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Economic Consultant's Report

Award of 800MHz, 900MHz and 1800MHz spectrum - Further update report on benchmarking

Prepared for ComReg by DotEcon (non-confidential version)

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1 Introduction and background

1.1 First report (09/99c)

1. In 2009, DotEcon undertook a benchmarking analysis as part of advice provided to ComReg on aspects of a 900MHz award process in Ireland. This analysis produced a proposed lower bound estimate of the market value of liberalised 900MHz spectrum. This estimate was used to provide a recommended range of values for a minimum price (consisting of an upfront payment plus annual usage fees) for auctioning 900MHz spectrum. The results of this analysis were published in Part C of DotEcon's report (09/99c) which accompanied ComReg's response to and further consultation[1] on its approach to liberalising 900MHz and 1800MHz spectrum published in December 2009.

2. In Part C of that report, we discussed the key issues that need to be considered when setting minimum prices in the light of ComReg's objectives, in particular its objective to ensure the efficient use of spectrum.

3. We had particular concerns about the possibilities for tacit collusion given the acute scarcity of spectrum and the likely limited field of bidders. For instance, even without explicit coordination, there might be a 'natural' outcome in which in the absence of credible competition from entrants, the amount of spectrum won by incumbents was determined by their relative existing competitive positions. Also, there could be strong incentives for pooling of interests or non-participation simply to limit competition within the auction if minimum prices were set too low.

4. In selecting the most appropriate methodology for setting minimum prices we discussed the advantages and disadvantages of the various possible approaches, such as modelling the costs and revenues, benchmarking of prices achieved in other auction processes, setting a low but non-trivial price and setting the minimum price equal to the costs of administering licences over the duration of the licence period.[2] We considered that the concerns over low competition scenarios - in particular arising from the potential for strategic behaviour associated with the award of scarce 900MHz spectrum - meant that a minimum price reflecting market value should be set.[3]

5. In Section 10.5 of Part C we undertook two forms of simple benchmarking analysis: calculating means across different samples of data and a

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[1] *'Liberalising the future use of the 900 MHz and 1800 MHz spectrum bands',* ComReg document 09/99

[2] See paragraphs 457 – 479 in Part C of DotEcon report 09/99c for a discussion of the various methodologies.

[3] See paragraphs 480 – 487 and 471-475 in Part C of DotEcon report 09/99c for a discussion of the recent trends in setting minimum prices and why setting a low but non-trivial minimum price would not be appropriate in Ireland.

regression analysis that sought to explain observed prices in terms of macroeconomic, geographical and other factors.. Both methods used auction data from DotEcon's in-house Spectrum Awards Database available at the time of the report.[4]

6. Given the relatively small number of sub-1GHz data points and the use of higher frequency spectrum bands for the provision of 3G services (as will be possible with the liberalised 900MHz spectrum for award), we did not limit the analysis solely to 900MHz licences, but rather used a larger sample of mobile licences including frequencies up to the 2.6GHz band. The data and methodology used meant that results produced represent *conservative estimates* of the market value of liberalised 900MHz spectrum in Ireland:

    a) Data used in the analyses included mobile spectrum in the sub-1GHz range and higher frequencies above 1GHz. Given the superior propagation characteristics of 900MHz spectrum compared with higher frequency spectrum, taking benchmarks of average licence values across the full range of mobile frequencies (up to 2.6GHz) would present a conservative lower bound estimate of the likely value of 900MHz spectrum in Ireland.

    b) At that time, data for sub-1GHz frequency spectrum covered only licences awarded for unliberalised use. However, the 900MHz licences to be awarded in the planned auction in Ireland would be liberalised. While spectrum in this band is currently used for providing GSM services, liberalised licence holders would be permitted to deploy 3G and indeed more advanced technologies over the envisaged licence period. Therefore, the actual value of liberalised 900MHz spectrum in Ireland should reflect the licence value with the option to provide more advanced services using 3G and successor technologies such as LTE.

7. Even controlling for country and market differences, any average licence value calculated using values for unliberalised sub-1GHz frequency spectrum and high frequency spectrum (only some of which was for liberalised use) will inevitably yield a conservative lower bound estimate of the value of liberalised 900MHz spectrum in Ireland. This is a limitation due to the available data and an appropriate interpretation needs to be applied to the results in the light of this limitation.

8. We would re-emphasise that our benchmarking exercise did *not* set out to predict the final winning licence price in the proposed auction, but derived a conservative lower bound estimate of the market value of liberalised 900MHz spectrum in order to allow ComReg to set an appropriate minimum price in the proposed auction. Such a conservative lower bound basis should minimise the risk of setting a minimum price that chokes off efficient demand (i.e. demand of serious bidders) in the auction. It is this risk of inefficiently choking-off demand by setting too high a reserve price that is informed by the benchmarking exercise.

[4] See section 10.5 in Part C of DotEcon report 09/99c.

9. Many of the respondents of 09/99 did not support the approach of setting minimum prices based on market value. Instead, they were inclined towards low but non-trivial minimum prices. Further, some respondents felt that our benchmarking analysis should have benchmarked minimum prices set by spectrum authorities instead of licence prices actually achieved. Others raised issues with the model we adopted for benchmarking, for instance raising the issue that Gross National Product (GNP) should have been used instead of Gross Domestic Product (GDP) in our regression models. We summarise these comments in Annex C. In Annex D we analyse and provide responses to these comments.

10. In terms of modifying auction data to make it comparable across countries, it was necessary to convert the award prices from the respective local currencies into a common currency. We did this by first converting prices in local currency into US dollar (USD) using Purchasing Price Parity rates (PPP) to reflect price level differences across countries.[5] We then adjusted for USD inflation so that all prices would be in real terms and then used a USD to Euro PPP rate to convert prices into real Euro terms. The procedure for doing this is set out in detail in Section 17.3 of DotEcon's December 2009 report (09/99c).[6] All benchmarks in this report were presented in June 2009 Euros.

11. In addition to the winning price paid upfront for licences awarded in relevant bands by auction, we included in our licence prices the net present value (NPV) stream of annual licence fees, discounted using Eircom's weighted average cost of capital determined by ComReg in 2008 as an approximation of the cost of capital for potential bidders. We then adjusted all licences in our sample for differences in licence duration using a similar NPV calculation so that all benchmark values derived were for a 15-year licence.[7]

12. The benchmarking analysis detailed in DotEcon report 09/99c produced a conservative lower bound estimate of the market value of liberalised 900MHz spectrum of between €16m to €34m (in June 2009 prices) per 2x5MHz lot.[8] This range is a reflection of the idiosyncratic factors affecting the prices paid in different auctions that cannot be explained by factors such as GDP, population size and so on.

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[5] US dollars are used as the currency of comparison as data is available on PPP rates against the local currencies of all of the countries in the database.

[6] Briefly, this involved converting the nominal licence prices which were expressed in the local currency of the respective country into US dollars using an annual Purchasing Price Parity (PPP) rate. The PPP rate accounts for price differences between the country in which the licences were auctioned and the US. This price in US dollars in the year of the award is then adjusted for US dollar inflation using CPI data from the US Bureau of Labour and all prices are expressed in common June 2009 US dollar terms. Finally prices are then converted into Euros using the relevant PPP rate for the first half of 2009.

[7] See footnote 44 in Part C of DotEcon report 09/99c for a detailed explanation of these calculations.

[8] See Table 12 in Part C of DotEcon report 09/99c, which summarises the various benchmark results (both average and regression results).

13. We made a specific recommendation in this report that ComReg consider a minimum price towards the upper end of this range (€25m-€30m) because of strong concerns about tacit collusion given the potential for a 'natural' outcome amongst incumbents if competition from entrants were weak.

1.2 Second report (10/71b) and inclusion of the 800MHz band

14. Subsequently in September 2010, following the development of greater certainty over the date of availability of 800MHz spectrum for mobile use, ComReg consulted on the inclusion of 800MHz spectrum in a joint award process along with 900MHz spectrum (*'800MHz, 900MHz and 1800MHz release',* ComReg document 10/71). ComReg published two reports prepared by DotEcon: (i) "Award of liberalised spectrum in the 900MHz and other bands" (10/71a) and (ii) "Award of 800MHz and 900MHz spectrum – Update report on benchmarking" (10/71b) alongside its own consultation document, considering different aspects of a joint award.

15. DotEcon Report 10/71a discussed the inclusion of the 800MHz band in a joint award with 900MHz spectrum while DotEcon Report 10/71b recommended a suitable minimum price for 800MHz spectrum in Ireland within such a joint award. In DotEcon Report 10/71b, we concluded that it was appropriate to set a common minimum price for 800MHz and 900MHz spectrum within a joint auction.

16. Whilst some respondents to consultation 10/71 supported a common minimum price for 800MHz and 900MHz spectrum, others such as H3GI and UPC Ireland argued that 900MHz and 800MHz spectrum are not substitutable hence would not have similar values. Annex C summarises respondent views whilst DotEcon's consideration and response can be found in Annex D.

17. We noted in DotEcon report 10/71b that proposing a common minimum price does not imply that 800MHz spectrum is of identical value to liberalised 900MHz spectrum or suggest that the final auction outcome would necessarily reflect this price parity. Rather, the setting of a common minimum price for 800MHz and 900MHz spectrum reflects the similarities between the two bands in terms of propagation characteristics and their potential substitutability in the long run. Clearly there may be differences in equipment availability timetables for the two bands that will affect their usage in the short-run, but in the long-run such differences are much less relevant, as with liberalised spectrum and flexible technologies it should primarily be the physical characteristics of the spectrum that determine its fundamental long-run value.

18. While we noted the uncertainties over the relative valuation of spectrum in these two bands, the current lack of data about this relativity meant that there is an absence of evidence that these values differ substantially. Under these circumstances, the *a priori* similarity of the spectrum justifies setting a common minimum price for the two bands provided this value is conservatively set and does not choke off efficient demand (demand from

serious bidders). Any residual uncertainty regarding the differing values of these two bands should be reflected in the use of a more conservative approach to setting the common sub-1GHz minimum price.[9] Clearly there is a strong interrelationship between the justification of setting a common price and taking a reasonably conservative approach to setting the overall level of minimum prices; if minimum prices were set at high levels relative to likely market value, a common minimum price for the two bands would be more questionable (though the problem of a lack of solid evidence for setting a differential would remain).

19. In DotEcon report 10/71b, the original benchmarking analysis (09/99c) was updated with new auction data. Prices were also updated to May 2010 Euros using the same approach to adjust licence prices to a common currency, while accounting for price differences across countries and inflation as in the analysis described in 09/99c and summarised in paragraph 10 of this report. Further, we also updated the economic and demographic data inputs (Irish GDP and population) used for predicting licence prices in our analysis to that of 2009 (the latest available at the time of the analysis). [10]

20. Further, in 10/71b we modified both the simple average approach and regression models slightly to cater for the inclusion of new auction data. First, improvements had been made in the dataset since our first report to identify where a single auction process had sold licences in different spectrum bands. Second, in the "all mobile auctions" regression model, we included a dummy variable for all 2.6GHz licences and in the "European auctions" model we dropped all 2.6GHz licences. We discuss these modifications further in section 3.2 below.[11]

21. The combination of these modifications to our benchmarking approach, the updated dataset and the additional argument for needing to adopt a conservative approach when setting a common minimum price for both 800MHz and 900MHz spectrum (to reflect any residual uncertainty over the relative valuations of 800MHz versus 900MHz frequencies) led us to conclude in 10/71b that a suitable minimum price for 2x5MHz of sub-1GHz spectrum should be set at a value between €18m and €26m (in May 2010 prices). The results of this updated benchmarking analysis are compared to that from 09/99c in Table 8 in 10/71b and reproduced in Table 1 below.

22. The lower boundary of the estimated range increased slightly from our 09/99c report (€18m rather than €16m) due to the reduced weight given to 2.6GHz spectrum in determining the results. The upper boundary fell (€34m to €26m) in part due to better fitting models (with more similar results obtained from the regressions with different sets of data).

