Obs per group: min =         1
                                                               avg =       2.7
                                                               max =         4

                                                LR chi2(4)         =     48.20
Log likelihood  = -54.808617                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
        logp |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        band |
          26 |          0  (base)
         800 |   2.254688   .2045062    11.03   0.000     1.853864    2.655513
         900 |   1.998966   .2615855     7.64   0.000     1.486268    2.511665
        1800 |   .9145035   .2197497     4.16   0.000      .483802    1.345205
             |
         pop |   9.55e-09   8.97e-09     1.06   0.287    -8.04e-09    2.71e-08
       _cons |   .7561069   .3243832     2.33   0.020     .1203274    1.391886
-------------+----------------------------------------------------------------
    /sigma_u |   .8558345   .1813481                      .5649674    1.296451
    /sigma_e |   .5178826   .0696667                       .397856    .6741194
         rho |   .7319732   .1072518                      .4922974    .8956036
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=   19.47 Prob>=chibar2 = 0.000
```

The results of the price regressions for the ratio price benchmarks for Sample 1 and Sample 2 are reported in Figure 3 and Figure 4 respectively.

Figure 3: Results of the price regression for ratio price benchmarks (Sample 1)

```
Random-effects ML regression                    Number of obs      =        15
Group variable: c                               Number of groups   =        11

Random effects u_i ~ Gaussian                   Obs per group: min =         1
                                                               avg =       1.4
                                                               max =         2

                                                LR chi2(2)         =      7.09
Log likelihood  = -10.664281                    Prob > chi2        =    0.0288

------------------------------------------------------------------------------
        logr |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        band |
         900 |          0  (base)
        1800 |  -.7106563   .1878123    -3.78   0.000    -1.078762    -.342551
             |
         pop |  -1.65e-09   6.46e-09    -0.26   0.798    -1.43e-08    1.10e-08
       _cons |    3.04411     .24151    12.60   0.000     2.570759    3.517461
-------------+----------------------------------------------------------------
    /sigma_u |   .4641053   .1440333                      .2526094    .8526752
    /sigma_e |   .2847241   .1058752                      .1373736    .5901265
