dot·econ

Award of 800MHz and 900MHz spectrum

Update report on benchmarking

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Contents

Tables & Figures

1   Benchmarking update

1.   In Part C of the DotEcon Report[1] (09/99c) accompanying ComReg's Response to Consultation and Further Consutlation Document (09/99) published in Dec 2009, DotEcon carried out a benchmarking analysis comprising calculating simple averages benchmarks as well as using a regression analysis to estimate the value of 900MHz spectrum in Ireland (here by known as the original benchmarking analysis). The estimates produced an implied value for a 2x5MHz licence of liberalised 900MHz spectrum ranging from €16m-€34m, presented in Table 12 of the DotEcon Report (09/99c) and reproduced in Figure 1 below.

2.   In section 2, we consider the impact of including 800MHz spectrum in the upcoming auction to be awarded alongside liberalized 900MHz spectrum in Ireland.

Figure 1: Original benchmark results

Benchmark group	Technique	Implied price of a 2x5MHz licence in Ireland
All mobile	Average benchmark	€29.1m
	Regression benchmark	€24.3m
Europe	Average benchmark	€22.9m
	Regression benchmark	€16.7m
GDP	Average benchmark	€26.3m
GSM only	Average benchmark	€33.2m
	Regression benchmark	€26.1m
3G only	Average benchmark	€33.6m
	Irish average	€22.3m

3.   At the request of ComReg, following responses to the 09/99 Consultation, we have updated the benchmarking analysis to include some of the more recent auctions such as the wave of 2.5/2.6GHz auctions in Europe and the Singapore Public Cellular Mobile Telecommunication Services (PCMTS) spectrum auction that were not included in the original analysis. The latter, in particular, was

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[1] DotEcon Limited, 2009, Liberalisation of spectrum in the 900MHz and 1800MHz bands – Final Report to ComReg. ComReg Document Number 09/99c.

cited as relevant comparator to 900MHz spectrum value in Ireland by one respondent in the consultation process.

4. We have also updated the Irish GDP and population data used to predict prices in our regression model (displayed in Table 5) to that that are available at present. In particular, we use data from the Central Statistics Office Ireland for this purpose. We describe this further in section 3.3. Doing so allows our regression analysis to reflect to a certain extent the effects of the current on-going recession; several respondents complained that the historic time period for the original benchmark analysis did not reflect the more recent economic downturn.

5. The original benchmarking analysis was carried out using spectrum awards data from DotEcon's spectrum awards database. This database has been compiled over many years for a wide range of tasks, not just for the current benchmarking exercise. The database is updated regularly with the addition of new data as well, as updates whenever audits of the data are carried out or new information comes to light. In particular, these regular maintenance updates have lead to some minor changes in the data. The relevant changes to the data sets used are presented in Section 2 below.

6. The same benchmarking analysis as in our previous report has been carried out on the updated data sets (referred to below as "original averages approach" or "original regression analysis"). Further, where applicable, some modifications have been made to the benchmarking approaches so as to account for the impact of new auction data added (referred to as "modified averages approach" or "modified regression analysis").

7. A description of the updated benchmarking analysis and results are presented in Section 4.

2   Impact of including 800MHz spectrum in auction

8.   ComReg has decided to consult on the inclusion of the 800MHz digital dividend spectrum alongside the sale of liberalized 900MHz spectrum in the upcoming auction. In the DotEcon Report (09/99c), we recommended a minimum price towards the upper end of the estimated valuation for liberalized 900MHz spectrum on the basis that there were substantial concerns about weak competition given the close match between the spectrum available for sale and the likely demand.

9.   We note that 900MHz and 800MHz spectrum could differ in value depending on the idiosyncrasies of potential bidders. For instance, an incumbent could have a higher valuation for liberalized 900MHz spectrum compared to 800MHz spectrum due to short-run business continuity reasons or as part of their long term network migration strategy. However, 800MHz provides an opportunity to roll out new services unencumbered by transitional problems due to legacy services. Some operators may even want a mix of 800MHz and 900MHz to reduce risks of technologies and equipment being available sooner in one band than the other. Different operators might well have quite different views about all these different factors depending on their future plans.

10.   Given the current lack of data on the relative value of liberalized 900MHz spectrum and 800MHz spectrum, there is no way to explore the potential for differences in spectrum value across these bands. Indeed, given the very similar radio propagation characteristics, one would expect the long-run value to be similar and value differences to be limited, mainly as a result of short-run legacy issues with the 900MHz band.

11.   Therefore, while in theory the minimum price for 800MHz should too be set according to a specific market valuation of 800MHz spectrum and ComReg's objectives and concern for spectrum in this band, to date there is insufficient information and data to predict this valuation with any certainty. Indeed, only Germany has awarded 800MHz spectrum in its auction that ended in May 2010. This data point provides valuable information about the value of liberalised sub-1GHz spectrum and is taken into account in this updated benchmarking exercise.

12.   Therefore, there are good reasons to expect 800MHz and 900MHz spectrum to have similar market value. In any case, there is no evidence yet available to suggest a systematic value difference. Even if such a different existed, it would very likely be swamped by the 'noise' in measuring it. This means that there is a strong case for a common minimum price for 800MHz and 900MHz spectrum in the upcoming auction and reflecting any residual uncertainty in a slightly more conservative approach to setting the common level.

13.   Note that this does not mean that 800MHz would be or is of identical value to liberalized 900MHz spectrum or suggest that the final auction outcome would yield such an outcome. Rather that given the similarities between the two bands and simultaneously the uncertainties over relative valuation, it is sensible and practical to set a common reservation value for these spectrum bands and as long as efficient demand is not choked off at the common minimum price chosen, the auction process will determine the final values of these licences.

14. The difficulty that inclusion of 800MHz spectrum creates is the greater uncertainty about market valuation. This is both because there is uncertainty over the relative values of 800MHz versus 900MHz spectrum and also because the supply of sub-1GHz spectrum would be significantly increased. However, at the same time, ComReg may be able to set a more relaxed spectrum cap (as compared with its proposal of 2 x 10MHz in ComReg 09/99) which may significantly boost total demand. Overall, it is difficult to reach any firm conclusions about what these various factors may mean for likely auction prices.

15. Thus, in determining the minimum price for 800MHz and 900MHz for the upcoming auction, it would be wise to take account of the somewhat greater uncertainty about value that the new situation creates. In particular, setting a reserve price too high risks choking off demand inefficiently; arguably we need to give somewhat greater weight to this risk that previously to reflect this greater uncertainty. This consideration suggests that a modest adjustment of minimum price may be needed.

3   Changes to the data

16.   This section describes the changes to the dataset since last used to produce the original benchmarking analysis in June 2009. Changes include new auction data, as well as some augmented data as a result of the audits DotEcon has carried out on its database since the original benchmark analysis. This is a large dataset and it is under continuous maintenance. Further, we include updated USD Consumer Price Index data (CPI) as well as PPP rates for May 2010 so that all prices are presented in current real terms rather than estimates of inflation being used as previously (due to official data not yet being published).