[9] See paragraphs 10-15 of DotEcon report 10/71b for a further discussion on implications of including 800MHz spectrum on the appropriate minimum price.

[10] See section 3.2 of DotEcon report 10/71b for more details on adjusting licence prices to a common currency and Section 3.3 on updates to Irish GDP and population.

[11] See section 4.1 of DotEcon report 10/71b for more information on these modifications.

However, we considered that the inclusion of the 800MHz band itself increased the risk of setting minimum prices too high, which warranted less weight being given to the upper outliers amongst the various benchmarks calculated. Furthermore, including the 800MHz band might make it more difficult to achieve a 'natural' outcome amongst incumbents (for instance, it is not obvious even given the current relative strengths of incumbents how they might choose between 800MHz and 900MHz spectrum). Therefore, concerns about tacit collusion, although still present, were somewhat reduced in importance relative to our first report.

23. For these reasons, we modified our recommendation to provide a tighter range for minimum prices (i.e. €18m to €26m) than the range of benchmarks found in our first report (i.e. €16m to €34m), primarily due to less weight being given to upper outliers. However, we did not provide any further specific recommendation within this range. The range remained fairly wide, reflecting uncertainty (though remembering always that the methodologies employed mean that these estimates are likely to be lower bounds of the market value of sub-1GHz spectrum).

Table 1: Benchmark values in 10/71b and 09/99c

Benchmark group	**Technique**	**09/99c benchmarks (June 2009 Euros)**	**10/71b benchmarks (May 2010 Euros)**
		Implied value of a 2x5MHz lot	
All mobile	Average	€29.1m	€29.2m
	Regression	€24.3m	€18.6m
Europe	Average	€22.9m	€23.5m
	Regression	€16.7m	€20.3m
Similar GDP per capita to Ireland	Average	€26.3m	€26.0m
GSM	Average	€33.2m	€30.4m
	Regression	€26.1m	€18.3m
3G	Average	€33.6m	€39.5m
	Regression	€22.3m	€23.9m
Recommended Minimum Price range		€25m-€30m	€18m-€26m

Source: Table 8 of 10/71b

24. We note that in 09/99c, the "GSM" benchmark contained auctions of 900MHz and 1800MHz licences as well as the US 700MHz auction. In addition, with the completion of the German multi-band auction in May 2010, the "GSM" benchmark in the benchmarking analysis in 10/71b, , also included the German 800MHz licences. Above we have explained that we consider 800MHz and 900MHz spectrum to be of comparable value in the long run due to their potential substitutability in the long run.

Therefore 800MHz licences should be included within a benchmark of relevant spectrum frequency bands. In this regard, we consider it more appropriate to term the benchmark formerly known as the "GSM" benchmark as the "sub-1GHz and 1800MHz" benchmark instead. Below we adopt this terminology.

1.3 Third report (10/105a) and relative value of 1800MHz and sub-1GHz spectrum

25. In December 2010, DotEcon considered the implications of the inclusion of 1800MHz spectrum in the proposed joint award of 800MHz and 900MHz spectrum. Its analysis was published in a report (10/105a) alongside ComReg's consultation on the same issue (10/105). In Section 7 of our report, we considered an appropriate minimum price for 1800MHz spectrum if it were included in the proposed joint sub-1GHz award. We noted again in 10/105a that our benchmarking analysis in 10/71b and 09/99c yielded a conservative lower bound to the value of sub-1GHz spectrum in Ireland. However, applying the same approach to the 1800MHz band might not yield benchmarks for 1800MHz frequencies on the same basis for the following reasons.

26. This difference stems from the fact that the sub-1GHz minimum prices were based on a blend of prices achieved for spectrum in different bands (as explained above in paragraphs 6 and 7). Given that sub-1GHz spectrum is more valuable than high frequency spectrum on account of its superior propagation characteristics, minimum prices for sub-1GHz spectrum based on a blend of prices across spectrum bands including both sub-1GHz and higher frequency spectrum would constitute a lower bound value of sub-1GHz spectrum. However, as 1800MHz spectrum does not necessarily offer materially better propagation than other frequency bands (such as 2.1GHz and 2.6GHz), applying the same methodology to benchmark 1800MHz spectrum would tend to produce a more central estimate of market value, rather than a lower bound estimate. Therefore, we need to be cautious in interpreting the results of the benchmarking methodology for 800MHz/900MHz spectrum on the one hand and 1800MHz spectrum on the other, as they are differently affected by the mix of price data across different bands in our benchmark dataset.

27. In order to ensure the efficiency of the auction process, the relative minimum prices should not distort bidders' choice between spectrum in different bands, hence the minimum price for 1800MHz spectrum should in some way take into account the differences between the likely value of sub-1GHz and 1800MHz spectrum. In particular, we would ideally not want a situation in which the price of one band was determined by competition within the auction, yet the price of another band never rose above the minimum price, as then the relative prices of these type of spectrum would not be free floating and market-determined. As with the issue of the inclusion of the 800MHz band discussed above, including the 1800MHz band creates additional uncertainty that may need to be reflected in a somewhat more cautious approach to setting the level of the minimum prices (subject to balancing other considerations).

28. For these reasons, we adopted the approach of determining an appropriate minimum price for 1800MHz spectrum by using auction data

to estimate the *relative* market value of 1800MHz to sub-1GHz spectrum. We then used this ratio to set the minimum price for 1800MHz spectrum relative to that of sub-1GHz frequencies. This ensures that the minimum prices for 1800MHz would also be set on a reasonably consistent *"conservative lower bound basis"* with the other bands.

29. The results from our calculations in 10/105a estimated that the relative value of 1800MHz spectrum to sub-1GHz frequencies ranged between 45% and 60%. On the basis of this analysis, we recommended that the minimum price of a 2x5MHz lot of spectrum in the 1800MHz band be set between €8m and €16m (in May 2010 prices) based on 10/71b's recommendations on minimum prices for sub-1GHz spectrum in the proposed auction. In addition in 10/105, we considered there to be merit in setting the relative reserve prices of sub-1GHz and 1800MHz to match the proposed a 2:1 an eligibility point ratio of sub-1GHz versus 1800MHz spectrum so as to not distort bidders' choices between spectrum in different bands.

30. Most responses to ComReg consultation 10/105 concerning the minimum price of 1800MHz spectrum (see Annex C) could be related back to respondents' previous comments on the proposed sub-1GHz minimum prices being too high and, by implication, a minimum price for 1800MHz spectrum derived from that of sub-1GHz spectrum necessarily also being too high. Therefore, no fundamental new issues were introduced by these consultation responses.

1.4 This report

31. In this report, we update the benchmarking analysis in our previous reports (10/71b and 10/105a)[12] to include the impact of recently completed awards of relevant spectrum bands. We discuss the changes to the data since the most recent analysis was carried out in December 2010 in Section 2. Following this, we present our updated benchmarking results in Section 3 and our conclusions in Section 4. Annex A presents lists of auctions in the datasets we consider for our analysis and Annex B presents the regression results for mobile auctions in Europe and sub-1GHz and 1800MHz auctions. In Annex C we summarise respondents' comments on consultations 09/99, 10/71 and 10/105 on the matter of minimum prices, while in Annex D we respond to these comments.

32. A summary of our conclusions in Section 4 are that:

    a) It is still reasonable to treat 800MHz and 900MHz on a par for setting minimum prices provided these are set conservatively relative to central estimates of likely market value;

    b) sub-1GHz spectrum should have a minimum price for a 2x5MHz block in the range €15m to €26m, with the entire range reflecting a likely lower bound estimate of market value for Ireland;

[12] The analysis presented in 09/99c was updated by 10/71b.

c) 1800MHz spectrum should have a minimum price at around 45% to 60% of that of sub-1GHz spectrum (€6.75m to €15.6m), again assuming reasonably conservative minimum prices; and

d) within this range, the primary consideration is trading off the suppression of incentives for strategic behaviour to weaken competition within the auction and the risk of choking off demand from serious bidders.

33. The views expressed in this report are those of DotEcon only and do not necessarily represent the views of ComReg.

2 Updates to the data

34. This section describes the changes to the dataset since it was last used to produce the updated benchmarking analysis of sub-1GHz spectrum in September 2010 (10/71b) and to produce a relative valuation of bands to recommend a suitable minimum price for 1800MHz in December 2010 (10/105a).

35. These changes include the addition of auction data relating to recent relevant awards, as well as augmentation of the original auction dataset due to the regular maintenance DotEcon carries out on its Spectrum Awards Database from which the dataset is drawn. Further, we used updated USD Consumer Price Index (CPI) data as well as PPP rates up to January 2011 in adjusting for currency and price differences across countries, so that all prices are presented in current real terms. However, USD CPI data is not yet available for February and March 2011, hence we present our prices in January 2011 terms. Finally we also updated Irish GDP per capita and population data to include that of 2010 (the latest available at the time of analysis) for predicting licence values in Ireland.

36. Some respondents to 10/71b (see Annexes C and D) criticised our benchmarking approach for not taking into account the impact of the current economic climate on spectrum valuations. However, including recently completed auctions in the dataset used for our analysis will be informative on spectrum valuations in the current economic climate. Further, using updated GDP per capita data for Ireland reflects the economic climate in Ireland at present. This has resulted in a downward adjustment of licence valuations in Ireland.

37. It is important to recognise that radio spectrum licences are *long-run assets* whose value should be expected to change less than proportionately with changes in *contemporaneous* GDP. First, any shifts in GDP will in part be transient rather than permanent, with the transient component not having much effect on the value of long-lived assets. Second, consumer demand for mobile telecoms services may not be strongly affected by consumers' income levels.[13] Third, changes in GDP

[13] In particular, a study by Chabossou, Strok, Strok and Zahonogo (2009) on "Mobile Telephony Access & Usage in Africa" (see http://www.sajic.org.za/index.php/SAJIC/article/view/191/122) finds in the African mobile market that *"mobile expenditure proofs to be inelastic with regard to income, ie as income increases mobile expenditure increases to a lesser extent…"*

Further we note from the Ofcom's 2010 International Communications Market Report that while consumers are most likely to some what reduce mobile usage and spend amongst the range of communication services; compared to other goods and services such as furniture, nights/meals out, holidays, groceries, footwear or clothing, consumer spending on communication services including that on mobile services, is more resilient in an economic downturn across the five countries surveyed (consumers in the UK, France, Italy, Germany and US were surveyed on their likely usage and spending habits for the period of October 2009 and October 2010). See http://stakeholders.ofcom.org.uk/market-data-research/market-data/communications-market-reports/cmr10/international/

(footnote continued)

are likely to be associated with changes in input costs for MNOs, such as capital costs, labour and site costs, all of which mitigate any reduction in demand for mobile services.[14] For these reasons, although shifts in GDP will affect spectrum values, there is no reason to expect this to be a particularly sensitive relationship.

2.1 Auction data

38. Several new auctions have taken place since September 2010, including sub-1GHz auctions in Denmark (900MHz), Hong Kong (850MHz and 900MHz) and most recently Sweden completed its auction of digital dividend spectrum (800MHz). In addition, during the period, higher frequency spectrum has also been auctioned in Austria (2.6GHz), Denmark (1800MHz) and Singapore (2.1GHz). Table 2 below presents a list of new awards that have been added to the dataset since the DotEcon September 2010 Report (10/71b).

39. In addition, we also have some backdated inclusions in our Spectrum Awards Database as part of the on-going task of maintaining and extending the dataset. These are the Broadband Personal Communication Services (PCS) auction (1900MHz) in May 2007 and multi-band auction in August 2008 where Broadband PCS licences (1900MHz) and Advanced Wireless Services (AWS) licences were sold in the United States. These auctions were included in our analysis in our 10/105a report.

40. Through a regular audit of our Spectrum Awards Database we have also reclassified one of the previous auctions that was included in the 10/71b dataset: the Norwegian 1790-1800MHz auction in 2008. The licence awarded in this auction is for terrestrial radio services use and not mobile services. For this reason, this auction has been excluded from the present dataset we use to update previous benchmarking analysis.[15]

41. All of these revisions are detailed in tables listing the auctions included in the various datasets considered in our analysis, presented in Annex A.