         rho |   .7265487   .2284443                      .2286788    .9742938
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=    2.18 Prob>=chibar2 = 0.070
```

Figure 4: Results of the price regression for ratio price benchmarks (Sample 2)

```
Random-effects ML regression                    Number of obs      =        16
Group variable: c                               Number of groups   =        11

Random effects u_i ~ Gaussian                   Obs per group: min =         1
                                                               avg =       1.5
                                                               max =         2

                                                LR chi2(2)         =     12.66
Log likelihood  = -8.3157162                    Prob > chi2        =    0.0018

------------------------------------------------------------------------------
        logr |      Coef.   Std. Err.       z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        band |
         900 |          0  (base)
        1800 |  -.8706653   .1985659    -4.38   0.000    -1.259847   -.4814832
             |
         pop |  -2.98e-09   4.54e-09    -0.66   0.512    -1.19e-08    5.91e-09
       _cons |   3.250475   .1796877    18.09   0.000     2.898294    3.602656
-------------+----------------------------------------------------------------
    /sigma_u |   .1351814          .                           .           .
    /sigma_e |    .373791   .0777264                      .2486734    .5618603
         rho |   .1156629          .                           .           .
------------------------------------------------------------------------------
Likelihood-ratio test of sigma_u=0: chibar2(01)=    0.82 Prob>=chibar2 = 0.183
```

From these regressions, we can then generate predictions under the assumption that all of the benchmarks fit the model and then compare the 98% confidence intervals for those predictions with the benchmark used. In the following charts, produced using Stata 13: the yellow line represents the predicted price for each country; the green line is the upper 98% confidence interval; the blue line is the lower 98% confidence interval; and the red dots are the actual observations. Those observations above the green line or below the blue line are potential outliers.

Figure 5 and Figure 6 report actual versus predicted observations for absolute price benchmarks using Sample 1 and Sample 2 data respectively.

Figure 5: Actual versus predicted absolute price benchmarks for Sample 1

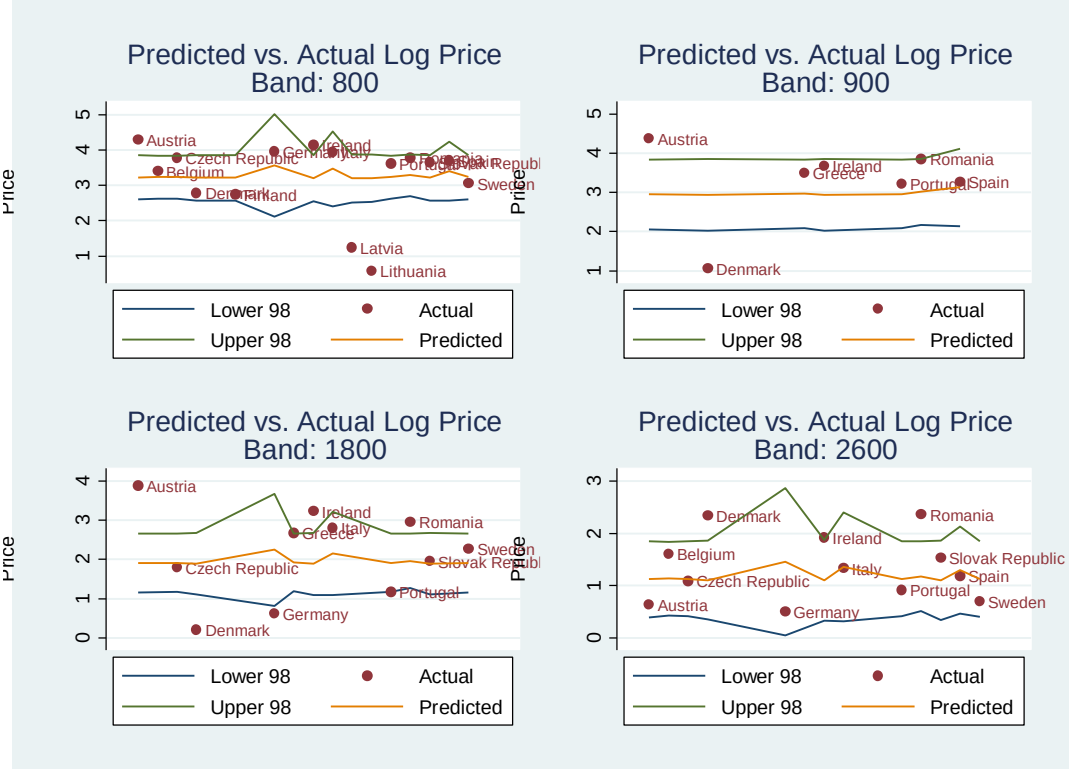


Figure 6: Actual versus predicted absolute price benchmarks for Sample 2

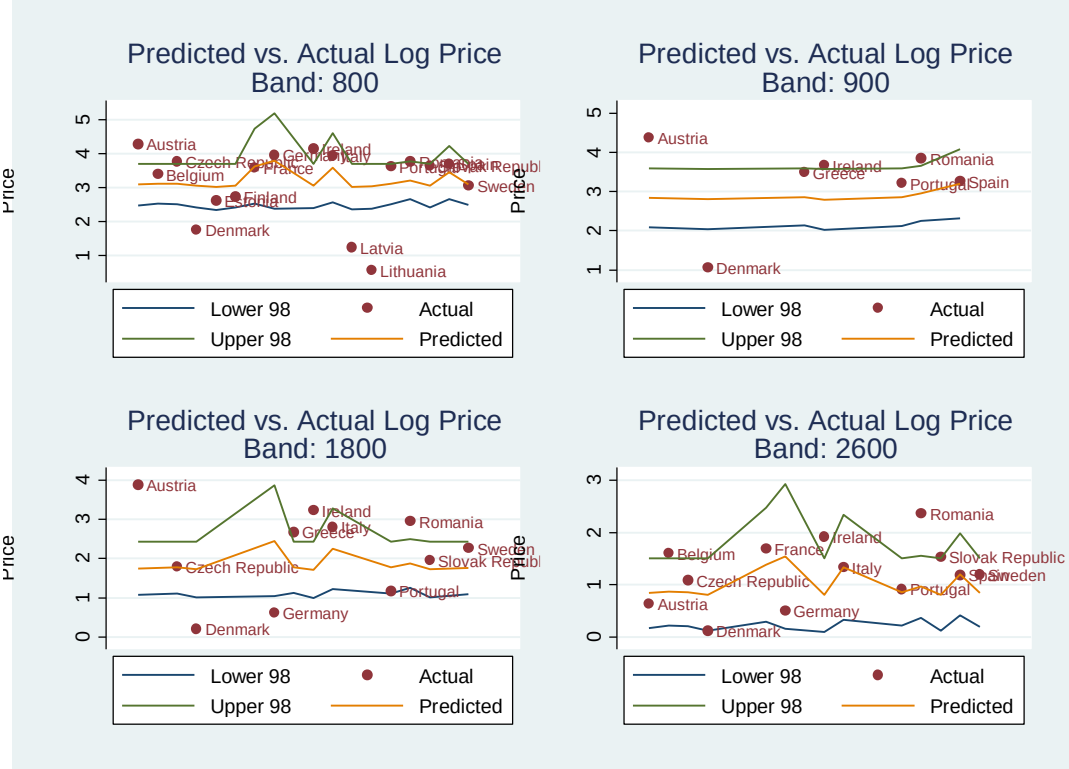