3.1   Auction data

17.   Several new auctions have taken place since June 2009, namely the recent wave of 2.5/2.6GHz auctions across Europe. Germany, in particular, has held a multiple frequency auction in which frequencies in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz band have been auctioned off simultaneously. India completed its 3G auction in May 2010.

18.   Further, the Singapore Public Cellular Mobile Telecommunications Services Auction in 2008 and the 1800MHz auction in 2009 have been added to the dataset. The Brazil 2G auction at the end of 2007 had been dropped from the data set used in our original benchmarking analysis as regional population data of the area covered by the licences were missing. This has now been added to the database and the price data from this auction included in the updated benchmarking analysis. Although this new data mainly includes 2G frequencies awarded other than 900MHz, there is still benefit to including the additional information due to the econometric approach we employ. Table 1 below presents a list of new awards that have added to the original data set.

Table 1: New auction data used in updated benchmarking analysis

Country	Award	Date	Average auction price per MHz per pop Euro[2]
Brazil	2G licences Auction	Dec 2007	€0.0628
Singapore	Public Cellular Mobile Telecommunications Service Auction	Feb 2008	€0.0318
Singapore	1800MHz Auction	Feb 2009	€0.0332
Finland	2.6GHz Auction	Nov 2009	€0.00286
Netherlands	2.6GHz Auction	April 2010	€0.00380
Denmark	2.5GHz Auction	May 2010	€0.0914
India	3G Auction	May 2010	€0.615
Germany	Frequency Auction	May 2010	€0.208

19.   In addition, through several audits on DotEcon's spectrum awards database, some of the changes made have led to alterations to the original dataset applied for the original benchmarking analysis:

- Poland E-GSM auction in 2008 – The award process was originally listed as a sealed bid, but further checks carried out have found the award process to be a beauty contest with a monetary value component as part of the evaluation criteria. Given the benchmarking analysis only takes into account spectrum allocated through auctions, this data point has been dropped from the dataset that will be applied to the updated benchmarking analysis;

- US Auction 33 and Auction 38 on Upper 700MHz guardbands – Audits have shown that while 700MHz spectrum was awarded in these auctions,

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[2] Prices are expressed in May2010 real Euro terms and licence value have been adjusted to reflect that of a 15 year licences as described in footnote 44 of the DotEcon Report (09/99c). Auction prices are converted from local currency into May 2010 real Euro terms using the same methodology as described in section 17.3 of the DotEcon Report (09/99c). Updated CPI data and PPP rates are described in section 3.2 below.

The average auction price is calculated by using a population weighted approach, that is, for an auction where regional licences are sold, the licence value in the more populous regions will hold more weight in the calculation of the auction average price, where licences are national, and this approach would be identical to calculating a simple average.

cellular systems were not permissible operations in the spectrum sold. Hence these auctions were dropped given we only consider spectrum that could be use for the provision cellular mobile service;

- Ireland Wideband Digital Mobile Auction in 2005 – The spectrum sold in this auction (2 licences in the 450MHz band and 1 licence in the 900MHz band) were service specific to provide high speed data services and not cellular mobile services and hence have been drop from the dataset.

- Saudi Arabia 3rd mobile licence in 2007 – in addition to GSM frequencies, 3G spectrum (2GHz) was also awarded to the winner (MTC Consortium), hence this price point will be added to the 3G auctions dataset.

20. A full list of auctions used in the updated benchmarking analysis is presented in Annex A.

3.2 USD CPI Monthly data and Euro PPP rates

21. DotEcon's spectrum awards database stores licence price and minimum price information in local currency. When carrying out analysis, we typically apply a Purchasing Price Parity (PPP) exchange rate to account for price differences across countries in converting these prices into USD. We then adjust for USD inflation using monthly CPI data published by the US Bureau of Labour Statistics[3]. This establishes comparable prices in real US dollars.

22. The CPI data presented by the US Bureau of Labour Statistics for months within a year are approximations that receive interim adjustments the following year and are eventually finalised the year after that. Therefore, the CPI data used in the original analysis in June 2009 used finalised CPI figures for 2007 and earlier only. This data has now been updated such that 2008 and earlier CPI data is now finalised and interim adjustments have been made to 2009 CPI data.

23. After prices are expressed in real USD May 2010 terms we then convert prices into Euro using a US dollar to Euro PPP rate. The interbank rate in 2010 up till the end of May of USD to Euro was on average 0.741$/€. Using the same methodology explained in section 17.3 of the DotEcon Report (09/99c), the USD to Euro PPP rate is approximately 10% higher than the interbank rate. Therefore the USD to Euro PPP rate used is 0.815 and all prices presented in the updated benchmarking analysis below are expressed in Euro May 2010 terms.

3.3 GDP and population data in Ireland as inputs for prediction in regression model

24. We have updated the Irish GDP and population data used as inputs for predicting licence value in Ireland with the regression models. In particular when we last did the benchmarking analysis presented in the DotEcon Report (09/99c), only data from 2008 on GDP and population were available. Currently

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[3] http://www.bls.gov/

we have updated this to 2009 data with information from the Central Statistics Office Ireland.

25.   In 2009, Irish GDP at current market value was €159,646m and population was 4,459,300; this equates to a GDP per capita of €35,800/head. This is 17.4% lower than the GDP per capita in 2008 (€43,400/head) we used in our original analysis. Therefore, our price predictions would consequently be depressed from this shrinkage of GDP per capita even if no other changes had been made[4]. Notice that the econometric model used for predictions uses GDP at the time of licence award as an explanator of licence value. Although predictions are strongly influenced by assuming lower GDP, we must also remember that licences are long-lived and that the recent fall in GDP may be only a short-run deviation from long-term trends that will in part be made up over the long run. In this case it is possible that the fall in predicted licence values as a result of lower GDP is an overstatement of the true impact on the value of long-lived licences. However, this comment can only be speculative as we clearly have little means to forecast such developments and the recent fall in GDP is unprecedented within the period being analysed.

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[4] Further we note that the movements of Irish GDP versus GNP may be quite stark. We have chosen GDP as an independent variable in our regression model over GNP as it is a better reflection of the domestic value of output in a country which in turn is a closer proxy factors that may affect spectrum valuations such as the level of development in a country and potential willingness to pay for telecommunications services.

4 Updated benchmarking analysis

26. The same methodology of benchmarking auction data as presented in Section 10.5 of the DotEcon Report (09/99c) was applied to the updated auction datasets as described in section 2 above and presented in Annex A. This comprises of two approaches:

    1. Averages are benchmarks calculated using various cuts of spectrum auction data:
        a. All mobile spectrum auctions;
        b. All mobile spectrum auctions in Europe;
        c. All mobile spectrum auctions in countries with similar GDP per capita to Ireland[5]
        d. All mobile spectrum auctions of GSM licences; and
        e. All mobile spectrum auctions of 3G licences.
    2. Regression analysis run on 3 datasets:
        a. All mobile spectrum auctions;
        b. All mobile spectrum auctions in Europe; and
        c. All mobile spectrum auctions of GSM licences.