Finally, we note that ComReg's 2010 Q4 Quarterly Report shows recovery in mobile usage and revenues despite falling GDP per capita. See http://www.comreg.ie/_fileupload/publications/ComReg1121.pdf

[14] Indeed we note from Ofcom's 2010 International Communication Market Report that between October 2007 and April 2010, telecom shares perform in line with or out performs the wider market and between late 2008 and early 2009, telecoms shares consistently out perform the wider market.

[15] H3GI in response to ComReg's consultation 11(11) on interim licences for the 900 MHz spectrum band queried the validity of the auctions dataset adopted by DotEcon for its benchmarking analysis including the appropriateness of including awards such as the DECT Guardband in the UK and 1785-1805MHz in UK and Ireland. These queries are included in our review of respondents' comments in Annex C (Table 24) and discussed in Annex D where we respond to these comments in paragraph 165.

Table 2: New auction data used in updated benchmarking analysis[16]

Country	Award	Date	Average auction price per MHz per pop[17] (January 2011 Euro)
United States	Auction 78 – Broadband PCS	August 2008	€0.222
United States	Auction 78 – AWS1	August 2008	€0.0736
Austria	2.6GHz Auction	September 2010	€0.0242
Denmark	900MHz Auction	October 2010	€0.0120
Denmark	1800MHz Auction	October 2010	€0.00308
Singapore	2.1GHz Auction	October 2010	€0.347
Hong Kong	850MHz, 900MHz and 2GHz Auction	March 2011	€2.08
Sweden	800MHz Auction	March 2011	€0.236

42. Further, note that the auctions in Denmark and the 2.1GHz auction in Singapore were uncompetitive and the licences were awarded at the reserve prices.

2.2 USD CPI Monthly data and Euro PPP rates

43. DotEcon's Spectrum Awards Database stores licence price and minimum price information in local currency.[18] When using the data, we apply a Purchasing Price Parity (PPP) exchange rate to account for price differences across countries in converting these prices into a common currency (the US Dollar (USD)). This is because the dataset includes a wide range of countries far beyond just the Euro area. The PPP rate accounts for price differences between the country in which the licences

[16] Further we note that post completing the benchmarking analysis in this report, the Singapore 1800MHz auction which we refer to later in this report was subsequently concluded on the 28th March 2011 hence is not included in this iteration of the benchmarking analysis.

[17] We note that our per MHz per pop calculations utilizes aggregate spectrum available (including spectrum for both uplink and downlink for paired spectrum). For instance for a 3G licence comprising 2x15MHz plus 5MHz unpaired spectrum would have an aggregate spectrum amounting to 35MHz.

[18] The minimum price of a licence refers to the sum of reserve price and the total stream of annual fees across the licence term. Licence price similarly refers to the sum of the headline price of the licence in the auction and the total stream of annual fees across the licence term.

were auctioned and the US and avoids difficulties that might be caused otherwise by exchange rates being misaligned (possibly for long periods). This price in US dollars in the year of the award is then adjusted for USD inflation using monthly CPI data published by the US Bureau of Labour Statistics.[19] This establishes comparable prices in real US dollars.

44. 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 analysis in September 2010 used finalised CPI figures for 2008 and earlier only. This data has now been updated such that 2009 and earlier CPI data is now finalised and interim adjustments have been made to 2010 CPI data.

45. The latest available USD CPI data from the US Bureau of Labour Statistics is that for January 2011. As the Swedish and Hong Kong auctions added were completed in March 2011, we have assumed as noted above for the purpose of converting these auctions' prices into USD that there are no changes in price levels between January 2011 and March 2011 i.e. the USD CPI rate used is the same for January 2011, February 2011 and March 2011.

46. After prices are expressed in real USD January 2011 terms we then convert prices into Euro using a US dollar to Euro PPP rate. In 09/99c and 10/71b we applied an USD to Euro PPP rate estimated to be 10% above the interbank exchange rate as an actual PPP rate was not available at that time.[20] Consistent with this approach and in line current currency and price trends, in this benchmarking analysis update we apply a PPP mark up over official exchange rate of 10%.[21] The interbank rate in 2011 up until the end of January of USD to Euro was on average 0.74903$/€. Therefore applying 10% to the interbank rate gives a US dollar to Euro PPP rate of 0.824$/€. Using this US dollar to Euro PPP rate all prices presented in the updated benchmarking analysis below are expressed in Euro January 2011 terms.

2.3 GDP and population data in Ireland

47. For our benchmarking analysis in 10/71b, only data from 2009 on GDP and population were available. Currently we have updated this to 2010 data with information from the Central Statistics Office Ireland.

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

[20] In footnote 45 of 09/99c we considered that 10% was a conservative value for the mark up of PPP rates over the official exchange rate 2007- 2009 which ranged from 8% to 30%. Over the 3 years leading up to January 2011 (2008-2010), the mark up of the PPP rate over the official exchange rate ranges between 1.5% and 33.5%. The average mark up of PPP over official exchange rate between 2008-2010 for the sample is around 21% and the average for 2010 is 15%. Therefore in line with our previous approach, we consider a 10% mark up of PPP over the official exchange rate.to be consistent and conservative.

[21] http://www.oanda.com/currency/average

48. Specifically, in 2010, Irish GDP at current market value (in 2010 prices) was an estimated €157,702m[22] and population in April 2010 was 4,470,700; this equates to a GDP per capita of €35,274. This is 1.5% lower than the GDP per capita in 2009 (€35,800), which we used in our 10/71b analysis and 18% lower than estimated GDP per capita in 2008 that was used for the analysis in 09/99c (€43,300).

49. Even if the estimated regression models were unchanged (i.e. the same data and models were used as in our second report 10/71b) then changes in GDP per capita lead to a lower benchmark purely through changing the explanatory variables used for predicting the price of an Irish licence. However, notice that the fall in per capita GDP mostly took part between 2008 and 2009. Therefore, using the latest GDP data causes only a small GDP reduction compared with 2009 GDP figures. We examine this effect in more detail in the following section.

[22] The GDP data available is up to quarter 3 2010 therefore we have estimated overall 2010 GDP for Ireland by equating quarter 4 GDP to quarter 3 GDP and taking the sum of all 4 quarters i.e. Q1(€39,233m) + Q2(€39,293m) + Q3(€39,588m) + Q4(€39,588m) = €15,7702m

3 Benchmarking analysis updated for 2011

50. In this section, we update the benchmarking analysis in our previous two reports in the light of:

    a) the additional and revised auction data (discussed already in Section 2.1);

    b) revised macroeconomic data (discussed in Section 2.2);

    c) the most recent data on Irish GDP and population (discussed in Section 2.3).

51. We start by considering the *relative* value of 1800MHz and sub-1GHz spectrum, where we maintain the conclusion that the relative value of these bands is likely to be in the 45% to 60% range. More recent data does not lead us to revise this conclusion.

52. We then go on to consider the value of sub-1GHz spectrum. Updates to the dataset lead to some changes to our regression models, though little change to any of the benchmarks based on simple averages.

3.1 Relative value of 1800MHz and sub-1GHz spectrum

53. As described in Section 1 above, in our first report on aspects of a 900MHz award (09/99c), we originally set out a benchmarking approach that resulted in the derivation of a conservative lower bound estimate of the market value of liberalised 900MHz spectrum. This analysis was updated in 10/71b to consider the inclusion of the 800MHz band.

54. Interpretation of the benchmarking results needs to consider that GSM 900MHz licences in most countries were commonly awarded administratively rather than via competitive auctions and that these licences were typically unliberalised. Furthermore, the available dataset of 800MHz auction results was small. Therefore, in determining the value of sub-1GHz spectrum, it would be more robust to consider a larger dataset of mobile frequency licence prices due to the large amount of noise observed in individual outcomes.[23] In particular, when using a regression model, better estimates of the impact of GDP, population and other factors on licence value could be obtained from a larger dataset, even if some of the auctions considered were for different bands (provided appropriate dummy variables were included to represent the impact of different bands).[24]

[23] Noise here refer to outcomes that are unexplained by the econometric model applied. In order words, there are unobserved variables influencing the auction outcome and these may vary from auction to auction hence can not be systematically controlled for under the model applied..

[24] Clearly, this is predicated on GDP and other explanatory variables having a similar influence on spectrum in different bands given an appropriate model specification (e.g. logarithmic). There is no evidence from the data that this assumption is inappropriate. Therefore it is not clear what the appropriate frequency band dummies should be.

55. In any case, as already discussed in Section 1, a blended average price of a "mobile" licence (including both sub-1GHz and higher frequency spectrum) serves as a conservative lower bound for the value of liberalised sub-1GHz licences, as the superior propagation characteristics and liberalised nature of the sub-1GHz spectrum concerned would at best be partially reflected in the available benchmark data. For the purpose of setting the sub-1GHz minimum price in the proposed auction, an approach yielding a conservative lower bound estimate of sub-1GHz spectrum market value is still useful given ComReg's objectives for setting a minimum price.

56. However, as 1800MHz spectrum does not have the same superior propagation characteristics as sub-1GHz spectrum, adopting the same benchmarking approach as in our sub-1GHz analysis would not yield a 'conservative lower bound' estimate of 1800MHz spectrum. The uncertainty as to whether the estimate represents a lower, average or upper level estimate of market value in the context of 1800MHz means that setting a minimum price for 1800MHz spectrum based on these estimates could pose a non-trivial risk that demand from serious bidders is choked off.

57. For these reasons we did not use the same approach for setting the minimum price of 1800MHz spectrum as we did for setting the minimum price sub-1GHz spectrum. In order to ensure that our analysis produced a minimum price for 1800MHz spectrum that was in line with the minimum price set for sub-1GHz spectrum, we adopted the alternative approach of using auction data to determine the relative competitive market value of 1800MHz to sub-1GHz spectrum and used this ratio to set the minimum price for 1800MHz spectrum relative to that of sub-1GHz frequencies. This ensures that the minimum prices of different bands are being set on a comparable basis in terms of the likely relativity of minimum price to market value (and so hopefully also in terms of the risk of lots going inefficiently unsold as previously described in paragraph 8).

58. In this benchmarking exercise, we compared the average licence prices of spectrum comparable to that in the 1800MHz band (1800MHz or 1900MHz) to that of spectrum comparable with that in the 800MHz and 900MHz bands (700MHz, 800MHz or 900MHz):

- at the auction level within auctions for which both categories of frequencies were offered at the same time; and/or
- at a country level within countries which have held separate auctions for both category of frequencies under comparable economic and competitive conditions.

59. In order to include more data points for our analysis we included all the auction data available in our Spectrum Awards Database including auctions that were held before the year 2000 which were not included in our sub-1GHz benchmarking analysis. While this meant using older auction data, our implicit assumption was that the relativity of sub-1GHz to1800MHz spectrum value has remained fairly constant over time. Given that differences in radio propagation characteristics arise from physical constraints, there was good reason to expect this to be a tolerable approximation. Our results, which were presented in Section 7.2.3 of our

report (10/105a), showed that this relativity seems to have remained fairly stable over time.

60. Our analysis compared – for each band within each auction[25] - the average licence price per MHz per capita of sub-1GHz licences to that of 1800MHz licences. As in the sub-1GHz analysis the duration of licences was also adjusted to a common 15-year basis to account for any licence duration discrepancies across auctions.

61. The licence price (per MHz per capita) was left in nominal local currency terms when comparing relative value between the different categories of spectrum. Where we were comparing the relative band value of the spectrum frequency categories across auctions in different time periods, this approach ignored inflation effects on licence prices across auctions.[26] These effects should have been immaterial to our conclusions as inflation did not have a large impact on relative band value in the two countries constituting useful data points:

- Norway which had auctions of close chronological order hence inflation would not have a material impact on relative band value; and
- The US which had sub-1GHz and 1900MHz auctions roughly evenly spread out across the sample period there by netting off inflationary effects.