Figure 7 and Figure 8 report actual versus predicted observations for ratio price benchmarks using Sample 1 and Sample 2 data respectively.

Figure 7: Actual versus predicted ratio price benchmarks for Sample 1

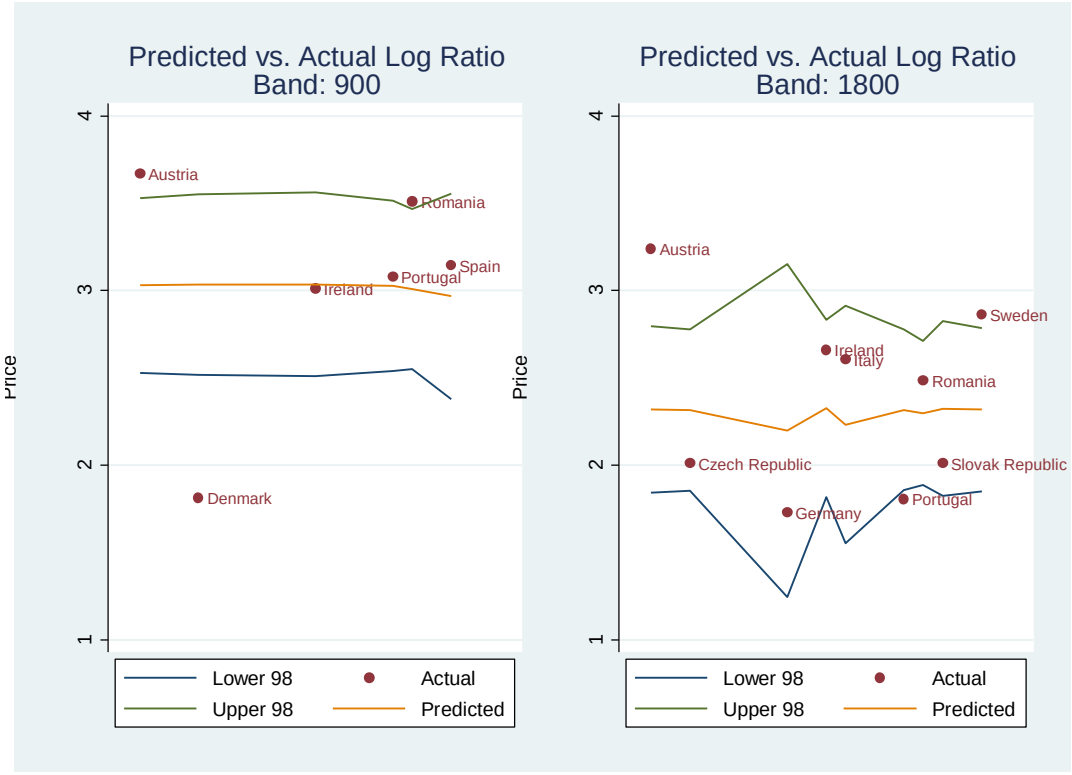
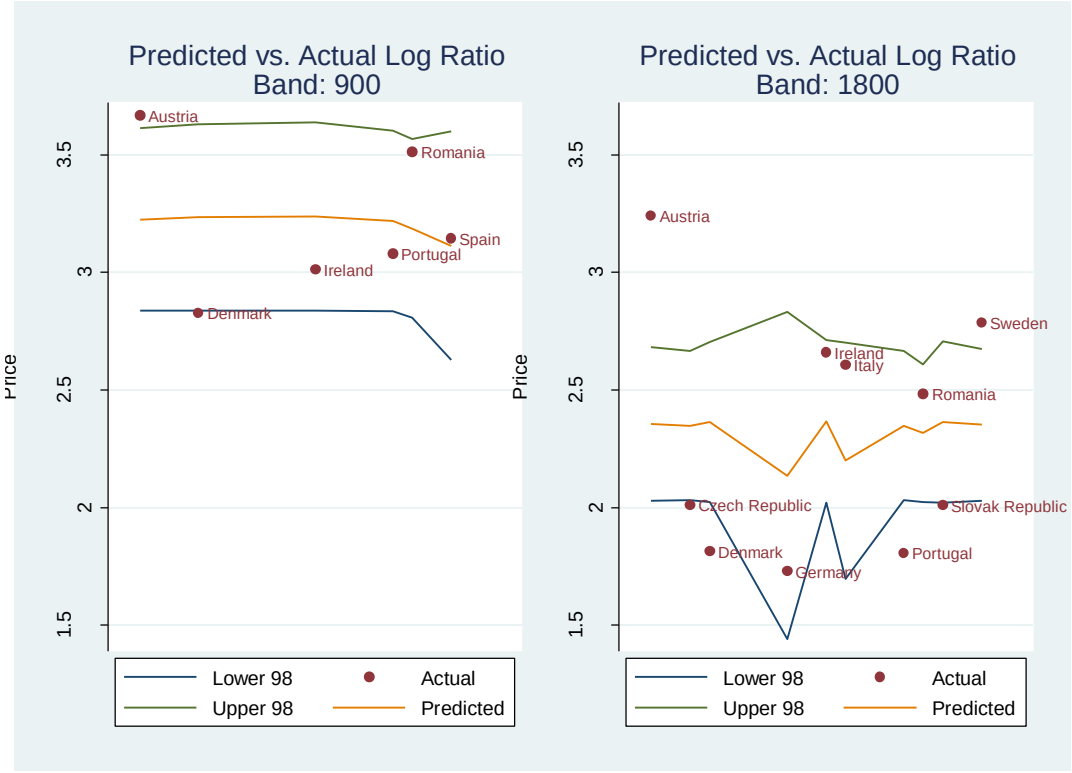


Figure 8: Actual versus predicted ratio price benchmarks for Sample 2



2.4. What do the results mean?

For both Samples 1 and 2, the results suggest that there are a number of country data points that are potential outliers. In particular, the following country data points stand out as outliers from the sample under the ratio benchmarks (Figure 7 and Figure 8):

- **Austria.** Austria is a high price outlier for both 900 and 1800 MHz ratio benchmarks. Moreover, in each case (apart from Denmark in Sample 1), it is substantially further away from the confidence intervals than any other country data points. We note that Austria is also a high price outlier for each of the 800, 900 and 1800 MHz absolute price ratios, although not for the 2600 MHz award, which was awarded in a separate auction. The implication is that prices in Austria's 2013 multi-band auction of 800, 900 and 1800 MHz were inflated by some factor that cannot be explained by the model.

- **Denmark.** Denmark is a low price outlier for both 900 and 1800 MHz ratio benchmarks in Sample 1. The changes proposed by Telefónica reduce the gap between absolute and predicted values, but it is still at the boundary for the 900 MHz confidence interval and below the 1800 MHz confidence interval. The source of these observations appears to be the low absolute price benchmarks for 900 MHz and 1800 MHz. As we know these values were set by reserve price, the implication is that the Danish regulator set those prices below what we would expect based on our model.

- **Portugal 1800 MHz.** Whereas Portugal appears to be a good ratio benchmark for 900 MHz, the 1800 MHz ratio value is a low price outlier. Looking at the absolute benchmarks, it is apparent that 1800 MHz stands out as being below the predicted level, especially relative to 2600 MHz. As we know these values were set by reserve price, the implication is that the Portuguese regulator set the 1800 MHz reserve relative to the 2600 MHz reserve below what we would expect based on our model.

- **Sweden 1800 MHz.** Sweden is a high price outlier for the 1800 MHz ratio benchmark. This is true for both samples, but especially for Sample 1. Looking at the absolute benchmarks, this appears to be driven by the relatively high price of 1800 MHz relative to both 800 MHz and 2600 MHz. The 2600 MHz benchmark is a proxy valuation, so one implication could be that this has been set too low.