27. The new auction data added is particularly heavy on non-GSM spectrum, especially given the recent wave of 2.5/2.6GHz spectrum auctions across Europe. Non-GSM spectrum can be expected to have a lower value at it tends to be at higher frequency (on average) and there may be less de facto transnational coordination in how it is used. Indeed, the auction average prices of these auctions (presented in Table 1) are mostly below that of the benchmarks from the original benchmarking analysis (see Figure 1) which range roughly from €0.40 to €0.80 per MHz per pop[6.] Thus it is to be expected that the inclusion of this new auction data will drag down the benchmarks of sub-1GHz spectrum. In the remainder of this section below, we consider some modifications to both approaches to better take into account the impacts of the new auction data.

28. These modifications are elaborated further below in Section 4.1 for the averages approach and Section 4.2 for the regression approach. All benchmarking analysis is done on a price per pop per MHz basis and then converted to the value of a 2x5MHz licence in Ireland by multiplying by the Irish population of 4,459,300 and licence spectrum size of 10MHz. An overview of results of the updated benchmarking analysis is presented in Section 4.3 below.

4.1 Modifications to benchmarking using averaging method

29. The benchmarking using averaging method approach calculated the average price per MHz per head of population[7] of all auction average prices within the

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[5] Countries with GDP per capita higher than €20,000.

[6] See Table 8 and 11 of the DotEcon Report in document 09/99c.

[7] Such a price is calculated on a per unpaired MHz per head of population basis.

dataset considered to produce a benchmark. It is simple and quick to apply, though it is a relatively blunt tool particularly when different frequency bands are sold in the same auction, such as in the recent German Frequency Auction. The auction average price was roughly €0.20 per MHz per pop across all spectrum frequency licences, however the 800MHz frequencies licences sold for an average of approximately €0.70 per MHz per pop. In calculating the averages benchmark for all mobile spectrum auctions of GSM licences for instance, it would make more sense to take the €0.70 average price point rather than the auction average of €0.20.

30. Hence for band-specific average benchmarks (i.e. the GSM licences and 3G licences averages benchmarks), we consider the relevant frequency band specific average auction price. For example in the GSM averages benchmarks, we will take both the average 800MHz prices as well as the average 1800MHz prices (but not the 2GHz or 2.6GHz prices) in calculating the benchmark.

31. The results of the averages benchmarks (for each of the different data cuts listed above) using the updated data set in applying the original averaging method as well as the modified averaging method as described above is presented in Table 2 below. The implied value of 2x5MHz in Ireland calculated in the table belows applies the 2009 Irish population of 4,459,300 from the Central Statistic Office Ireland.

Table 2: Updated averages benchmarks with new dataset

Benchmark group	Original averaging method		Modified averaging method	
	Average price per MHz per pop (Euros)	Implied value of 2x5MHz in Ireland (Euros)	Average price per MHz per pop (Euros)	Implied value of 2x5MHz in Ireland (Euros)
All mobile	€0.654	€29.2m	Not applicable	
Europe	€0.527	€23.5m		
Similar GDP per capita	€0.582	€26.0m		
GSM	€0.683	€30.4	€0.692	€30.9m
3G	€0.891	€39.7m	€0.887	€39.5m

32. All the updated averages benchmarks are lower on a per MHz per pop basis than that in the original benchmarking analysis except for the 3G benchmark group. The updated 3G average benchmark has been inflated by the inclusion of the Saudi Arabia mobile licences won by MTC in 2007 as described at the end of Section 3.1 above. If we were to exclude this particular price point, the original averaging method would produce a benchmark of €0.765 per MHz per pop (€34.1m for a 2x5MHz licence in Ireland) and similarly for the modified approach, €0.761 per MHz per pop (€33.9m for a 2x5MHz licence in Ireland),

which would be slightly lower on a per MHz per pop basis - as expected - than the original benchmarking analysis.

33. Further we note that the 3G benchmark group contains a number of outliers including other than the Saudi Arabian price point described above such as 3G auctions in UK and Germany during the 2000/1 TMT equity bubble that inflates the benchmark average price for this benchmark category. This does not necessarily render the benchmark uninformative but does suggest that caution be applied in interpreting the benchmarks.

4.2 Modifications to regression analysis

34. The first of the original regression data set consists of all mobile licences sold in an auction and is specified as follows:

Equation 1: Original regression equation for all mobile licences sold in an auction

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + ...$$
$$... + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \beta_{AFME} \cdot AFME + ...$$
$$... + \beta_{preIT} \cdot preIT + \beta_{year01} \cdot year01 + \beta_{year0203} \cdot year0203 + \beta_{year0405} \cdot year0405 + ...$$
$$... + \beta_{year0607} \cdot year0607 + \beta_{year080910} \cdot year080910$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $ApPop$ is area per capita, a measure of population density;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNMNOs$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $AFME$ is a dummy variable which is 1 if it is an African or Middle-Eastern country and 0 if not; and
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy, which is 1 if the licence was sold in these years and 0 if not. Years are grouped where there are few awards in a year. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

35.   We use a weighted least squares estimator (using the same weights for each individual licence as for the calculation of weighted average price per MHz per population for each auction as used in the average-based benchmark approach) to estimate the coefficients of the model.[8] The results are summarised in the following table.

Table 3: Original regression analysis using all mobile licences sold in an auction

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000181**	0.000001
ApPop	-0.919**	0.229
WtB	-1.93**	0.0688
invNmnos	2.20**	0.255
national	0.0429	0.0445
AFME	0.775**	0.0593
preIT	0.758**	0.101
yearD_01	-1.03**	0.0849
yearD_0203	-1.82**	0.0970
yearD_0405	-1.49**	0.0906
yearD_0607	-1.49**	0.0876
yearD_080910	-1.33**	0.0856
Constant	2.26**	0.127

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively.

36.   We note that in the changes to the dataset has resulted in the dragging down of the GDPpc coefficient by about 10% as compared to that in the original benchmarking exercise presented in Table 9 of the DotEcon Report (09/99c). In addition the reduction of GDP per capita in Ireland in 2009 of about 17.4% will further drag down predicted spectrum value for sub-1GHz spectrum in Ireland. On the other hand, the coefficient of ApPop has increased by about 15%, which will have an uplift impact on predicted licence value. The net effect of these

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[8] For more information on this estimator, see Greene, W, 2003, Econometric Analysis Fifth Edition, pp.225-227.

effects on predicted spectrum value in Ireland is illustrated in more detail in Table 7.