62. Our analysis of relative bands values in 10/105a found that the value of 1800MHz spectrum in competitive auctions was approximately 45% to 60% of the value of sub-1GHz spectrum. We call this ratio the "relative band value".[27]

63. Of the new auctions added to our dataset discussed in section 2.1 above, only the Danish auctions yielded a new data point for relative band value between sub-1GHz and 1800MHz frequencies. The Danish auctions were for re-farmed spectrum, and existing incumbents with spectrum holdings in the 900MHz and 1800MHz bands were not allowed to participate. Neither auction was competitive as only one bid for each band was received and the spectrum in both bands was awarded to H3G at the reserve prices.

64. We note in particular that the reserve prices set in the Danish 900/1800MHz auctions were DKK8m for 2x5MHz of 900MHz spectrum

[25] A data point was an average price for a band in an auction, rather than the individual prices of lots within the auction.

[26] In addition, the advantage of this approach is that it is not necessary to consider exchange rate data, with the associated uncertainties that this creates. DotEcon's Spectrum Awards Database only stores the United States Consumer Price Index (CPI) data, in our sub-1GHz benchmarking analysis licence prices are converted into US Dollar before controlling for inflations using the CPI data. If we were to control for inflation in the relative band value analysis, this would introduce uncertainties associate with exchange rate data.

[27] See section 7.2.3 of DotEcon report 10/105a for a more detailed discussion of the 1800MHz spectrum benchmarking results.

and DKK4m for 2x10MHz of 1800MHz spectrum. These reserve prices reflect a relative band value of 25%. The Danish regulator, NITA notes in section 6.1 of the Information Memorandum[28] for the auctions that the relative reserve prices reflect the differing technical characteristics of the spectrum bands, namely that 900MHz spectrum has superior propagation characteristics. However, NITA also noted that the reserve prices were set at a level to ensure that only serious bidders would take part in the auction and was not meant to be reflective of the market value of these licences. That is, while the reserve price of 900MHz spectrum was higher than that of 1800MHz spectrum in Denmark, this did not reflect the relative market value of these frequency bands.

65. Further, there is no information on the relative value of spectrum in these different bands given the fact that this spectrum was sold at the reserve price set for 900MHz and 1800MHz spectrum by the regulator. That is, given that there was only one bidder in this auction, we cannot glean any information about the relative willingness to pay for spectrum in these different bands; we simply know that the willingness to pay of the relevant bidder was at least the level of the reserve price in these two cases.

66. Overall, given the Danish 900/1800MHz auctions were uncompetitive and the prices at which the spectrum was awarded in the Danish auctions do not reflect relative competitive market value of 900MHz and 1800MHz spectrum, hence is not a useful data point for our purpose of estimating a relative band value and there is no reason to alter our conclusion about the relative band value between 1800MHz and sub-1GHz spectrum in 10/105a. Our analysis of relative band value considered data points of competitive auctions only. Hence, we maintain our previous conclusion that the relative value of 1800MHz to sub-1GHz spectrum should be between 45% to 60%.

67. Further, we noted in 10/105a, and discussed above, that the purpose of finding a relative valuation of 1800MHz to sub-1GHz spectrum is to allow us to be consistent in setting minimum prices in both categories of spectrum on a *conservative lower bound* basis. The exact relative valuation of 1800MHz spectrum to that of sub-1GHz spectrum is not crucial for this purpose provided any uncertainty is reflected in appropriate conservatism in setting the level of minimum prices. Where the relative value is somewhat different, this will be reflected in different relative prices of sub-1GHz and 1800MHz spectrum established in the auction itself; as long as both prices constitute conservative lower bounds to actual market value of the respective frequencies, no efficient demand in either category will be choked off in advance of the auction. If there are concerns over the uncertainty of the relative values of 1800MHz to sub-1GHz spectrum, as with that between 800MHz and 900MHz spectrum as discussed in 10/71b, a more conservative minimum price should be chosen to reflect this.

[28] See http://www.itst.dk/frekvenser-og-udstyr/auktioner-og-udbud/tidligere-auktioner-og-udbud/900-og-1800-mhz-auktion/resolveuid/4bfb9c4c497da199b128ff625ef9b5f8

3.2 Sub-1GHz spectrum benchmarks

68. In this sub-section, we apply the same benchmarking methodology as described in Section 4 of DotEcon Report 10/71b (a brief overview of the methodology is provided below) to generate benchmark values for sub-1GHz spectrum. However, we use our updated auctions dataset (see section 2.1) and we adjust prices using updated USD CPI and PPP data (see Section 2.2). In deriving an implied licence value for sub-1GHz spectrum in Ireland, we apply updated GDP per capita and population data from 2010 (see Section 2.3).

69. Specifically, we first calculate the average spectrum value for the following datasets:

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;[29]
d) All mobile spectrum auctions of sub-1GHz and 1800MHz licences (that is, licences to be used for mobile between 800MHz and 1900MHz inclusive); and
e) All mobile spectrum auctions of 3G licences.

We then run our regression analysis on the following datasets:

f) All mobile spectrum auctions;
g) All mobile spectrum auctions in Europe; and
h) All mobile spectrum auctions of sub-1GHz and 1800MHz licences.

70. In line with our approach to derive a conservative lower bound estimate of the value of sub-1GHz spectrum, as discussed above, our dataset includes mobile licences in both sub-1GHz and higher frequency spectrum bands, many of which are for unliberalised spectrum.

71. Below we update our averages benchmarks followed by our regression analysis benchmarks and explain the methodology used.

3.2.1 Updated averages benchmarks

72. In this simple average approach, we first derive an auction price for each auction by calculating the population-weighted average of all licence values within the auction. We then take a simple average (all auction entries have equal weight across the sample) of the auction price of all auctions within the sample to derive a benchmark value for the dataset (see Equation 1 below). This approach is appropriate as it gives equal weight to each auction, regardless of the number of licences sold within an auction.

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

Equation 1: Calculating an average benchmark

$$\overline{p} = \sum_{k=1}^{K} \frac{1}{K} \left(\sum_{i=1}^{I_k} w_{k,i} p_{k,i} \right)$$

where

- $\overline{p}$ is the average price per MHz per population (our benchmark price);
- K is the number of awards in the dataset;
- $w_{k,i}$ is the adjusted[30], licence-specific weight of licence i, where each licence is weighted by the population within its licence region in relation to the national population in the country of award k (that is, the licences in an auction of national licences will have equal weight);
- I_k is the number of licences in award k; and
- $p_{k,i}$ is the price of licence i in award k.

73. In 10/71b, we modified our averaging benchmark analysis to also consider band-specific averages. That is, we calculated an "auction-band" average for licences of a particular frequency band within an auction. That is, in Equation 1 above, in calculating an "auction-band" average, I_k only includes the licences of the frequency concerned (be it 3G or "sub-1GHz and 1800MHz") in award *k*.

74. For example, in the German multi-band auction in May 2010, several different frequency bands were auctioned. The auction average approach described above would yield a price of €0.21per MHz per population (January 2011 prices). This average included 800MHz, 1800MHz, 2GHz and 2.6GHz licences while the auction-band average price for 800MHz spectrum in the German auction was €0.71 per capita per MHz. For the frequency-specific cuts of the data such as in the case of our "sub-1GHz and 1800MHz" and "3G" benchmark, the auction-band average presents a more focussed estimate of the average value of the licences linked to frequencies of interest in the auction.

75. In Table 3 below we present the updated benchmarks using the averaging method on the modified dataset discussed above. In addition, we present the previous results from 10/71b in Table 4 for comparison.

[30] We use adjusted weights, which take into account that population coverage stated in regional licences does not always add up to the population figure from which they were divided. We therefore adjust these weights by dividing them by the sum of all weights of the country as shown in the following equation:

$w_{k,i} = w^*_{k,i} \Big/ \sum_{i=1}^{I_k} w^*_{k,i}$ where $w^*_{k,i}$ are the unadjusted weights.

Table 3: 2011 averages benchmarks

Benchmark group	Auction average		Auction-Band average	
	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	€0.639	€28.6m	Not applicable	
Europe	€0.506	€22.6m		
Similar GDP per capita	€0.565	€25.3m		
Sub-1GHz and 1800MHz	€0.706	€31.5m	€0.714	€31.9m
3G	€0.860	€38.4m	€0.856	€38.3m

Table 4: 10/71b averages benchmarks (for comparison)

Benchmark group	Auction average		Auction-Band average	
	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" (sub-1GHz and 1800MHz)	€0.683	€30.4	€0.692	€30.9m
3G	€0.891	€39.7m	€0.887	€39.5m

76. We note that the updates made to the data had very little impact on our benchmarks constructed using the averaging method. The overall benchmark of all mobile auctions is now marginally lower. Auction results in Austria (2.6GHz), Denmark (900MHz and 1800MHz) and Sweden (800MHz) have jointly pulled down the "Europe" benchmark while the Hong Kong (850MHz and 900MHz) result in particular has pulled up the "sub-1GHz and 1800MHz" benchmark. Further, the "3G" and "similar GDP per capita" benchmarks have been reduced marginally.

3.2.2 Updated regression benchmarks

77. In our benchmarking analysis update published in September 2010 (10/71b), we ran the regression model from previous work published in December 2009 (09/99c) using the modified dataset. However, we found that the addition of 2.5/2.6GHz auctions in Europe depressed price predictions. In particular, in our view prices in Finland and the Netherlands were exceptionally low partly because of flaws in the auction design in the former case and strict spectrum caps in the latter.[31]

78. To control for this, we modified the regression model used in our work reported in 09/99c to take into account the greater weight of 2.5/2.6GHz auctions in recent years by including a dummy variable (twopointsix) for 2.5/2.6GHz licences. However, in the European regression model, the twopointsix dummy variable had a positive coefficient, which reduces the predicted licence value for sub-1GHz spectrum in Ireland (see Annex B in 10/71b). This is counter-intuitive to the relative technical benefits of sub-1GHz spectrum compared to 2.6GHz spectrum (though remember that all 2.6GHz spectrum is liberalised, whereas much of the sub-1GHz spectrum in the dataset is unliberalised which is the likely reason for this finding). Instead, when all 2.6GHz auctions were dropped from the European regression model dataset, the European regression model produced results more in line with the other benchmarks considered,[32] hence we presented the latter as the result of our European regression model.

The regression model used for this update

79. In this update, we will follow the same regression approach as that was adopted in DotEcon report 10/71b for both the mobile auction regression model (using the twopointsix dummy) and the European regression model (dropping the 2.6GHz auctions from the sample of European mobile auctions). In addition, given that there is now auction data for 2011, we have re-categorized the year dummy such that 2010 is no longer grouped with 2008 and 2009 as in the regression in 10/71b but rather that 2010 and 2011 are grouped together while 2008/2009 revert to being grouped together as in the models presented in 09/99c. Equation 2 below details the regression we ran in our main analysis using a dataset of all international mobile spectrum auctions.

[31] See DotEcon June 2010 Discussion Paper – Flexible or fixed? A survey of 2.6GHz spectrum awards. http://www.dotecon.com/publications/dp1001.pdf

[32] The sub-1GHz and 1800MHz regression model being a frequency specific dataset was not affected by the inclusion of auction results from the wave of 2.5/2.6GHz auction.

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

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \cdots$$
$$\ldots + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \cdots$$
$$\ldots + \beta_{twopointsix} \cdot twopointsix + \beta_{AFME} \cdot AFME + \beta_{preIT} \cdot preIT + \cdots$$
$$\ldots . + \beta_{year01} \cdot year01 + \beta_{year0203} \cdot year0203 + \beta_{year0405} \cdot year0405 + \cdots$$
$$\ldots + \beta_{year0607} \cdot year0607 + \beta_{year0809} \cdot year0809 + \cdots$$
$$\ldots + \beta_{year1011} \cdot year1011$$

where:

- $PMHzPop$ is price per MHz per population (our dependent variable);
- β_0 is a constant;
- $GDPpc$ is GDP per capita. We note that there are differences in recent movements of Irish GDP versus GNP. 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 of factors that may affect spectrum valuations such as the level of development in a country and potential willingness to pay for telecommunications services (i.e. economic activity within the borders of that country);
- $ApPop$ 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 with a network operating before the start date of the auction, 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;
- $twopointsix$ is a dummy variable that is 1 if the spectrum licence sold is within the 2500-2690MHz range;
- $AFME$ is a dummy variable which is 1 if the licence is awarded in an African or Middle-Eastern country and 0 if not;
- $preIT$ is a dummy which is 1 if the licence was awarded before the Italian 3G auction (the last auction before the TMT equity bubble burst) or 0 if the licence was awarded afterwards; and
- $year$ is a dummy, which is 1 if the licence was awarded in the relevant 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.