Note that these country data points are identified as outliers even in a model in which their effects are included. This is a very conservative approach to identifying outliers.

With respect to other countries that are particularly relevant for ratio benchmarks, we note that both Ireland and Romania are high price outliers for the absolute benchmarks but typically within the confidence interval for the ratio benchmarks. An interpretation could be that country specific effects supporting higher than predicted prices in these countries are closely correlated across bands and, to a significant extent, are cancelled out in the ratio benchmarks. That said, we note that Romania 900 MHz and Ireland 1800 MHz are close to the high end confidence interval (Romania is actually outside for 900 MHz Sample 1), and may therefore merit additional attention.

When attempting to determine a single UK benchmark value for 900 MHz and for 1800 MHz using the ratio approaches, a simple approach would be to take the mean average of the country data points for each band. If this were a large sample, this should be a good approximation for the UK value, as we would expect high values and low values to offset each other. Unfortunately, these are small noisy samples. Each individual observation contributes a lot to the mean, so the average is very vulnerable to distortions from outliers.

There are two potential solutions to this problem:

1. Drop outliers from the sample and recalculate the mean; or

2. Weight observations based on their performance in the model and other qualitative evidence, and derive the value from these weighted observations.

The problem with the first approach is that we are dealing with a small sample. Cutting values makes the sample even smaller. In such circumstances, if a confidence interval is used to eliminate outliers, the results may be unduly sensitive the choice of confidence interval.

In this case, we think the second approach is preferable, as it would allow Ofcom to place greater weight on more important evidence points without entirely disregarding other data points. To some extent, Ofcom is already doing this. The existence of tiers in Ofcom's qualitative analysis of country benchmarks is de facto recognition that some data points may be more reliable than others. The weakness of Ofcom's approach is that it does not start its analysis by considering whether particular data points may be outliers. As we explain in the next section, this omission appears to be distorting Ofcom's qualitative analysis of benchmarks. Specifically, it appears to do a good job at weeding out outliers when there are simple explanations, such as the reserve price being set "too low", but struggles when the explanation is more complex, such as the potential impact of strategic bidding or proxy bid setting.

3. Qualitative analysis of outliers

In section 2, we developed a statistical test to compare actual observations against predicted observations for different country benchmarks. Using this approach, we identified a number of outliers to the samples. In this section, we undertake a qualitative review of relevant country data points, with particular focus on outliers identified in the econometric tests. We focus on the ratio benchmarks for 900 MHz and 1800 MHz, as these are the approaches used by Ofcom in its analysis.

In its review, Ofcom ranks each country data point as Tier 3 (weakest evidence), Tier 2 (better evidence) or Tier 1 (best evidence), and weights its analysis accordingly. Where relevant, we highlight and seek qualitative explanation for discrepancies between Ofcom's tier choices and those implied by the results of the econometric tests. In most cases, Ofcom's tiering is consistent with the econometric model with some minor deviations that can be explained by qualitative analysis. A major exception is Austria, which Ofcom identifies as Tier 1 evidence for both 900 MHz and 1800 MHz, even though the econometric test implies it should be Tier 3. As we explain below, we do not identify any compelling qualitative reasons why Ofcom rates Austria above Tier 3.

3.1. 900 MHz band

The UK value of 900 MHz is derived from the ratio benchmark, which in turn is based on a sample of six observations. Amongst these observations, three country data points – Ireland, Portugal and Spain – are fairly close to the predicted level. Ofcom identifies Ireland as a Tier 1 observation, based on the fact the 800/900 ratio was derived from a competitive auction, and Portugal and Spain as Tier 2 observations based on the fact that the 800/900 ratio was influenced by reserve price setting. This approach seems entirely reasonable, so we do not consider these ratings any further.

Amongst the remaining country data points:

- **Austria** is a high price outlier, which implies it should be a Tier 3 observation unless there is strong qualitative evidence to suggest it should be viewed differently. However, Ofcom identifies it as Tier 1. This conclusion seems particularly odd given the statistical evidence, so we review the qualitative evidence in more detail in section 3.3.

- **Denmark** is a low price outlier in Sample 1 and at the bounds of the confidence interval in Sample 2. The implication is that it should be a Tier 3 observation for Sample 1 and either Tier 2 or Tier 3 for Sample 2, subject to qualitative review. Ofcom identifies Denmark 900 MHz as Tier 3.

  Ofcom's summary of stakeholder responses implies a broad consensus that the 900 MHz price was below market value, more so than the 800 MHz value, owing to a low reserve price and an absence of competition in the 900 MHz auction.[7] This is clear

[7] Ofcom, August 2014 Consultation, Annex 8, p.29.

qualitative evidence to support the statistical observation that Denmark is below the confidence interval using Sample 1 data, and hence Ofcom's decision to designate Denmark as Tier 3. Telefónica proposes using different data for Denmark (based on comparing the 800 and 900 MHz reserve prices), which has the effect of lifting the value up to the level of the lower confidence interval (and also narrows the confidence interval). This creates a borderline case for upgrading Denmark to Tier 2 when using Sample 2 data, given that there is precedent for using reserve price ratios (e.g. Portugal) as a measure of UK value.

- **Romania** is a high price outlier for Sample 1 and close to the upper bound confidence interval for Sample 2. This implies it should be Tier 3 under Sample 1, and either Tier 2 or Tier 3 under Sample 2, subject to qualitative review. Ofcom originally identified Romania as "more important evidence" but in its most recent consultation, downgrades it to Tier 3.