37. In addition, we should also consider if the augmented data set impact on the coefficients of the regression model is sensible and contextual for the upcoming auction of sub-1GHz frequencies in Ireland. In particular, prices for 2.6GHz spectrum in the recent wave of 2.6GHz auctions are below the average value of mobile spectrum. This is to be expected, as differences in radio propagation suggest that higher frequency bands such as 2.6GHz should be less valuable than sub-1GHz frequencies. Finland and the Netherlands in particular, saw exceptionally low prices in their 2.6GHz spectrum that was partly caused by flaws in the auction design in the former case and strict spectrum caps in the later. Hence it follows that the inclusion of these data would depress price predictions. To control for this, we may include a dummy for 2.5/2.6GHz, which proves to be a significant explanatory variable in this regression model. The modified regression analysis is specified as follows:

Equation 2: Modified regression equation for all mobile licences sold in an auction

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \ldots$$
$$\ldots + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \beta_{twopoint six} \cdot twopoint\ six + \ldots$$
$$\ldots + \beta_{AFME} \cdot AFME + \beta_{preIT} \cdot preIT + \beta_{year01} \cdot year01 + \beta_{year0203} \cdot year0203 + \ldots$$
$$\ldots + \beta_{year0405} \cdot year0405 + \beta_{year0607} \cdot year0607 + \beta_{year080910} \cdot year080910$$

where:

- $twopoint\ six$ is a dummy variable that is 1 if the spectrum licences sold is within the 2500-2690MHz range;

- and all other variables are as above.

38. The results are summarised in the following table.

Table 4: Modified Regression analysis using all mobile licences sold in an auction

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000184**	0.000001
ApPop	-0.942**	0.229
WtB	-1.89**	0.0696
invNmnos	2.24**	0.255
national	-0.150	0.0445
twopointsix	-0.230**	0.0602
AFME	0.771**	0.0592
preIT	0.759**	0.101
yearD_01	-1.04**	0.0848
yearD_0203	-1.83**	0.0969
yearD_0405	-1.49**	0.0904
yearD_0607	-1.47**	0.0876
yearD_080910	-1.26**	0.0875
Constant	2.22**	0.128

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively.

39.   The Irish-specific assumptions for explanatory variable used for predictions presented in Table 10 of the DotEcon Report (09/99c) is reproduced in Table 5 below, we first predicted the value for sub-1GHz spectrum in Ireland using these same explanatory variables (2009 explanatory variables) and the original benchmarking analysis to allow comparability of the results due to the augmentation of the datasets. In addition we will also apply the updated explanatory variables for Ireland (2010 explanatory variables) as presented in Table 6 to the original benchmarking analysis to show the impact of change of Irish explanatory variables such as GDP and population. This will allow comparability of results from the changes in Irish explanatory variables in the past year. Finally we apply the 2010 explanatory variables for Ireland to the modified regression analysis to provide a more contextual update to the valuation of sub 1-GHz spectrum in Ireland in 2010. We present these effects in Table 7.

Table 5: Inputs used for predictions in original benchmarking exercise

Independent variable	Value
Population	4,203,200
GDP per capita (in Euros)	43,300
Number of mobile network operators	4
Number of participating bidders	5
Winners to bidders	0.86
Area (in square kilometres)	70,280
Year	2009

Table 6: Inputs used for predictions in updated benchmarking exercise

Independent variable	Value
Population	4,459,300
GDP per capita (in Euros)	35,800
Number of mobile network operators	4
Number of participating bidders	5
Winners to bidders	0.86
Area (in square kilometres)	70,280
Year	2010

40. The same regression analysis is applied to the European spectrum auctions data set as well as to the GSM spectrum auctions dataset as per the original benchmarking analysis in the DotEcon Report (09/99c). However we note that in the case of the European spectrum auctions dataset, the "twopointsix" dummy does not fully account for the effects of depression of mobile spectrum valuation as a result of the addition of new 2.6GHz auction data, as a substantial chunk of explanatory power in this regard would in any case be attributed to the year080910 dummy given the dates of these auctions. We should therefore expect the European spectrum auctions regression model to produce significantly lower benchmark for Irish sub-1GHz spectrum than before.

41. Indeed this is the case as shown in comparing our original benchmarking results in Figure 1 to the updated regression benchmarks in Table 7 for the case in which the orginal regression approach was applied with 2009 Irish explanatory variables (a) to produce an estimated spectrum value for Ireland. However we

note that this is mainly a result of depression of mobile spectrum valuation as a result of the weight of recent 2.6GHz data within the European spectrum auction dataset. If we were to run the original regression analysis without any 2.6GHz licence price points, the predicted price using Irish 2010 explanatory variables (Table 6) for a 2x5MHz licence in Ireland would be around €20.3m which is consistent with our original benchmark from the DotEcon Report (09/99c) as shown in Table 8. We present this as our "modified regression approach" benchmark[9] for the European mobile spectrum auctions dataset in Table 7 below and display the regression results in Table 15. A full list of all spectrum auctions considered can be found in Annex B.

42. As described in paragraph 39, the following table summarizes the impact of (a) the augmentation of the dataset, (b) the changes to Irish explanatory variables and finally (c) the modified regression approach on predicted licence value for sub-1GHz spectrum in Ireland.

Table 7: Updated regression benchmarks

Data set	(a) Original regression approach with 2009 explanatory variables		(b) Original regression approach with 2010 explanatory variables		(c) Modified regression approach with 2010 explanatory variables	
	Price per MHz per pop (Euro)	Implied vale of a 2x5MHz block in Ireland (Euro)	Price per MHz per pop (Euro)	Implied vale of a 2x5MHz block in Ireland (Euro)	Price per MHz per pop (Euro)	Implied vale of a 2x5MHz block in Ireland (Euro)
All mobile	€0.474	€19.9m	€0.339	€15.1m	€0.416	€18.6m
Europe	€0.161	€6.7m	€0.128	€5.7m	€0.455*	€20.3m
GSM	€0.754	€31.7m	€0.409	€18.3m	Not applicable	

*Benchmark produced excludes 2.6GHz spectrum

43. In general, across all the data sets, the changes to the data sets concerned have dragged down the licence price predictions. In addition the change in Irish explanatory variables, namely the significant drop in GDP per capita has further reduced the predicted licence value of spectrum in Ireland. The modified regression approach goes some way in putting into context the impact on

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[9] When the 2.6GHz data is dropped from the European data set, the twopointsix dummy in the modified regression equation would have no explanatory power and hence dropped from the modified equation regression. Hence the original and modified regression approach in this case would be equivalent.

predicted value of the augmented data set, but nonetheless there is still an overall reduction in predicted spectrum value in 2010 as compared to the original benchmarking analysis in the DotEcon Report (09/99c).

44.   We have explained above the likely motivation behind the significantly lower predictions from the European spectrum auction dataset regression model. Specifically, we note that dropping 2.6GHz licence price points would result in a predicted value for a 2x5MHx licence in Ireland of around €20.3m which is consistent with the rest of our benchmarks in Table 8.

45.   In addition, the GSM benchmark is *higher* than in the original analysis. This is not surprising as the recent German 800MHz addition to the GSM dataset sold for a higher price per MHz per pop than the original benchmark. This is also a result of the augmented GSM spectrum auctions dataset including dropping the US guard band auctions for which cellular use is not permitted in the frequencies auctioned as explained in section 3.1 above.