80. 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.[33] The results are summarised in the following table:

Table 5: Regression analysis results using all mobile licences sold in an auction

Coefficient for	Estimated coefficient	Standard error
GDPpc	0.0000191**	0.00000136
ApPop	-0.647**	0.232
WtB	-1.94**	0.0664
invNMNOs	2.39**	0.251
national	0.0847*	0.0427
twopointsix	-0.149**	0.0562
AFME	0.797**	0.0602
preIT	0.775**	0.102
yearD_01	-1.04**	0.0862
yearD_0203	-1.80**	0.0982
yearD_0405	-1.49**	0.0919
yearD_0607	-1.50**	0.0887
yearD_0809	-1.45**	0.0898
yearD_1011	-1.13**	0.0932
Constant (β_0)	2.11**	0.126

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

81. We present the corresponding regression results for our European and sub-1GHz and 1800MHz regression model in Annex B. In Table 7 below we present the forecasts of current licence values for Ireland obtained from all three of these regression models. We have updated the Irish population data from that available in 2009 (explanatory variables used in 2010 for analysis in 10/71b, see Table 6 below) to that in 2010 to use as our explanatory variables (2011 explanatory variables). We present the set of 2011 explanatory variables used for prediction in Table 6 below. In order to distil the impact of the change in explanatory variables from the

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

impact on the current regression results with the use of new auction data (see Table 5 above), we also present the predicted licence price using the revised regression models with the 2010 explanatory variables in Table 7 below.

Table 6: Inputs used for predictions in 2011 10/71b regression analysis (2010 explanatory variables) and current benchmarking exercise (2011 explanatory variables)

Independent variable	Value Report 10/71b 2010 variables	Value Current report 2011 variables
Population	4,459,300	4,470,700
GDP per capita (in Euros)	35,800	35,274
Number of mobile network operators	4	4
Number of participating bidders	5	5
Winners to bidders	0.86	0.86
Area (in square kilometres)	70,280	70,280
Year	2010	2011

Table 7: 2011 all mobile auctions regression benchmarks

Dataset	(a) 10/71b regression with 2010 explanatory variables		(b) Current regression* with 2010 explanatory variables		(c) Current regression* with 2011 explanatory variables	
	Price per MHz per pop (Euro)	Implied value of a 2x5MHz block in Ireland (Euro)	Price per MHz per pop (Euro)	Implied value of a 2x5MHz block in Ireland (Euro)	Price per MHz per pop (Euro)	Implied value of a 2x5MHz block in Ireland (Euro)
All mobile	€0.416	€18.6m	€0.556	€24.8m	€0.546	€24.4m
Europe	€0.455	€20.3m	€0.283	€12.6m	€0.273	€12.1m
Sub-1GHz and 1800MHz	€0.409	€18.3m	€0.663	€26.7m	€0.639	€25.5m

*The regression model specified in Equation 2 above using the new auction data set described in section 2.1 of this report.

82. The addition of new auction data will alter the coefficients on all the explanatory variables (see Table 5 above). Therefore, even if the explanatory variables were held the same as those used as in 10/71b, the new coefficients would result in different predicted licence prices. Table 7 shows that most of the change in the results is due to changes in the estimated regression model relative to that in 10/71b, not updates of the explanatory variables.

83. Due to the structure of the regression model used, adding new auction within the last two years will have a larger impact on predicted licence values compared to adding older auction data, the former would alter the coefficient of the 2010-2011 year dummy. The estimated coefficient on this "year_1011" dummy directly affects the predicted current licence values in Ireland (unlike time dummies for previous periods). The year dummies sought to capture the time trends in licence values, hence if current market value of spectrum licences is relatively low (i.e. awards in 2010 and 2011) this would be reflected in lower coefficient of the 2010-2011 year dummy and a lower current predicted licence value for Ireland.

84. This is a key point to keep in mind when interpreting the results. In terms of the level of licence value predicted for Ireland, the regression model being used gives much greater weight to outcomes in 2010 and 2011 than the simpler averaging process. This is because of the structure of time dummies being used in the regression model allows for time-varying factors affecting valuations.

Trends in licence valuations

85. A priori, we can see that there are a variety of supply-side and demand-side effects that might cause the value of spectrum to change. Increasing demand for data bandwidth is the key factor tending to increase spectrum value over the long run. However, at the same time, there are short to medium-run supply-side effects, in that technological and regulatory changes are increasingly making it easier to use one band as an alternative to another. Further, many countries are actively seeking under-utilised spectrum for release.

86. Therefore, the picture is mixed and it is not at all clear whether there are systematic trends in licence values *currently* at work:

    a) Looking at the world-wide regression model, there is evidence of a sustained upwards trend in prices from 2002 onwards (the year dummy coefficients reported in Table 5 become successively less negative);

    b) Looking only at European auctions, the situation is far less clear, as the corresponding coefficients are not all significant and vary from year to year (see Table 19 which is comparable to Table 5). This is perhaps unsurprising, as once we restrict attention to European auctions only there is much more similarity in the bands being offered at any particular time; this means that differences between the value of bands tend to mask time trends. Also during this period, the impact of digital switchover commitments and EU-wide initiatives to make spectrum available in the 800MHz band may have had a common effect on the perceived scarcity of sub-1GHz spectrum.

87. Comparing results in section (a) to section (b) of Table 7 above, the addition of new auction data has the effect of increasing predicted licence prices in both the worldwide mobile auctions and sub-1GHz and 1800MHz auctions regression models while decreasing predicted licence value in the European regression models. In particular, we see the greatest change in predicted licence prices from the sub-1GHz and 1800MHz regression model. This is perhaps unsurprising considering that the sub-1GHz licence prices achieved in the Hong Kong 2011 auction (which are part of the 'sub-1GHz and 1800MHz auctions' dataset) are significantly higher than the sample average.

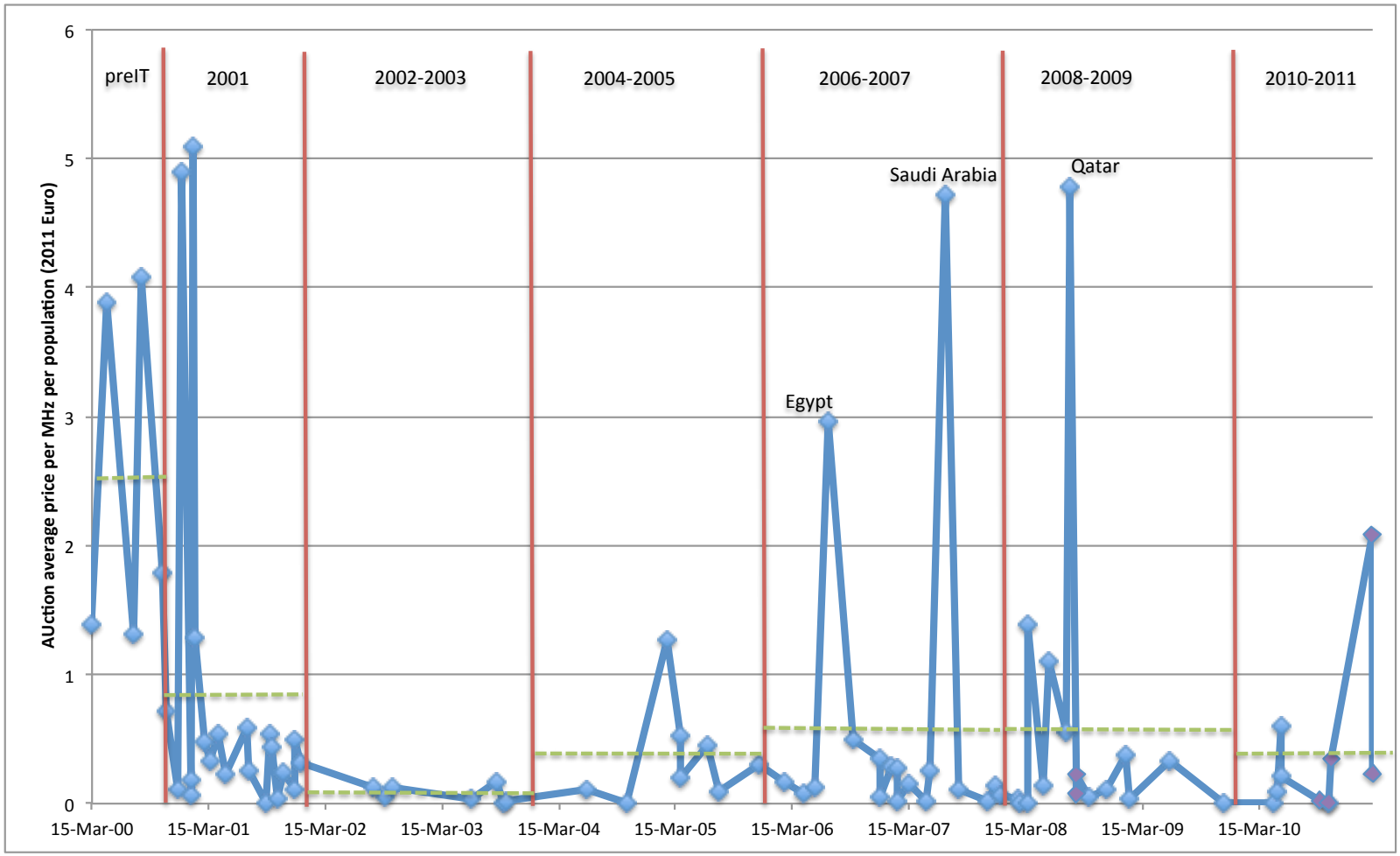
88. In the dataset of 'European mobile auctions' on the other hand, the relatively low prices of the uncompetitive Danish auctions[34] and the recently completed Swedish 800MHz auction means that the new regression results yields a lower predicted licence price compared to 10/71b. We have noted above that the reserve prices set by NITA in the Danish auctions were not reflective of the market value of the spectrum as discussed in paragraphs 64 and 65.

[34] See paragraph 63.

89. In order to see these time trends, in Figure 1 below we chart the chronological average licence price movement of all mobile auctions in our sample.[35] The blue trend line charts average auction prices while the red lines segregate the data into respective time periods. The green dotted line indicated the average licence value for each period. (These are just simple averages, not predictions of the regression model.) New auction data added (as described in Section 2.1) is reflected with a purple marker.

[35] This is the dataset of our "Mobile" regression model.

Figure 1: Average prices in mobile spectrum auctions



90. The general pattern shown is one of a broad upward trend in prices since the end of the telecoms bubble (i.e. from the end 2001 to 2009) with a modest drop back in this average in the final 2010-2011 period. This is broadly consistent with the increasing coefficients on the dummy variables for time periods (after 2001) estimated in the regression model and shown in Table 5. In particular, there is no inconsistency between the drop back in the average prices for 2010-2011 shown in **Error! Reference source not found.** and the unbroken trend of increasing coefficients on dummy variables for time periods shown in Table 5:

    a) Within the regression model part of this modest decline in average values in the final time period (2010-2011) is accounted for by a decline in GDP in some countries;

    b) High prices paid in Egypt, Saudi Arabia and Qatar are reflected in part in the Africa-Middle East dummy variable (AFME), so these particular auctions only have a weak influence on the estimated coefficients on the dummy variables for time periods. Nevertheless, these auctions do significantly contribute to the average prices across 2006-2007 and 2008-2009 periods. This is part of the explanation for the apparent drop back in average prices in 2010-2011 shown in Figure 1 (i.e. average prices in the previous periods were inflated due to these outliers).