  In its revised analysis of Romania, Ofcom concludes that there is "*a risk that the 900 MHz auction price overstates market value in Romania (of an unknown extent and scale)*".[8] This analysis is consistent with comments from AM&A, Telefónica and Vodafone, as reported by Ofcom.[9] Ofcom also implicitly acknowledges that Romania may be a poor benchmark for lower frequency spectrum in the UK, as 2G traffic levels are particularly high, compared to the UK and other benchmark countries.[10] Taken together, this evidence supports Ofcom's decision to identify Romania as Tier 3, regardless of whether Sample 1 or Sample 2 data is used.

One further peculiar feature of the benchmarks for Austria and Romania is that the 900/800 ratio is greater than 1.0, meaning that the reported value for 900 MHz is higher than 800 MHz. This appears contrary to the general hypothesis that the value of 900MHz is less than 800 MHz, given that it is a higher frequency band and, unlike 800 MHz, not (yet) a core LTE band. Indeed, logically, it is difficult to reconcile Ofcom's conclusion that the 900/800 value ratio is 65% and its assertion that substantial weight should be placed on Austria as a benchmark for 900 MHz, when it has a ratio of 110%. We note that, under Sample 1, Ofcom disregards Denmark as an observation because its 2600 MHz price is above 1800 MHz. This precedent might imply that Ofcom should eliminate Austria and Romania from its 900 MHz observations, or else downgrade Austria to Tier 3 alongside Romania.

In summary, the statistical and qualitative evidence for 900 MHz ratio benchmarks appears to support Ofcom's categorisation of all benchmarks with the significant exception of Austria.

3.2. 1800 MHz band

The UK value of 1800 MHz ratio is derived using the distance methodology ratio benchmarks, which in turn is based on a sample of nine observations under Sample 1 and ten observations under Sample 2. In this case, there is significant variation from the predicted

[8] Ofcom, August 2014 Consultation, Annex 8, p.73.

[9] Ofcom, August 2014 Consultation, Annex 8, p.72.

[10] Ofcom, August 2014 Consultation, Annex 8, p.74.

levels. Four country data points – Germany, Ireland, Italy and Romania – are within the confidence interval. Amongst these, Ofcom identifies Ireland and Italy as Tier 1, Germany as Tier 2 and Romania as Tier 3. Two further data points – Czech Republic and Slovakia – are either inside or sit upon the lower confidence interval depending on which sample is used. Ofcom identifies both as Tier 3.

All these categorization decisions, except Romania, appear consistent with the econometric results. Furthermore, Ofcom's decision to downgrade Romania can readily be explained by the same qualitative issues identified above for 900 MHz. On first view, the decision to rank Germany below Ireland and Italy looks odd, but Ofcom justifies this on the basis that the German auction took place relatively early in the sample period when the position of 1800 MHz as a prime LTE band was less firm and that the 1800 MHz price may have been relatively weak owing to strategic bidding[11], both of which are plausible arguments. Therefore, with the exception of Ireland, where we have a concern regarding the impact of proxy values for 2600 MHz, we do not consider these rankings further.

Amongst the remaining country data points:

- **Austria** is an exceptional high price outlier, which implies it should be a Tier 3 observation unless there is strong qualitative evidence to suggest it should be viewed differently. However, Ofcom identifies it as Tier 1. As with 900 MHz, this conclusion seems particularly odd given the statistical evidence, so we review the qualitative evidence in more detail in section 3.3.

- **Denmark** was eliminated from Sample 1 because the reported 1800 MHz value is below the 2600 MHz value, an observation incompatible with the underlying thesis that the value of 1800 MHz lies between 800 MHz and 2600 MHz. Based on this data, this decision makes sense, but we note the inconsistency with the 900 MHz ratio, where observations that report a 900 MHz price above 800 MHz are not eliminated. Using Telefónica's alternative Danish data in Sample 2, no such problems arise but Denmark is a low price outlier, implying it should be a Tier 3 observation subject to qualitative review.

  Ofcom concludes that the Danish 1800 MHz likely understates market value relative to the 800 MHz and 2600 MHz, owing to a low reserve price and absence of competition in the 900 MHz auction.[12] Stakeholders provide no evidence to dispute this conclusion.[13] Accordingly, we conclude that there is qualitative evidence that supports the statistical observation that Denmark is an outlier using Sample 2, which implies it should be designated as Tier 3.

[11] Ofcom, August 2014 Consultation, Annex 8, p.37-38.

[12] Ofcom, August 2014 Consultation, Annex 8, p.30.

[13] Based on responses reported in: Ofcom, August 2014 Consultation, Annex 8, p.29-30

- **Portugal** is a low price outlier, which implies it should be Tier 3, subject to qualitative review. Ofcom identifies it as Tier 3.

  Ofcom concludes that the Portuguese 1800 MHz price likely understates value relative to 800 MHz and 2600 MHz, but the scale is unknown, because all these prices were at reserve level and may be underestimates.[14] Stakeholder comments primarily focus on absolute values and are not informative regarding the relative value of 1800 MHz.[15] Given statistical evidence that Portugal is an outlier and the lack of qualitative evidence to challenge this observation, Ofcom's designation of Portugal as Tier 3 seems sound.

- **Sweden** is a high price outlier, albeit much less so than Austria, which implies it should be a Tier 3 observation subject to qualitative review. Ofcom identifies it as Tier 2.

  Ofcom concludes that the Swedish 1800 MHz benchmark "*could be an understatement or overstatement of UK market value*."[16] This conclusion is at odds with statistical evidence, which suggests it is likely to be an overestimate. We have reviewed the qualitative evidence and conclude that Ofcom is probably in error on this point, as:

  - Ofcom concludes that the 800 MHz price likely understates value in Sweden and stakeholders apparently do not dispute this.[17] We note that the observed value in the statistical model is below the predicted level.