46.   In the following section we present an overview of benchmarks from both the averaging approach as well as the regression approach, using the modified approach benchmarks where applicable.

4.3   Updated benchmarking results

47.   Table 8 compared the updated benchmarking results (mainly from that of the modified regression approach with Irish 2010 explanatory variables to present a 2010 valuation to sub-1GHz spectrum in Ireland) to that of the original benchmarking analysis.

48.   In general, the benchmarks from the updated analysis are comparable or lower than in the original benchmarking analysis (with the exception of the 3G benchmark group). Further, despite the fact that Irish population used to calculate the predicted licence value for 2x5MHz has increased over the past year;, the benchmarks from the updated analysis are generally lower than those in the original analysis on a per pop basis. This is to be expected given the nature of the auctions with which the data set has been augmented.

Table 8: Updated benchmarking analysis results

Benchmark group	Technique	Original benchmarking analysis in DotEcon Report (09/99c)[10]	Updated benchmarking analysis
		Implied value of a 2x5MHz lot (Euro)	
All mobile	Averages benchmark	€29.1m	€29.2m
	Regression benchmark*	€24.3m	€18.6m
Europe	Average benchmark	€22.9m	€23.5m
	Regression benchmark*	€16.7m	€20.3m
Similar GDP per capita	Average benchmark	€26.3m	€26.0m
GSM only	Average benchmark*	€33.2m	€30.4m
	Regression benchmark	€26.1m	€18.3m
3G only	Average benchmark*	€33.6m	€39.5m
	Irish average[11]	€22.3m	€23.9m

*Modified approaches used

49. We consider that the depressing effects of the 2.6GHz auction prices on the European regression model results are not particularly relevant to the estimated spectrum valuation of liberalized sub-1GHz spectrum in Ireland. The relative weight of the 2.6GHz data in the European mobile spectrum auctions dataset in recent years gives these a disproportionate influence on the outcome. Hence we drop the 2.6GHz licences from our European mobile spectrum auctions dataset in our modified regression approach for this cut of data.

50. As earlier noted, the averages benchmark for the 3G benchmark group is relatively high, inflated by a number of outlier price points such as the 3rd Saudi mobile licence auction as well as bubble 3G auctions such as those in UK and Germany. Hence we can consider that this particular benchmark is over-

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[10] Presented in Table 12 of the DotEcon Report (09/99c).

[11] The discounted licences prices in May 2010 real Euro are €13.5m for H3G, €25.5 for Vodafone and O2 and €25.4 for Eircom which averages out to €22.3m. See footnote 53 of the DotEcon Report (09/99c) for further explanations on these discounted licence prices.

inflated as an indicator of spectrum value in Ireland, especially since a direct comparison for the average Irish 3G licence value is only just above half that of the 3G only benchmark.

51. Overall, the combination of the inclusion of relatively lower value higher frequency spectrum (3G and 2.6GHz auctions) as well as the shrinking of GDP per capita with the recession on-going depresses our licence price predictions as compared with that of our original analysis. Ignoring the possibly over-inflated average benchmark from the "3G only" benchmark group and conservatively disregarding upper end of the benchmark values range, the updated benchmarking analysis presents an estimated spectrum value for 2x5MHz of sub-1GHz spectrum in Ireland of between €18m-€26m. In interpreting this recommendation, it is important to remember that the upper end of this range is conservatively set reflecting our uncertainty about the estimates.

52. In addition, we re-iterate our view in our earlier report that our estimated values are likely to be under-estimates of actual spectrum value of liberalized sub-1GHz spectrum in Ireland. In particular, in the datasets that include the recent wave of 2.5/2.6GHz spectrum auctions, spectrum valuation has been depressed by the inclusion of auction prices from these auctions. With the range of €18m-26m, we have also conservatively disregarded the upper end of the benchmark value.

53. The only price point to date for liberalized sub-1GHz spectrum - 800MHz spectrum sold in the recent Germany Frequency Auction - serves as an useful cross-check on the consistency of our benchmarks. The spectrum sold for an average of €0.70 per MHz per head of population or equivalently just above €31m for a 2x5MHz licence in Ireland. This supports our argument that our benchmark values are modest and likely to understate the true value of liberalized sub 1-GHz spectrum in Ireland. Hence the risk associated with choking off efficient demand by setting minimum prices in this range should not be high.

54. Given the uncertainties over the relative values of 800MHz and 900MHz and the effects of increase supply of sub-1GHz spectrum in the auction as mentioned in Section 2, we would recommend ComReg to set minimum prices within the €18m-€26m predicted price range for a 2x5MHz sub-1GHz licence with 15-years duration so as to err on the side of caution in terms of minimizing the risk of choking off efficient demand for both 800MHz and 900MHz spectrum.

Annex A: Updated benchmarking analysis data sets

In this Annex we present the list of awards included in the various benchmark groups.

A.1   All mobile spectrum auctions

Table 9: Mobile spectrum auctions

Country	Award	Date
Australia	PCS 2000 auction	15-Mar-00
United Kingdom	3G Auction	27-Apr-00
Netherlands	3G Auction	24-Jul-00
Germany	3G Auction	18-Aug-00
Italy	3G Auction	23-Oct-00
Austria	3G Auction	03-Nov-00
Switzerland	3G Auction	06-Dec-00
Bulgaria	2nd GSM Licence Auction	18-Dec-00
New Zealand	Auction 3: 1710 - 2300 MHz	18-Jan-01
Nigeria	GSM Auction	19-Jan-01
United States	Auction 35 - C and F Block Broadband PCS	26-Jan-01
Canada	Additional PCS Auction	01-Feb-01
Belgium	3G Auction	02-Mar-01
Australia	3G Auction	22-Mar-01
Singapore	3G Auction	11-Apr-01
Austria	GSM 1800 Auction	07-May-01
Greece	3G Auction	13-Jul-01
Greece	2G	17-Jul-01
Singapore	2G Auction	11-Sep-01
Denmark	3G Auction	20-Sep-01
Hong Kong China	3G Auction	26-Sep-01
United States	Auction 41 Narrowband PCS	18-Oct-01
Norway	E-GSM Auction	31-Oct-01
Norway	GSM 1800 Auction	06-Dec-01
Czech Republic	3G Auction	07-Dec-01
Israel	2G/3G Auction	26-Dec-01
Nigeria	SNO (Digital Mobile License)	12-Aug-02
United States	Auction 44 - Lower 700 MHz Band	18-Sep-02
Austria	GSM 2002 Auction	14-Oct-02
United States	Auction 49 - Lower 700 MHz Band	13-Jun-03
Norway	3G Auction 2	02-Sep-03
United States	Auction 51 Regional Narrowband PCS	25-Sep-03
United States	Auction 50 Narrowband PCS	29-Sep-03
Norway	450 MHz Auction	08-Jun-04
Austria	GSM 2004 Auction	11-Oct-04
United States	Auction 58 - Broadband PCS	15-Feb-05
Sweden	450 MHz Auction	17-Feb-05
Bulgaria	3G Auction	30-Mar-05
Latvia	2G/3G Auction	01-Apr-05
Trinidad and Tobago	GSM Auction	23-Jun-05
United States	Auction 60 - Lower 700 MHz Band Auction	26-Jul-05