91. Therefore, it is fair to characterise the situation as being one in which there has been an *underlying* upward trend in spectrum values since 2002. (This is what the upward trend in coefficients on the time dummies in Table 5 shows.) However, actual *observed* prices have also been subject to some high outliers (especially high prices in Egypt and the Middle East) and have been modulated by declines in GDP, changes in competitive intensity and the bands actually being sold.

92. This interpretation is evident if we consider an alternative regression model in which we simply omit the time dummies altogether. In this case, all three versions of the regression model predict strictly lower prices for Ireland, as we now show. This is because such a model without time dummies treats spectrum value as being untrended, so past auctions have much greater weight in the predictions of current value for Ireland.

93. With this change, the regression model is now given by Equation 5, with the corresponding estimated coefficient shown in Table 8 and the corresponding predicted values for Ireland shown in Table 9.

Equation 3: Mobile regression model without year dummies

$$PMHzPop = \beta_0 + \beta_{GDPp} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \beta_{twopointsix} \cdot twopointsix + \beta_{AFME} \cdot AFME + \beta_{preIT} \cdot preIT$$

Table 8: Results of regression without year dummies using all mobile licences sold in an auction

Coefficient for	Estimated coefficient	Standard error
GDPpc	0.0000169**	0.00000138
ApPop	-0. 472*	0.239
WtB	-1.75**	0.0656
invNMNOs	3.64**	0.247
national	0.188**	0.0440
twopointsix	-0.171**	0.0536
AFME	0.515**	0.0593
preIT	2.07**	0.0678
Constant (β_0)	0.389**	0.0892

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

Table 9: Predicted licence value of 2x5MHz in Ireland if year dummies are omitted

Regression model	Current regression without year dummies* with 2011 explanatory variables
Mobile	€17.4m
Europe	€11.1m
Sub-1GHz and 1800MHz	€14.7m

*Note that current regression without year dummies refers to the regression model specified in Equation 3 above using the new auction data set described in Section 2.1.

94. The key point to note here is that if we do not allow for a time trend, then the forecast values for the all mobile and sub-1GHz and 1800MHz only cases are *much* reduced relative to the model that allows for time trends. However, the Europe-only forecast is reduced only a little. This is consistent with an underlying *upward* trend (since the end of 2002) in spectrum value within the global data, though this trend seems to be much weaker for Europe. (We might speculate that this is because of offsetting supply-side initiatives to boost supply of sub-1GHz spectrum in Europe.) This *underlying* trend is modulated by changes in the various explanatory factors within the regression model (e.g. changes in GDP and so on) and is overlaid by considerable noise in terms of the individual auction outcomes. Nevertheless, what is clear is that the data rejects any notion that, conditional on the explanatory factors such as GDP, spectrum values have recently fallen to any great degree, even within Europe.

95. Finally, notice that our regression model with time dummies has a higher adjusted R-squared hence is a significantly better fit than the regression excluding the year dummies.[36] This supports the inclusion of the year dummies to taking account the time trend of spectrum value in predicting current licence values.

Other changes in the estimated regression model

96. In the 'all mobile auctions' regression model, we note that the addition of new auction data has resulted in the coefficient of the national licence dummy variable (*"national"*) becoming positive where it had been negative in the previous estimated model in 10/71b. This positive correlation is more in line with the general logic that a national licence should be more valuable than a collection of regional licences. This largely drives the increase in the predicted licence value in the 'mobile' regression model compared to that derived in the analysis published in 10/71b.

Values of independent variables used in predicting licence prices

97. From section (c) of Table 7 above, we note that the changes in GDP per capita (a decrease of 1.5%) and population (an increase of 0.26%) from 2009 to 2010 has a small depressing effect on the predicted licence value for Ireland. This ranges from a €0.4m reduction in the mobile and European auctions regression model to a €1m reduction in the sub-1GHz and 1800MHz auctions model. The impact necessarily depends on the coefficient of GDP per capita in each regression model (see regression output in Table 5 and in Annex B).

98. Further, we note that in all three regression models, the level of competitiveness in the auction measured by the "ratio of number of winners to bidders" has a non-trivial impact on predicted licence prices for Ireland. The lower the ratio, the more competitive the auction, and a less competitive auction will have a winners to bidders ratio closer to 1.[37] In the original benchmarking analysis published in DotEcon report 09/99c, we applied the sample average winners to bidders ratio of all auctions with national licences of 0.86 as the explanatory value for Ireland. We

[36] The term "R-squared" refers to the sum of square of residuals in a regression and suggests a measure of the fit of the regression line to the data - the higher the R-squared, the better the fit. However the R-squared will never decrease when an additional explanatory variable is added to the model regardless of its explanatory power. The adjusted R-squared takes into account the degrees of freedom lost when new variables are added to a model – it includes a "degrees of freedom penalty" when a new variable is introduced and measures if the improved fit out weighs this penalty. Indeed the adjusted R-squared of a regression may decline when a new variable is added, hence the adjusted R-squared is a more robust measure of the goodness of fit of a regression model.

In the worldwide regression model with time dummies, the adjusted R-squared value is 0.448. The worldwide regression without the time dummies has an adjusted R-squared of 0.391. In the European auctions model, the adjusted R-squared of the regression model with time dummies is 0.760 and that without is 0.733. In the sub-1GHz and 1800MHz auctions regression model, the regression model with the time dummies has an adjusted R-squared of 0.4832 and that without is 0.355.

[37] Specifically, in an auction where the aggregate sum of the spectrum cap on each bidder adds up to the total amount of spectrum available, an auction with a winners-to-bidders ratio of 1 represents a non-competitive auction.

used the same value in our analysis in 10/71b and in our current regression analysis results in Table 7.

99. We note however that in our current dataset, the sample average winners to bidders ratio (WtB) for all auction comprising national licences is currently 0.77; that is, the average level of competitiveness of the auctions in our current dataset has *increased* as a result of adding new data points.[38] In Table 10 below, we examine the impact of predicted prices from our updated regression results using 2011 explanatory variables for the following winners to bidders ratio against our base case of 0.86:

- 0.77 - current sample average;
- 0.8 – the situation if there were 5 bidders and 4 winners in the Irish auction;
- 0.86 – the situation assumed in 09/99c and 10/71b; and
- 1 – where the upcoming auction is only competitive among participating incumbents.

Table 10: Winners to bidders ratio sensitivities

	Implied licence price (2x5MHz) when WtB is 0.77 (Base case revised for new auction dataset)	Implied licence price (2x5MHz) when WtB is 0.8 (e.g. 5 bidders for 4 licences)	Implied licence price (2x5MHz) when WtB is 0.86 (Original base Case)	Implied licence price (2x5MHz) when WtB is 1
Mobile	€32.1m	€29.5m	€24.4m	€12.3m
Europe	€15.3m	€14.2m	€12.1m	€6.06m
Regression	€33.0m	€30.4m	€25.5m	€13.9m

100. We expect that the range in Table 10 above encompasses the range of reasonable competitive scenarios in the proposed multi-band auction in Ireland. In terms of setting a minimum price, clearly even if there were few bidders (say a winner to bidder ratio of 1) this does not mean that the forecast price is necessarily an appropriate level for a minimum price. Clearly, in such a case winning bidders would be enjoying a significant surplus by paying much less than value and such a level might not be

[38] Here auction competitiveness is measured by the winners to bidders ratio, which becomes smaller as the number of bidders increases and the auction becomes more competitive.

consistent with the objective of disincentivising tacit collusion and/or pre-auction consolidation.

101. Therefore, the winner to bidder ratio needs to be set at a value that reflects a plausible view of potential participation by serious bidders. In this regard, simply using the sample average of the winner to bidder ratio has merit (as this reflects actual levels of participation achieved) or possibly more conservatively the case of 0.8 (equivalent to 5 participants for 4 licences). Overall, we consider that there is a good case for lowering the assumed winner to bidder ratio from the previous assumption of 0.86 given the new data. This would have an isolated impact of increasing predicted licence value as shown by comparing the predicted licence values in the second (WtB=0.77) and fourth (WtB=0.86) columns in the table above.

3.2.3 The impact of imposing a coverage obligation on minimum prices

102. A coverage obligation should not affect licence values if the coverage obligation is less than or equal to the level of coverage that an operator would itself choose to provide based on commercial decisions (including the need to compete with rivals on coverage and service quality) if no coverage obligation were in place. Conversely, if the coverage obligation on a licence exceeds the coverage that an operator would itself choose based on commercial considerations, such a coverage obligation will reduce potential bidders' valuations of the spectrum to some degree depending on the cost of meeting the obligation. This reduction in the value of such spectrum depends on the extent of difference between operators' optimal coverage (given competition with other operators) and the level of the coverage obligation that might be imposed.

103. In its most recent consultation (10/105), ComReg proposed a coverage obligation on 1800MHz and sub-1GHz spectrum licences. This licence condition requires that licence holders for these frequencies cover 70% of the population in Ireland within 3 years of being awarded a licence for an existing operator and within 7 years of being awarded a licence for a new entrant. This obligation will be band neutral, meaning it can be met using spectrum in other frequency bands held by the operator. In the case of a bidder only winning sub-1GHz spectrum, a minimum of half of this 70% population coverage level must be met using sub-1GHz spectrum.

104. Therefore, provided the coverage obligation proposed by ComReg is not overly onerous - in the sense that licensees would meet such service roll out purely based on their respective commercial interests anyway - we expect our benchmark derived from the value of licences both with and without behaviour-modifying coverage obligation to yield a conservative lower bound estimate of market value of the spectrum to be auction in Ireland.

105. While it is difficult to judge at exactly what level a coverage obligation in Ireland would surpass the level of coverage that operators would otherwise provide, we note that ComReg's current proposals for coverage

obligation for the upcoming auction is *muc*h less than the current level of voice and 3G coverage obligations in Ireland, which are in any case exceeded by actual coverage.[39] Bidders for sub-1GHz spectrum need only serve a minimum of 35% (half of the 70% requirement) of Irish population using sub-1GHz spectrum. In addition, the band neutral approach to meeting the coverage obligation provides flexibility and eases the rollout burden on potential licensees as up to half of the coverage obligation can bet met using other spectrum bands.

106. Therefore, there is no particular reason to expect the coverage obligations proposed for licences awarded in the envisaged multi-band auction in Ireland would significantly affect the market value of the underlying spectrum to either potential or existing operators. For instance, coverage obligations in both the German "big" auction and the Swedish 800MHz auction have been more onerous.

107. The benchmark dataset consists of licence awards in which there are a variety of coverage obligations. In some cases these coverage obligations are material and are likely to have had some impact on commercial roll-out decisions and hence licence valuation. Therefore, in line with ComReg's statutory objectives, coverage obligation proposals for new licences awarded in the upcoming auction in Ireland safeguard against cherry-picking entry.[40] Amongst the benchmark data there are cases in which coverage obligations have affected licence value. Again, this means that our forecasts of Irish licence values are likely to be an under-estimate.

[39] We understand that the 3G licence obligations for Vodafone, O2 and HI3G run till 2022 and for Meteor runs till 2027.

[40] ComReg's current proposals on coverage require that licensee' with current networks cover 70% of the population within 3 years, and new network operators to cover the same level of the population within 7 years. Other frequency bands can count towards the 70% coverage obligation, provided that a minimum of half of the 70% population coverage level (i.e. 35% population coverage) is provided using sub-1GHz spectrum. These proposed obligations will apply to all spectrum bands in the proposed multi-band award.

4 Conclusions

4.1 Distillation of benchmarking results for sub-1GHz spectrum

108. Table 11 below summaries our current benchmarking results and compares these with the results of the previous benchmarking exercise presented in DotEcon's report published in September 2010 (10/71b). There have been no significant changes from the analysis presented in 10/71b in benchmarks based on simple averages.

109. The regressions benchmarks have changed in relation to 10/71b. Changes in the estimated regression model are partly due to new auction data and partly due to the different treatment of time trends within a longer sample period (i.e. bringing in a dummy variable for the 2010-2011 period). In addition, the underlying assumptions for the independent variables of the model needed to forecast Irish prices have changed, with lower GDP, but a higher winner-to-bidder ratio being suggested by the revised auction dataset.