  - Ofcom also concludes that the 1800 MHz price likely understates value, owing to competition allegedly being reduced by the impact of a joint bid arrangement between two bidders. This conclusion is disputed by Telefónica, which points out that competition in the auction could have been enhanced by the joint bid, notwithstanding the lower number of bidders.[18] In the absence of any clear qualitative evidence to support either hypothesis, we note that the fact that the observed value for 1800 MHz is above the predicted level in our model suggests that greater weight should be attached to Telefónica's position.

  - The 2600 MHz price is a proxy value estimated by Ofcom. This has been set below the predicted value.

  - Taken together, the probable combination of a low 800 MHz benchmark, high 1800 MHz benchmark and low 2600 MHz benchmark would have the effect of exaggerating the ratio benchmark when using the distance methodology.

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14 Ofcom, August 2014 Consultation, Annex 8, p.68.

15 Based on comments reported in: Ofcom, August 2014 Consultation, Annex 8, p.65-67.

16 Ofcom, August 2014 Consultation, Annex 8, p.95.

17 Ofcom, August 2014 Consultation, Annex 8, p.95.

18 Ofcom, August 2014 Consultation, Annex 8, p.94.

> When comparing the results using Sample 1 and Sample 2, it is apparent that raising the proxy value for 2600 MHz reduces the 1800 MHz ratio benchmark. Indeed were it not for the impact of Denmark being added to Sample 2 (which squeezes the confidence intervals), the proposed change would have brought Sweden inside the confidence interval. We conclude that Sweden is potentially a Tier 2 benchmark, but with a significant risk of overstating the value of 1800 MHz.

Amongst the data sets, the Ireland and Sweden 1800 MHz ratio benchmarks stand out because they alone are derived using proxy values for 2600 MHz. As Telefónica describes in their response to this consultation, Ofcom's approach to determining proxy values is just one of many possible approaches, each of which give different results. Given the uncertainty over the proxy methodology, we recommend downgrading Ireland to Tier 2. Meanwhile, if Sweden is kept as Tier 2, Ofcom should put greater weight on the possibility it is overstating UK value.

In summary, the statistical and qualitative evidence for 1800 MHz ratio benchmarks broadly supports Ofcom's categorisation of available benchmarks with the significant exception of Austria. Some other, more modest changes should be also be considered: Ofcom should review the weight it places on the Irish and Swedish benchmarks given the impact of proxy values; it should acknowledge the risk that the Swedish benchmark is overstated and it should consider reinstating Denmark as a Tier 2/Tier 3 benchmark based on the alternative bid data proposed by Telefónica.

3.3. Austrian bid data

Amongst all the reported outliers in the 900 MHz and 1800 MHz ratio benchmark samples, Austria stands out because it is the only one rated as Tier 1. For both 900 MHz and 1800 MHz, the statistical evidence is that Austria should be a Tier 3 observation. Indeed, for 900 MHz, there is a plausible argument that it should be eliminated entirely given that it reports a value for 900 MHz that is 10% higher than 800 MHz, an observation which is clearly at odds with the consensus that 800 MHz is more valuable than 900 MHz.

In this subsection, we consider the qualitative evidence put forward regarding the merit or otherwise of Austria as a benchmark for the UK. We start by noting that Ofcom's position on Austria is highly controversial and this is reflected in the attention it gets in the August consultation document: 14 pages versus only 6-7 pages each for other countries used in the ratio benchmarks.[19] We observe that stakeholders have put forward multiple reasons why they believe Austria is likely to significantly over-estimate UK values. We recognise Ofcom's point that many of the arguments they put forward, such as the impact of strategic bidding, are hard to prove. However, we think that Ofcom is missing the point. Given the statistical evidence that Austria is an outlier, it should be for Ofcom to prove that Austria is nevertheless a good benchmark, not for stakeholders to prove that it is not.

[19] Ofcom, August 2014 Consultation, Annex 8.

Based on a review of Ofcom's consultation paper[20], the arguments put forward by stakeholders against placing substantial weight on Austria include the following:

- The Austrian award of 800, 900 and 1800 MHz used a CCA format, and band specific prices cannot be inferred directly. Instead, prices in Austria are derived using the LRP methodology, which is an approximation method. This introduces a risk or error, although it is ambiguous whether this could lead to ratios being over or under-stated.

- The underlying bid data for the Austrian multi-band auction has not been released. The analysis of UK auction prices has been supported by a rich debate over the impact of different bids. Such an analysis is impossible in the case of Austria.

- Relative to the UK and other auctions in the sample, spectrum caps were unusually lax. This may have encouraged bidders to make bids for larger packages than they needed, with bid values inflated by what Ofcom calls "strategic investment" (i.e. blocking value – the value of denying spectrum to a rival operator). However, absent publication of bid data, this cannot be proved.

- The lack of aggregate demand data in most of the clock rounds may have encouraged aggressive bidding behaviour, as each bidder likely feared paying proportionately more for smaller quantities of spectrum than their rivals. We note that other CCAs in Europe have been run with aggregate demand data published at the end of each round, so the perceived risk of relative overpayment may have been greater in Austria than elsewhere.

- Bidders may have engaged in deliberate price-setting strategic bids. Such tactics are potentially particularly relevant to a CCA, as prices are determined based on the losing bids of rivals. It is often the case in a CCA that bidders can identify packages and associated bid amounts that they have little or no chance of winning but which will like set an opportunity cost for rivals. However, there is no bid data available to test this hypothesis.

- If there was strategic bidding, based on blocking value and/or price setting, this may have had a disproportionate upward impact on the prices of 900 MHz and 1800 MHz. Incumbent operators may have had predictable, irreducible demands for these bands in order to avoid disruption to legacy operations. As a result, bids for large amounts of 900 MHz and 1800 MHz spectrum may either (a) carry particularly high blocking value because if they won they are certain to cause disruption to an rival; or (b) be particularly effective in price setting, as they have low chance of winning given that rivals will place particularly high values on packages that block such a bid. Predictable asymmetries between bidders may also encourage such behaviour: a stronger bidder, such as Telkom Austria, may have pursued strategy (a), while a weaker bidder, such as H3G, may have pursued strategy (b).