Denmark	3G Auction 2	02-Dec-05
Indonesia	3G auction	14-Feb-06
Austria	450 MHz Auction	18-Apr-06
United Kingdom	DECT Guard Block Auction	20-Apr-06
Georgia	3G Auction	23-May-06
Egypt	2G/3G Auction	04-Jul-06
United States	Auction 66 - Advanced Wireless Services	18-Sep-06
Georgia	GSM 1800 MHz	15-Dec-06
Denmark	450 MHz	15-Dec-06
Estonia	3G Tender	18-Jan-07
Macedonia FYR	Third GSM licence	05-Feb-07
Denmark	870 MHz	06-Feb-07
Nigeria	3G Auction	16-Mar-07
Ireland	1785-1805 MHz	27-Apr-07
United Kingdom	1785-1805 MHz	09-May-07
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	07-Jul-07
Hong Kong China	Hong Kong CDMA	15-Aug-07
Norway	2.6 GHz	13-Nov-07
Norway	3G 4th licence	12-Dec-07
Brazil	2G Licences	27-Dec-07
Singapore	Public Cellular Mobile Telecommunications Services Auction	22-Feb-08
Norway	Residual 2.6GHz	28-Feb-08
Sweden	1900-1905MHz	18-Mar-08
United States	Auction 73- 700MHz	18-Mar-08
Sweden	2.6GHz	08-May-08
Canada	AWS auction	27-May-08
Bulgaria	Bulgaria 4th GSM License	18-Jul-08
Qatar	Qatar second mobile licence	29-Jul-08
Austria	900 MHz Auction	29-Sep-08
Turkey	3G	24-Nov-08
Norway	1790-1800MHz	11-Dec-08
Hong Kong China	BWA Auction	22-Jan-09
Singapore	1800MHz auction	04-Feb-09
Hong Kong China	1800MHz auction (expansion)	10-Jun-09
Finland	2.6GHz	22-Nov-09
Netherlands	2.6 GHz band	26-Apr-10
Denmark	2.5GHz auction	10-May-10
India	3G auction	19-May-10
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	21-May-10

A.2   All European mobile spectrum auctions

Table 10: European mobile spectrum auctions

Country	Award	Date
United Kingdom	3G Auction	27-Apr-00
Netherlands	3G Auction	24-Jul-00
Germany	3G Auction	18-Aug-00
Italy	3G Auction	23-Oct-00
Austria	3G Auction	03-Nov-00
Switzerland	3G Auction	06-Dec-00
Bulgaria	2nd GSM Licence Auction	18-Dec-00
Belgium	3G Auction	02-Mar-01
Austria	GSM 1800 Auction	07-May-01
Greece	3G Auction	13-Jul-01
Greece	2G	17-Jul-01
Denmark	3G Auction	20-Sep-01
Norway	E-GSM Auction	31-Oct-01
Norway	GSM 1800 Auction	06-Dec-01
Czech Republic	3G Auction	07-Dec-01
Austria	GSM 2002 Auction	14-Oct-02
Norway	3G Auction 2	02-Sep-03
Norway	450 MHz Auction	08-Jun-04
Austria	GSM 2004 Auction	11-Oct-04
Sweden	450 MHz Auction	17-Feb-05
Bulgaria	3G Auction	30-Mar-05
Latvia	2G/3G Auction	01-Apr-05
Denmark	3G Auction 2	02-Dec-05
Austria	450 MHz Auction	18-Apr-06
United Kingdom	DECT Guard Block Auction	20-Apr-06
Denmark	450 MHz	15-Dec-06
Estonia	3G Tender	18-Jan-07
Macedonia FYR	Third GSM licence	05-Feb-07
Denmark	870 MHz	06-Feb-07
Ireland	1785-1805 MHz	27-Apr-07
United Kingdom	1785-1805 MHz	09-May-07
Norway	2.6 GHz	13-Nov-07
Norway	3G 4th licence	12-Dec-07
Norway	Residual 2.6GHz	28-Feb-08
Sweden	1900-1905MHz	18-Mar-08
Sweden	2.6GHz	08-May-08
Bulgaria	Bulgaria 4th GSM License	18-Jul-08
Austria	900 MHz Auction	29-Sep-08
Turkey	3G	24-Nov-08
Norway	1790-1800MHz	11-Dec-08
Finland	2.6GHz	22-Nov-09
Netherlands	2.6 GHz band	26-Apr-10
Denmark	2.5GHz auction	10-May-10
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	21-May-10

A.3 All mobile spectrum auctions of countries with comparable GDP per capita to Ireland

Table 11: Mobile spectrum auctions of countries with comparable GDPpc mobile spectrum auctions

Country	Award	Date
Australia	PCS 2000 auction	15-Mar-00
United Kingdom	3G Auction	27-Apr-00
Netherlands	3G Auction	24-Jul-00
Germany	3G Auction	18-Aug-00
Italy	3G Auction	23-Oct-00
Austria	3G Auction	03-Nov-00
Switzerland	3G Auction	06-Dec-00
New Zealand	Auction 3: 1710 - 2300 MHz	18-Jan-01
United States	Auction 35 - C and F Block Broadband PCS	26-Jan-01
Canada	Additional PCS Auction	01-Feb-01
Belgium	3G Auction	02-Mar-01
Australia	3G Auction	22-Mar-01
Singapore	3G Auction	11-Apr-01
Austria	GSM 1800 Auction	07-May-01
Greece	3G Auction	13-Jul-01
Greece	2G	17-Jul-01
Singapore	2G Auction	11-Sep-01
Denmark	3G Auction	20-Sep-01
Hong Kong China	3G Auction	26-Sep-01
United States	Auction 41 Narrowband PCS	18-Oct-01
Norway	E-GSM Auction	31-Oct-01
Norway	GSM 1800 Auction	06-Dec-01
New Zealand	Auction 5 WLL and LMP and Cellular	01-Aug-02
United States	Auction 44 - Lower 700 MHz Band	18-Sep-02
Austria	GSM 2002 Auction	14-Oct-02
United States	Auction 49 - Lower 700 MHz Band	13-Jun-03
Norway	3G Auction 2	02-Sep-03
United States	Auction 51 Regional Narrowband PCS	25-Sep-03
United States	Auction 50 Narrowband PCS	29-Sep-03
Norway	450 MHz Auction	08-Jun-04
Austria	GSM 2004 Auction	11-Oct-04
United States	Auction 58 - Broadband PCS	15-Feb-05
Sweden	450 MHz Auction	17-Feb-05
United States	Auction 60 - Lower 700 MHz Band Auction	26-Jul-05
Denmark	3G Auction 2	02-Dec-05
Austria	450 MHz Auction	18-Apr-06
United Kingdom	DECT Guard Block Auction	20-Apr-06
United States	Auction 66 - Advanced Wireless Services	18-Sep-06
Denmark	450 MHz	15-Dec-06
Denmark	870 MHz	06-Feb-07
Ireland	1785-1805 MHz	27-Apr-07
United Kingdom	1785-1805 MHz	09-May-07
Hong Kong China	Hong Kong CDMA	15-Aug-07
Norway	2.6 GHz	13-Nov-07