110. The winner-to-bidder ratio (WtB) was originally set at the sample average of 0.86 in previous analysis, but the revised auction dataset has a lower sample mean of 0.77 due to the inclusion of a number of relatively competitive recent auctions. These values bracket a winner-to-bidder ratio of 0.8, which corresponds to a reasonable scenario of five bidders for four licences.

111. The 'mobile' and 'sub-1GHz and 1800MHz' regression models based on the revised dataset have been influenced by the high sub-1GHz licence prices in the recent Hong Kong auction, and as such yield higher predicted prices than those based on the 2010 dataset. Conversely, the predicted licence value from the European regression model based on the 2011 dataset has been reduced by the inclusion of the recent Danish and Swedish auction results.

112. The revision of benchmark regression values are a direct consequence of the regression model being used. The structure of this model means that relatively recent auctions have disproportionate weight in determining the results due to the flexible forms allowing for time trends in spectrum value (i.e. that values may shift up or down over time). Clearly it would be better if we were able to model the causes of any shifts in spectrum value over time in terms of more fundamental causes. However, there is no clear methodology or available data for doing this. Therefore, for the purposes of informing the choice of a minimum price, we consider that it is reasonable that the model is relatively responsive to recent developments and does not place too much weight on historic outcomes.

Table 11: 2011 benchmarking results

Benchmark group	Technique	Benchmarking analysis in DotEcon report 10/71b[41]	Revised benchmarking analysis Regressions shown with WtB ratio of 0.77 *(Maintaining original WtB ratio of 0.86)*
		Implied value of a 2x5MHz lot	
All mobile	Averages benchmark	€29.2m	€28.6m
	Regression benchmark	€18.6m	€32.1m *(€24.4m)*
Europe	Average benchmark	€23.5m	€22.6m
	Regression benchmark	€20.3m	€15.3m *(€12.1m)*
Similar GDP per capita	Average benchmark	€26.0m	€25.3m
Sub-1GHz and 1800MHz	Average benchmark*	€30.9m	€31.9m
	Regression benchmark	€18.3m	€33.0m *(€25.5m)*
3G	Average benchmark*	€39.5m	€38.3m
	Irish average	€23.9m	€24.2[42]

*Auction-band average

[41] Presented in Table 8 of the DotEcon Report (10/71b)

[42] Using the discounted licence price calculation method described in paragraph 494 of the DotEcon Report (09/99c) results in discounted licences prices in March 2011 real Euro of €14.5m for H3G, €27.5 for Vodafone and O2 and €27.4 for Eircom which averages out to €24.2m.

113. In terms of distilling a recommended range for minimum prices, we do not consider that much has changed relative to the conclusions expressed in 10/71b, which suggested a range of €18m-€26m.

114. Starting first at the upper boundary of this range, the key consideration is that above the average licence value for similar GDP per capita countries (which remains at €26m roughly even with the revised dataset) there are issues of comparability and sensitivity to modelling assumptions to be considered. Therefore, although some of the benchmarks yield values above this level, we must acknowledge the uncertainties that remain as to the degree to which these are transferrable to the Irish context. Therefore, in order to maintain our conservative approach to the benchmarking exercise and its analysis, we disregard these higher values and maintain €26m as the upper boundary of our recommended range.

115. The lower boundary is somewhat less clear. In 10/71b this lower boundary was €18m, which now sits above the prediction of the European regression model (€15m with the revised winner-to-bidder ratio). Therefore, we consider that there is a case for revising down our lower bound to €15m. This reflects greater uncertainty about our forecasts given the variability of recent EU auctions (which we turn to in a moment in Section 4.2).

116. Therefore, we recommend that ComReg considers a range of €15m to €26m for minimum prices for a 2x5MHz block of sub-1GHz spectrum. This is wider than the recommended range in our previous benchmark report (10/71b) of €18m to €26m, reflecting the increase in the range of our benchmarks as a result of the inclusion of new auction results.

4.2 Context of recent auctions

117. Our recommended range for sub-1GHz spectrum of €15m to €26m accords closely with the range of recent outcomes achieved in auctions of liberalised sub-1GHz spectrum. There are four existing benchmarks of liberalised sub-1GHz spectrum sold in auctions that merit specific consideration (see Figure 2):

    a) Licences sold in the US 700MHz auction in 2008;

    b) German 800MHz licences sold in a multi-band auction in 2010;

    c) 900MHz licence awarded in Hong Kong in 2011; and

    d) 800MHz licences awarded in the Swedish auction in March 2011.

118. The US, German and Hong Kong auctions were competitive and are informative about the actual market value of liberalised sub-1GHz spectrum. The auction-band average prices in these three auctions exceed the top end of our recommended range of €26m; indeed the auction-band average prices in the US and Hong Kong auctions exceed the top of our recommended range by a significant margin. This confirms our assertion that our benchmark range produces a conservative lower bound estimate of the market value of liberalised sub-1GHz spectrum.

The Swedish 800MHz auction

119. The recent Swedish auction of 800MHz spectrum produced a price benchmark that is not in line with other benchmark data. Therefore, it is

worth exploring further the prices achieved and the drivers of these licence price benchmarks in order to assess the relevance of these benchmarks for minimum prices of sub-1GHz spectrum in Ireland. The facts are as follows.

120. First, the Swedish 800MHz average auction price across all available lots was €0.24 per MHz per head of population, significantly lower than the 800MHz band average in the Germany 2010 auction of €0.71 per MHz per head of population.

121. Second, there were substantial differences in the prices paid for licences by the three winners in the auction. There were six frequency-specific 2x5MHz spectrum blocks available in the auction. The top block had a coverage obligation attached to it,[43] Hence the price of the top two lots (won by HI3G) was substantially lower than the price of the middle two blocks. The sum of the fund allocated to serve the coverage obligation – SEK300m – has been netted out from the licence price in our analysis (see licence price for blocks FDD5 and FDD6 won by Net4Mobility in **Table 12** below). In addition, the bottom two blocks in the band had tighter usage restrictions than other blocks due to DTT interference concerns. As a result the lowest two blocks (won by H3G) were also won at a substantial discount to the middle two blocks (won by TeliaSoneria). These results are presented in **Table 12** below. The differences in value between the middle and outer blocks are material (around a factor of two).

Table 12: Swedish 800MHz auction results

Winner	Blocks	Licence price per MHz per population (January 2011 Euros)
HI3G	FDD 1 and 2 (Higher usage restrictions)	€0.174
TeliaSonera	FDD3 and 4	€0.345
Net4Mobility	FDD 5 and 6 (Coverage obligation on FDD6)	€0.190
Auction average price across all lots awarded		€0.24

122. Furthermore, the Swedish 800MHz auction used a Simultaneous Multi-Round Ascending (SMRA) auction format, which may have contributed to the premium paid for the centre blocks in the Swedish 800MHz auction. In auctions using this format, there is an increased risk that bidders bidding on spectrum at the edge of the band may suffer from aggregation

[43] The obligation was to serve a list of postcodes currently without access to "functional internet" (1Mbps download speeds).

risks and exposure to the strategic bidding of other bidders. Where a bidder is bidding on multiple lots of spectrum at the edge of the band, another bidder may bid on the lot adjacent to the edge lot, driving up the price of this lot. Where this occurs, the bidder bidding on the edge lot is left with a choice between paying a high price for this lot, bidding further on only one lot or bidding on alternative, non-contiguous spectrum within the same band. In contrast, centre blocks form part of a greater number of combinations of contiguous spectrum compared with blocks at the edge of the band and so are less subject to this risk. This means that the format creates a strategic reason within the auction itself for centre blocks being more valuable.

123. This 'cheaper edge block' effect was observed in both the Swedish and Norwegian 2.6GHz auctions, both of which used the augmented switching variant of the SMRA format. Therefore, in addition to not being subjected to more onerous usage restrictions and coverage obligations, the centre blocks of the 800MHz band in Sweden may also be subject a price premium due to an increased probability of contiguous spectrum holdings in the band after the auction.

124. Considering then the relatively low average price paid for licences in the Swedish 800MHz auction, we note that two out of the four mobile operators (Telenor and Tele2) in Sweden decided to bid jointly in the Swedish auction. The existing mobile operators in Sweden constituted only three bidders in the auction with 2x30MHz of available spectrum and a spectrum cap of 2x10MHz per bidder. Hence, the marginal bidders driving competition in this auction were Com Hem and Netett Sverige, neither of which were established mobile operators in Sweden at the time of the auction. In contrast, the marginal bidder for 800MHz spectrum in the German auction, E-Plus, was an established mobile operator in Germany at the time of the German auction.

125. In evaluating whether the Swedish 800MHz licence prices are reflective of market value, it is useful to compare the outcome with the results of the Swedish 2.6GHz auction held in 2008 (see Table 13 below). In this auction, H3GI paid €0.170 per population per MHz, TeliaSonera paid €0.161 per population per MHz, Telenor paid €0.152 per population per MHz and Tele2 paid €0.157 per population per MHz for their 2.6GHz licences. These prices are comparable to those paid for the outer two of the three 800MHz licences in Sweden; indeed, H3GI actually paid more for its 2.6GHz spectrum than it did for its 800MHz spectrum. As the Swedish 2.6GHz auction result is comparable to that of other competitive 2.6GHz auctions such as that in Denmark in 2010 and Hong Kong in 2009, it would seem reasonable to conclude that given that both 2.6GHz and 800MHz are ear-marked for LTE use in the near future and that 800MHz frequencies have relatively superior technical characteristics, the prices paid for the Swedish 800MHz licences were not fully reflective of its commercial and technical value to operators.

Table 13: Swedish 2.6GHz auction results

Winner	Blocks	Licence price per MHz per population (January 2011 Euros)

Tele2	FDD1, FDD2, FDD3 and FDD4	€0.157
HI3G	FDD5 and FDD6	€0.170
TeliaSonera	FDD7, FDD8, FDD9 and FDD10	€0.161
Telenor	FDD11, FDD12, FDD13 and FDD14	€0.153

126. Therefore while the Swedish 800MHz auction-band average price is below our recommended range, as we have discussed above, there are good reasons for not considering that the Swedish 800MHz auction is fully reflective of the competitive market value of sub-1GHz spectrum comparable to that which will be available in the proposed multi-band auction in Ireland. In addition, in taking into account the Swedish 800MHz auction results, we have in any case lowered the bottom end of our recommended range (from €18m previously in 10/71b to €15m presently) on account of the lower predicted licence price from our European regression model.

127. Considering the licence conditions proposed for licences in Ireland in ComReg consultation 10/105, and those linked to licences awarded in Sweden, we do not consider that the relatively low prices achieved for the lots awarded in Sweden with relatively onerous technical restrictions or coverage obligations attached to them to justify the use of minimum prices of this level in Ireland.[44] Separately, we note that the average licence value of the middle blocks of the 800MHz band in Sweden, the blocks most comparable to those proposed for award in Ireland sold in Ireland (those without a non-trivial coverage obligation or high usage restrictions) sold for €0.345/per MHz per pop, the equivalent of €15.4m for a 2x5MHz lot of sub-1GHz spectrum in Ireland. We do not consider that a simple average price of all blocks sold in the Swedish auction is a reasonable benchmark. The value of the centre blocks in the Swedish 800MHz auction accords the bottom end of our recommended range.