[20] Ofcom, August 2014 Consultation, Annex 8, p.9-13.

The lack of bid data means that allegations of strategic bidding in the Austrian auction cannot be verified from the auction results. However, as Telefónica reports in its response to the May Update Notice, there is direct evidence from the bidders that they believe that the auction process was flawed and that prices exceeded market value:[21]

- **Telekom Austria (TKA):** Under a slide entitled "*The Combinatorial Clock Auction Format is Highly Complex and Creates Partly Undesired Incentives*", Telekom states that "*Each bidder has a high incentive to bid on much more spectrum than its real demand and thus to reduce its demand late to influence the price of rivals*".[22]
- **T-Mobile:** "*If one of the three operators was unable to afford spectrum, they would not be able to provide 4G services, and we came very close to that scenario. Therefore, the prices set are at the market value of the entire company, rather than the market value of the spectrum.*"[23]
- **3 Austria:** "*For the industry as a whole, however, this auction result is a disaster…*"[24] "*The auction process was illegal in form and in substance. 3 Austria was considerably harmed. To simply accept this would be irresponsible.*"[25] "*Jan Trionow, CEO ofH3G, described the auction as a 'disaster for the industry' because the high pricing is likely to see rural rollouts abandoned*".[26]

In defence of its decision to designate Austria as a Tier 1 benchmark, Ofcom makes the following arguments:

- Some audit of Ofcom's prices is possible. Ofcom made available the software used to calculate LRPs and also released relevant diagnostic statistics on the four scenarios that were run. RTR, the Austrian regulator, also released data on average final clock prices for each band, and the ratios across these bands are similar to the ratios of the LRPs. We note, however, that this data does not allow bid-level analysis of the type that Ofcom itself focuses on when deriving prices from the UK auction.

- Ofcom argues that "*the available evidence does not provide clear evidence for or against the various allegations of strategic bidding that were put forward by*

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21 Telefonica UK, Annual licence fees for 900 MHz and 1800 MHz spectrum, Ofcom consultation response, 10 October 2013, p.13-14.

22 Telecom Austria Group, Results of the Austrian Spectrum Auction, October 21, 2013, p. 5.

23 Telecoms.com, 28 November 2013, http://www.telecoms.com/201711/t-mobile-austria-confirms-intent-to-appeal-auction-results/.

24 Quote from Jan Trionow, CEO of 3 Austria, in European Communications, 23 October 2013, http://www.eurocomms.com/industry-news/49-online-press/9370-austrian-operators-slam-having-to-spend-2-billion-on-4g-lte-spectrum.

25 Quote from Jan Trionow, CEO of 3 Austria, Telecoms.com, 28 November 2013, http://www.telecoms.com/201711/t-mobile-austria-confirms-intent-to-appeal-auction-results/.

26 Telegeography, 22 October 2013, http://www.telegeography.com/products/commsupdate/articles/2013/10/22/a1-scoops-half-of-spectrum-spoils-h3g-brands-process-a-disaster-for-industry.

stakeholders as materially affecting the relative values we use in our benchmarking analysis."[27] This conclusion in turn rests on two points:

- Ofcom acknowledges that it is possible that that bids in the auction may have been influenced by strategic investment or price setting behaviour. However, it argues that there is no clear evidence of such behaviour and that such bidding would be risky.

- Ofcom further argues that, even if such behaviour took place, it is ambiguous what impact it would have had on its ratio benchmarks. In particular, it concludes that there is no evidence to suggest that prices of 900 MHz would have been driven up more than 800 MHz, and only weak evidence to suggest that 1800 MHz may have been driven up more than 800 MHz.

The approach put forward by Ofcom with respect to strategic bidding in consistent with its general position on this subject:

> *"As stated in paragraph 7.91 our approach to allegations of strategic bidding is to identify the direction of the potential understatement or overstatement, but to judge both the risk and the scale of any effect as being unknown, in the absence of clear evidence that it occurred.*"[28]

Such a position, however, lacks credibility in this case, for a number of reasons. Firstly, the statistical evidence is that Austria is an outlier for both ratio benchmarks and all absolute benchmarks relating to the multi-band auction. In this context, the argument that both absolute and relative prices were distorted by strategic bidding seems plausible (especially give the comments made by actual bidders), and it should be for Ofcom to disprove this allegation, not for stakeholders to prove it. Secondly, in the absence of any published bid data, it is obviously impossible to discern how relative prices were affected by strategic bidding, so Ofcom's demand for evidence is not reasonable. In this case, the presumption should be in favour of the statistical evidence, which tells us that Austrian benchmarks overstate UK value. Finally, in the case of 900 MHz, the observation that the price was above 800 MHz only reinforces the conclusion that something odd happened in the Austrian auction and the benchmarks are not reliable.

In conclusion, we observe that there is a plausible narrative to explain why Austrian benchmarks are high price outliers. This narrative alleges that strategic bidding behaviour drove prices upwards beyond the market level and also distorting price ratios across bands. The absence of published bid data means that it is not possible to verify this story. Equally, it is impossible to prove the counter-factual that price ratios were not distorted. Given the strong statistical evidence that Austrian data points are outliers, we conclude that the reasonable approach is to presume that Austrian bid data is suspect, and to downgrade it to a Tier 3 observation.

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[27] Ofcom, August 2014 Consultation, Annex 8, p.17.

[28] Ofcom, August 2014 Consultation, Annex 8, p.15.