Norway	3G 4th licence	12-Dec-07
Singapore	Public Cellular Mobile Telecommunications Services Auction	22-Feb-08
Norway	Residual 2.6GHz	28-Feb-08
Sweden	1900-1905MHz	18-Mar-08
United States	Auction 73- 700MHz	18-Mar-08
Sweden	2.6GHz	08-May-08
Canada	AWS auction	27-May-08
Qatar	Qatar second mobile licence	29-Jul-08
Austria	900 MHz Auction	29-Sep-08
Norway	1790-1800MHz	11-Dec-08
Hong Kong China	BWA Auction	22-Jan-09
Singapore	1800MHz auction	04-Feb-09
Hong Kong China	1800MHz auction (expansion)	10-Jun-09
Finland	2.6GHz	22-Nov-09
Netherlands	2.6 GHz band	26-Apr-10
Denmark	2.5GHz auction	10-May-10
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	21-May-10

A.4 All GSM900MHz and 1800MHz spectrum auctions

Table 12: 900MHz and 1800MHz spectrum auctions

Country	Award	Date
Australia	PCS 2000 auction	15-Mar-00
Bulgaria	2nd GSM Licence Auction	18-Dec-00
Nigeria	GSM Auction	19-Jan-01
United States	Auction 35 - C and F Block Broadband PCS	26-Jan-01
Canada	Additional PCS Auction	01-Feb-01
Austria	GSM 1800 Auction	07-May-01
Greece	2G (900MHz)	17-Jul-01
Greece	2G (900MHz and 1800MHz)	17-Jul-01
Singapore	2G Auction	11-Sep-01
United States	Auction 41 Narrowband PCS	18-Oct-01
Norway	E-GSM Auction	31-Oct-01
Norway	GSM 1800 Auction	06-Dec-01
Israel	2G/3G Auction	26-Dec-01
New Zealand	Auction 5 WLL and LMP and Cellular (900MHz)	01-Aug-02
Nigeria	SNO (Digital Mobile License)	12-Aug-02
United States	Auction 44 - Lower 700 MHz Band	18-Sep-02
Austria	GSM 2002 Auction	14-Oct-02
United States	Auction 49 - Lower 700 MHz Band	13-Jun-03
United States	Auction 51 Regional Narrowband PCS	25-Sep-03
United States	Auction 50 Narrowband PCS	29-Sep-03
Austria	GSM 2004 Auction (900MHz)	11-Oct-04
Austria	GSM 2004 Auction (1800MHz)	11-Oct-04
United States	Auction 58 - Broadband PCS	15-Feb-05
Latvia	2G/3G Auction	01-Apr-05
Trinidad and Tobago	GSM Auction (800MHz)	23-Jun-05
Trinidad and Tobago	GSM Auction (1900MHz)	23-Jun-05
United States	Auction 60 - Lower 700 MHz Band Auction	26-Jul-05
United Kingdom	DECT Guard Block Auction	20-Apr-06
Egypt	2G/3G Auction	04-Jul-06
Georgia	GSM 1800 MHz	15-Dec-06
Macedonia FYR	Third GSM licence	05-Feb-07
Ireland	1785-1805 MHz	27-Apr-07
United Kingdom	1785-1805 MHz	09-May-07
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	07-Jul-07
Brazil	2G Licences (800MHz)	27-Dec-07
Brazil	2G Licences (1800MHz)	27-Dec-07
Singapore	Public Cellular Mobile Telecommunications Services Auction (900MHz)	22-Feb-08
Singapore	Public Cellular Mobile Telecommunications Services Auction (1800MHz)	22-Feb-08
United States	Auction 73- 700MHz	18-Mar-08
Sweden	1900-1905MHz	18-Mar-08
Bulgaria	Bulgaria 4th GSM License	18-Jul-08
Qatar	Qatar second mobile licence	29-Jul-08

Austria	900 MHz Auction	29-Sep-08
Norway	1790-1800MHz	11-Dec-08
Singapore	1800MHz auction	04-Feb-09
Hong Kong China	1800MHz auction (expansion)	10-Jun-09
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands (800MHz)	21-May-10
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands (1800MHz)	21-May-10

A.5   All 3G spectrum auctions

Table 13: 3G spectrum auctions

Country	Award	Date
United Kingdom	3G Auction	27-Apr-00
Netherlands	3G Auction	24-Jul-00
Germany	3G Auction	18-Aug-00
Italy	3G Auction	23-Oct-00
Austria	3G Auction	03-Nov-00
Switzerland	3G Auction	06-Dec-00
New Zealand	Auction 3: 1710 - 2300 MHz	18-Jan-01
Belgium	3G Auction	02-Mar-01
Australia	3G Auction	22-Mar-01
Singapore	3G Auction	11-Apr-01
Greece	3G Auction	13-Jul-01
Denmark	3G Auction	20-Sep-01
Hong Kong China	3G Auction	26-Sep-01
Czech Republic	3G Auction	07-Dec-01
Israel	2G/3G Auction	26-Dec-01
Norway	3G Auction 2	02-Sep-03
Bulgaria	3G Auction	30-Mar-05
Latvia	2G/3G Auction	01-Apr-05
Denmark	3G Auction 2	02-Dec-05
Indonesia	3G auction	14-Feb-06
Georgia	3G Auction	23-May-06
Egypt	2G/3G Auction	04-Jul-06
United States	Auction 66 - Advanced Wireless Services	18-Sep-06
Estonia	3G Tender	18-Jan-07
Nigeria	3G Auction	16-Mar-07
Saudi Arabia	Saudi 3rd GSM license and 3rd 3G license	07-Jul-07
Norway	3G 4th licence	12-Dec-07
Canada	AWS auction	27-May-08
Turkey	3G	24-Nov-08
India	3G auction	19-May-10
Germany	Auction of spectrum in the 800MHz, 1800MHz, 2.1GHz and 2.6GHz bands (2.1GHz)	21-May-10

Annex B: Regression analysis

In section 4.2 of the main draft above, we applied both the original regression analysis as well as an updated regression analysis to the mobile spectrum auction dataset. As part of the updated benchmarking analysis, we also run these regressions on both the European mobile spectrum auctions dataset as well as the GSM spectrum auctions data set.

In this Annex we present the regression results for the regression analysis on the European mobile spectrum auctions dataset and that of the GSM spectrum auctions data set.

B.1   Auctions in Europe

Equation 3: Original regression equation for auctions in Europe

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{ApPop} \bullet ApPop + \beta_{WtB} \bullet WtB + \dots$$
$$\dots + \beta_{invNMNOs} \bullet invNMNOs + \beta_{national} \bullet national + \beta_{preIT} \bullet preIT \dots$$
$$\dots + \beta_{year01} \bullet year01 + \beta_{year0203} \bullet year0203 + \beta_{year0405} \bullet year0405 + \dots$$
$$\dots + \beta_{year0607} \bullet year0607 + \beta_{year080910} \bullet year080910$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $ApPop$ is area per capita, a measure of population density;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNMNOs$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy, which is 1 if the licence was sold in these years and 0 if not. Years are grouped where there are few awards in a year. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

We use a weighted least squares estimator (using the same weights for each individual licence as for the calculation of weighted average price per MHz per population for each

auction as used in the average-based benchmark approach) to estimate the coefficients of the model.[12] The results are summarised in the following table.

Table 14: Original regression analysis using all European mobile licences sold in auctions in Europe

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000005	0.000009
ApPop	-6.32*	3.24
WtB	--0.561**	0.251
invNmnos	8.01**	1.21
national	-0.353	0.173
preIT	1.67**	0.249
yearD_01	-1.04**	0.207
yearD_0203	-0.872*	0.288
yearD_0405	-0.916**	0.242
yearD_0607	-1.08**	0.228
yearD_080910	-0.917**	0.228
Constant	-0.118	0.553

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively.

The alterations to the European auctions data set has cause the coefficient of the national dummy to turn negative. The estimates produce a price per MHz per pop of €0.128 and an implied licence value for a 2x5MHz licence in Ireland of €5.7m when 2010 Irish explanatory variables are applied. We note that with 2009 Irish explanatory variables, the price per MHz per pop would be €0.161 and equivalent licence value of 2x5MHz would be €6.7m.

The modified regression analysis drops 2.6GHz licences from the dataset and re-runs the same regression.

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[12] For more information on this estimator, see Greene, W, 2003, Econometric Analysis Fifth Edition, pp.225-227.

Equation 4: Modified regression equation for all mobile licences sold in auctions in Europe

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{ApPop} \bullet ApPop + \beta_{WtB} \bullet WtB + \dots$$
$$\dots + \beta_{invNMNOs} \bullet invNMNOs + \beta_{national} \bullet national + \beta_{twopoint\ six} \bullet twopoint\ six + \dots$$
$$\dots + \beta_{preIT} \bullet preIT + \beta_{year01} \bullet year01 + \beta_{year0203} \bullet year0203 + \dots$$
$$\dots + \beta_{year0405} \bullet year0405 + \beta_{year0607} \bullet year0607 + \beta_{year080910} \bullet year080910$$

where:

- $twopoint\ six$ is a dummy variable that is 1 if the spectrum licences sold is within the 2500-2690MHz range;

- and all other variables are as above.

The results are summarised in the following table.

Table 15: Modified Regression analysis using all European mobile licences sold in an auction

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.000005	0.000009
ApPop	-6.40*	3.27
WtB	-0.578**	0.260
invNmnos	7.97**	1.22
national	-0.0181	0.186
twopointsix	0.0466	0.177
preIT	1.67**	0.251
yearD_01	-1.03**	0.208
yearD_0203	-0.868**	0.289
yearD_0405	-0.916**	0.243
yearD_0607	-1.09**	0.230
yearD_080910	-0.935**	0.238
Constant	-0.110	0.555

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively.

The introduction of the dummy for 2.5/2.6GHz auctions does not improve the explanatory power of the model significantly as some of the effects of the 2.6GHz auctions have been accounted for by the year080910 dummy. In particular, we note that unlike in the case of the modified regression analysis on the updated mobile spectrum auctions in section 4.2 above, the coefficient of the twopointsix dummy in this case is positive. This model presents a price per MHz per pop is €0.145 and implied price for a 2x5MHz licences is €6.09m. Further we note that if we were to drop all 2.6GHz licences from the European spectrum auctions data set and ran the original regression analysis as per Equation 3, the predicted price for a 2x5MHz licence in Ireland is €20.3m.

B.2 GSM auctions

Equation 5: Original regression equation for GSM auctions

$$PMHzPop = \beta_0 + \beta_{GDPpc} \bullet GDPpc + \beta_{PopDen} \bullet PopDen + \beta_{WtB} \bullet WtB + ...$$
$$... + \beta_{invNMNOs} \bullet invNMNOs + \beta_{national} \bullet national + \beta_{AFME} \bullet AFME + \beta_{preIT} \bullet preIT + ...$$
$$... + \beta_{year01} \bullet year01 + \beta_{year0203} \bullet year0203 + \beta_{year0405} \bullet year0405 + ...$$
$$... + \beta_{year0607} \bullet year0607 + \beta_{year080910} \bullet year080910$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita;
- $PopDen$ is population per area, a measure of population density;
- WtB is the ratio of winners to bidders in the auction, a measure of the level of competition in the auction;
- $invNMNOs$ is the inverse of the number of MNOs in the end, a measure of competitiveness in the telecommunications market;
- $national$ is a dummy variable which is 1 if it is a national licence and 0 if not;
- $AFME$ is a dummy variable which is 1 if it is an African or Middle-Eastern country and 0 if not; and
- $preIT$ is a dummy which is 1 if the licence was sold before the Italian 3G auction (the last auction before the spectrum bubble burst) or 0 if the licence was sold afterwards;
- $Year$ is a dummy which is 1 if the licence was sold in these years and 0 if not. Years are grouped biannually. For example $Year0607$ is one if licence was sold in 2006 or 2007 and 0 otherwise.

We use a weighted least squares estimator (using the same weights for each individual licence as for the calculation of weighted average price per MHz per population for each auction as used in the average-based benchmark approach) to estimate the coefficients of the model.[13] The results are summarised in the following table.

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[13] For more information on this estimator, see Greene, W, 2003, Econometric Analysis Fifth Edition, pp.225-227.

Table 16: Original regression analysis using all GSM mobile

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000459**	0.000002
PopDen	-0.000081**	0.000013
WtB	-1.72**	0.116
invNmnos	0.624*	0.336
national	0.0336	0.0660
AFME	1.42**	0.0871
preIT	-3.65**	0.217
yearD_01	-4.09**	0.179
yearD_0203	-4.99**	0.191
yearD_0405	-4.46**	0.176
yearD_0607	-4.07**	0.177
yearD_080910	-4.47**	0.184
Constant	4.56**	0.212

Note: Coefficients which are significant at the 5% and 1% level are marked with one and two stars, respectively.

The alterations to the GSM auctions data set has cause the coefficient of the population density (PopDen) to turn negative as compared to the regression results in the original benchmarking analysis. However the magnitude of the population density coefficient is small and would not make a significant impact on predicted price. Applying 2009 Irish explanatory vaiables would produce a price per MHz per pop of €0.754 and an implied licence value for a 2x5MHz licence in Ireland of €31.7m and in the case where 2010 explanatory variables are applied, the price per MHz per pop is €0.409 and implied licence value would be €18.3m.