4. Conclusion

In this paper, we make the case for Ofcom to introduce a new step in its analysis of country benchmarks. We propose that, prior to undertaking a "bottom up" qualitative analysis of individual observations, Ofcom should apply a "top down" econometric evaluation to screen for potential outliers. This approach provides a framework for allocating observations to Ofcom's three tiers of evidence which can then be refined through qualitative reasoning. In particular, in cases where lack of evidence may make qualitative reasoning difficult, it provides an objective basis for tier designation.

We develop such a test and apply it to the benchmark data used by Ofcom, with particular focus on the ratio benchmarks used by Ofcom to assess the UK value of 900 and 1800 MHz. We also consider the qualitative evidence used for tiering evidence points, with particular focus on observations identified as outliers. In most cases, Ofcom's tiering is consistent with the econometric model with some minor deviations that can be explained by qualitative analysis.

However, there are some country benchmarks where we propose changes:

- **Austria 900 MHz (Tier 3) and 1800 MHz (Tier 3).** These observations are outliers in the econometric test. There is qualitative evidence that ratios may have been distorted owing to strategic bidding. This hypothesis is uncertain but there is no firm evidence to refute it. Accordingly, the reasonable presumption is that both Austrian benchmarks should be Tier 3, not Tier 1.

- **Denmark 900 MHz (Tier 2/Tier 3) and 1800 MHz (Tier 3).** Telefónica put forward alternative benchmarks for Denmark from which it generates estimates for 900 MHz and 1800 MHz that are more plausible than the Ofcom data and improve the fit of the econometric model. The 900 MHz ratio sits on the confidence interval and there are qualitative arguments that could place it in either Tier 2 or Tier 3. The 1800 MHz value is an outlier and clearly Tier 3.

- **Ireland 1800 MHz (Tier 2).** This value is significantly above the predicted level. Given that this value is sensitive to the level of the 2600 MHz proxy, we think it should be downgraded from Tier 1.

- **Sweden 1800 MHz (Tier 2, risk of overstating).** This value is a high price outlier. There is a qualitative evidence to suggest that the benchmark overstates value and is sensitive to the level of the 2600 MHz proxy. We do not think it is necessary to downgrade the benchmark provided that Ofcom acknowledges the risk of over-statement (at present it says the benchmark could over or understate value).

Amongst these changes, Austria is by far the most important. Ofcom's designation of Austria as Tier 1 lacks credibility, and highlights the peril of relying solely on qualitative evidence (or, in this case, the lack of it) without a statistical screening process to identify outliers.

Appendix 1: Datasets

Sample A: Ofcom data

	Absolute price benchmarks by band (£m/MHz)				Ratio price benchmarks (£m/MHz)		
Country	800MHz	900MHz	1800MHz	2.6GHz	900/800	1800 (Distance)	Population
Austria	72.17	79.38	48.55	1.88	39.19	25.51	8,445,514
Belgium	30.01			4.99			11,100,000
Czech Republic	44.08		5.97	2.98		7.47	10,500,000
Denmark	16.21	2.88	1.23	10.30	6.13		5,558,382
Finland	15.59						5,440,314
Germany	52.94		1.85	1.64		5.63	81,800,000
Greece		32.85	14.48				11,300,000
Ireland	63.55	39.56	25.23	6.81	20.31	14.31	4,588,798
Italy	52.07		16.69	3.80		13.55	60,700,000
Latvia	3.50						1,992,762
Lithuania	1.79						2,940,845
Portugal	37.32	24.88	3.25	2.49	21.75	6.09	10,600,000
Romania	43.93	47.35	19.02	10.57	33.5	11.98	21,300,000
Slovak Republic	38.54		7.05	4.60		7.46	5,422,150
Spain	40.42	26.38		3.27	23.25		46,200,000
Sweden	21.16		9.66	2.00		17.51	9,449,213

Source: Ofcom, ALF 900-1800 MHz: Final benchmarking dataset

Notes: Empty cells indicate no data available in the Ofcom reference period. To calculate a single population point for each country, we took the simple average of the population amounts reported in the Ofcom spreadsheet for each relevant award for that country.

Sample B: Ofcom data with adjustments proposed by Telefónica

	Absolute price benchmarks by band (£m/MHz)				Ratio price benchmarks (£m/MHz)		
Country	800MHz	900MHz	1800MHz	2.6GHz	900/800	1800 (Distance)	Population
Austria	72.17	79.38	48.55	1.88	39.19	25.51	8,445,514
Belgium	30.01			4.99			11,100,000
Czech Republic	44.08		5.97	2.98		7.47	10,500,000
Denmark	5.84	2.88	1.23	1.12	16.91	6.14	5,558,382
Estonia	13.80						1,333,788
Finland	15.59						5,440,314
France	36.29			5.41			65,436,552
Germany	52.94		1.85	1.64		5.63	81,800,000
Greece		32.85	14.48				11,300,000
Ireland	63.55	39.56	25.23	6.83	20.31	14.30	4,588,798
Italy	52.07		16.69	3.80		13.55	60,700,000
Latvia	3.50						1,992,762
Lithuania	1.79						2,940,845
Portugal	37.32	24.88	3.25	2.49	21.75	6.09	10,600,000
Romania	43.93	47.35	19.02	10.57	33.5	11.98	21,300,000
Slovak Republic	38.54		7.05	4.60		7.46	5,422,150
Spain	40.42	26.38		3.27	23.25		46,200,000
Sweden	21.16		9.66	3.32		16.20	9,449,213

Sources: Ofcom, ALF 900-1800 MHz: Final benchmarking dataset; and adjustments proposed by Telefónica in Section 5 of its response to the August 2014 Consultation.

Notes: Highlighted cells indicate data points that are different from Sample 1. Empty cells indicate no data available in the Ofcom reference period. To calculate a single population point for each country, we took the simple average of the population amounts reported in the Ofcom spreadsheet for each relevant award for that country.

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