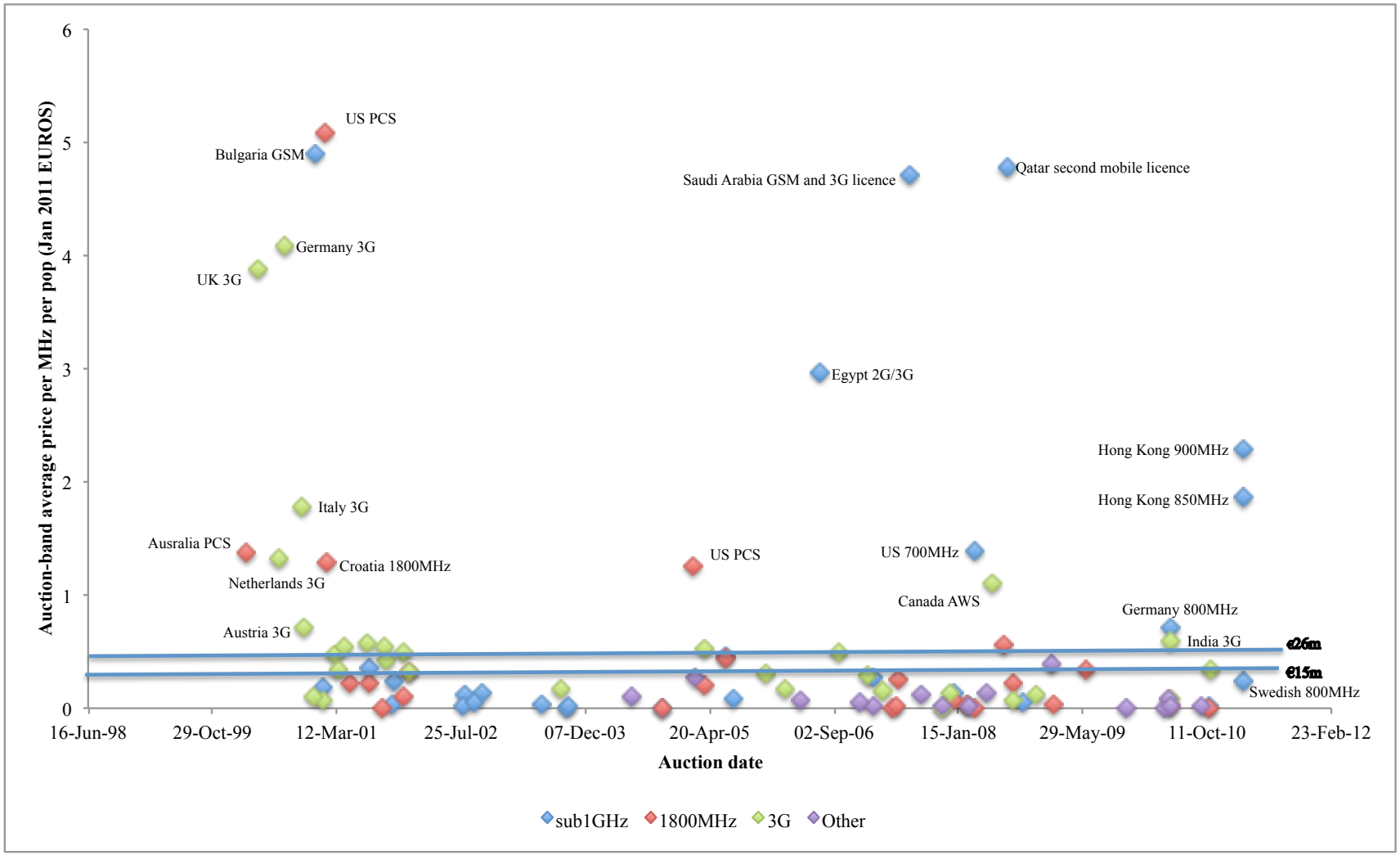
Other relevant award processes: UK 800MHz and 2.6GHz auction

128. We note that Ofcom in its most recent consultation on the auction of 800MHz and 2.6GHz spectrum in the UK (in March 2011) are considering a move away from its previous approach of setting low but non-trivial reserve prices, citing the need to manage strategic objectives of bidders in the upcoming UK auction as motivation for setting a reserve price more reflective of market value. Ofcom stated that a possible reserve price that might reflect market value but are not too high to risk inefficiently choking off demand in the auction could be £200m for a 2x5MHz lot in the

[44] Further, these blocks happen to be the edge blocks and may be of a lower licence value due to the "cheaper block edge" effect described in the paragraphs above.

800MHz band, though is one of a range of options currently subject to consultation. Using an exchange rate of £1 to €1.1 and adjusting for population differences, this is equivalent to €15.9m for a 2x5MHz lot.

Figure 2: Recommended minimum prices against auction data



4.3 Implications for 1800MHs spectrum

129. Applying our relative value of 1800MHz spectrum to sub-1GHz spectrum of 45% to 60%, this yields a recommended minimum price of €6.75m to €15.6m for 2x5MHz of 1800MHz spectrum. While the current recommended range is wider than before, we note that this is consistent with the most recent benchmarks of competitive auctions of liberalised 1800MHz and sub-1GHz spectrum.

130. In particular, an auction of 1800MHz spectrum was recently concluded (28 March 2011) in Singapore, with existing operator M1 winning 2x5MHz of liberalised spectrum[45] with a winning bid of SGD21.69m. This spectrum licence has a term of 6 years and an annual fee of SGD140,000 per 2x5MHz block. Adjusting for differences in licence duration (see paragraph 11 above) and population in Singapore and Ireland and including the net present value stream of annual fees across the licence term, the Singapore 1800MHz auction result in 2011 yields a average licence price of €19.6m for a 15-year, 2x5MHz licence of 1800MHz spectrum (adjusted to Irish population in 2010 of 4,470,700). This is substantially above our €6.75m to €15.6m range presented above, affirming that our proposed range is a conservative lower bound estimate of market value.

131. Any residual uncertainty that might exist regarding the relative valuations of 1800MHz and sub-1GHz spectrum, should be taken into account by setting a minimum price for 1800MHz spectrum within the lower half of our recommended range – between €6.75m to €15.6m for a 2x5MHz lot 1800MHz spectrum.

4.4 Considerations for choosing a minimum price

132. Choosing an appropriate minimum price depends on ComReg's concerns for the auction. A key issue is the balancing of the risk of tacit collusion or strategic behaviour with the risk of choking off efficient demand.

133. In its 09/99 consultation when only the 900MHz band was considered for auction, there were strong concerns over potential collusion risks. This was because the limited availability of 900MHz and the pre-existing pattern of relative strength amongst incumbents raised concerns about the ease of tacit collusion. Hence a high reserve price closely reflecting predicted market value (within the predicted licence value range) was proposed.

134. Following this, in consultation 10/71 and subsequently in consultation 10/105, the 800MHz and 1800MHz bands were respectively proposed to be included in a joint auction with 900MHz spectrum. This somewhat moderated these concerns in that tacitly coordinated sharing of the

[45] A licensee seeking to deploy any technology other than 2G and 3G such as LTE, would first have to seek approval from IDA Singapore to ensure that it will not pose any interference issues.

available spectrum is less easy, due to the added dimension of how demand might divide across the various bands.

135. However, this reduced rather than eliminated these concerns. In particular, if 800MHz and 1800MHz spectrum are not considered closely substitutable to 900MHz, then specific concerns about ease of tacit collusion may persist in regard of the 900MHz band. Particularly, in the short term where 800MHz and 900MHz are not directly substitutable due to non-equivalent availability of LTE equipment, then collusion concerns over 900MHz spectrum may very well still persist for the first time slice of 900MHz lots.

136. Furthermore, regardless of the inclusion of additional spectrum bands, there are still clearly incentives for pre-auction pooling of bidding interests by incumbents within the auction. Such a pooling could take the form of joint bidding followed by network sharing and need not involve an explicit merger.

137. The auction design needs to be robust to these risks of competition in the auction being weakened by strategic behaviour (both within and before the auction). However, alongside this, minimum prices are a useful instrument for reducing the incentives for such behaviour.

138. Under these conditions, it is appropriate to set minimum prices *reflecting* market value. The closer the chosen reserve price to market value, the less incentives bidders have to act strategically within the auction. This has to be balanced with the risk of exceeding market value given that this level is unknown. Therefore, it would be inappropriate to set minimum prices at an uncertain estimate of market value, but there is a good case for setting minimum prices as high as uncertainty about market value allows. This means striking a balance by picking a minimum price that is as high as possible subject to the risk of exceeding market value being acceptably low.

139. Given the multi-band nature of a joint award, we have proposed that the proposed minimum prices be linked:

- Set the same minimum price for 800MHz and 900MHz spectrum;
- Set the 1800MHz minimum price based on estimated competitive relative band value of sub-1GHz and 1800MHz spectrum.

We have re-iterated justifications from DotEcon report 10/71b and 10/105a in paragraphs 14 to 17 and 25 to 28 for doing so. In particular, provided that minimum prices are not set too high, all prices should increase above these levels in an open auction and relative prices of the bands can then be market-determined. However, any residual uncertainty over the relative valuations of these bands should then be reflected in additional weight being given to the risk of inefficiently unsold spectrum.

140. We consider that it is unlikely that demand would be choked off inefficiently within our recommended range of €15m-€26m for a 2x5MHz block of sub 1-GHz spectrum. However, clearly risks increase towards the upper end of the range and a trade-off needs to be struck. We do not make any specific recommendation within this range, but we consider that the lower half of the range is likely to create a useful moderation of

incentives for strategic behaviour whilst running very little risk of discouraging serious bidders with a chance of winning spectrum.

Annex A: Datasets

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

A.1 Global mobile spectrum auctions

Table 14: 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
United States	Auction 71 – Broadband PCS	21-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
United States	Auction 78 - Broadband PCS and AWS licences	20-Aug-08
Austria	900 MHz Auction	29-Sep-08
Turkey	3G	24-Nov-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
Austria	2.6GHz Auction	20-Sep-10
Denmark	900MHz Auction	18-Oct-10
Denmark	1800MHz Auction	18-Oct-10
Singapore	3G Auction	25-Oct-10
Hong Kong	850MHz, 900MHz and 2GHz Auction	03-March-11
Sweden	800MHz	04-March-11

A.2 European mobile spectrum auctions

Table 15: 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
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
Austria	2.6GHz Auction	20-Sep-10
Denmark	900MHz Auction	18-Oct-10
Denmark	1800MHz Auction	18-Oct-10
Sweden	800MHz	04-March-11

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

Table 16: Mobile spectrum auctions in countries with comparable GDP per capita

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

United States	Auction 71 – Broadband PCS	21-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
United States	Auction 78 - Broadband PCS and AWS licences	20-Aug-08
Austria	900 MHz Auction	29-Sep-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
Austria	2.6GHz Auction	20-Sep-10
Denmark	900MHz Auction	18-Oct-10
Denmark	1800MHz Auction	18-Oct-10
Singapore	3G Auction	25-Oct-10
Hong Kong	850MHz, 900MHz and 2GHz Auction	03-March-11
Sweden	800MHz	04-March-11

A.4 Sub-1GHz and 1800MHz spectrum auctions

Table 17: Sub-1GHz 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
United States	Auction 71 – Broadband PCS	21-May-07
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
United States	Auction 78 - Broadband PCS	20-Aug-08
Austria	900 MHz Auction	29-Sep-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
Austria	2.6GHz Auction	20-Sep-10
Denmark	900MHz Auction	18-Oct-10
Denmark	1800MHz Auction	18-Oct-10
Singapore	3G Auction	25-Oct-10
Hong Kong	850MHz, 900MHz and 2GHz Auction	03-March-11
Sweden	800MHz	04-March-11

A.5 3G spectrum auctions

Table 18: 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
United States	Auction 78 - AWS licences	20-Aug-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
Singapore	3G Auction	25-Oct-10

Annex B: Regression analysis for European and sub-1GHz and 1800MHz auctions dataset

In this Annex we present the regression results for the regression analysis on the European mobile spectrum auctions dataset and that of the sub-1GHz and 1800MHz spectrum auctions dataset.

B.1 Auctions in Europe

Equation 4: Regression equation for auctions in Europe

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \cdots$$
$$\ldots + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \cdots$$
$$\ldots + \beta_{preIT} \cdot preIT + \beta_{year01} \cdot year01 + \beta_{year0203} \cdot year0203 + \cdots$$
$$\ldots + \beta_{year0405} \cdot year0405 + \beta_{year0607} \cdot year0607 + \cdots$$
$$\ldots + \beta_{year0809} \cdot year0809 + \beta_{year1011} \cdot year1011$$

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.[46] The results are summarised in the following table.

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

Table 19: Regression analysis using all European mobile licences sold in auctions in Europe[47]

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.0000199	.0000126
ApPop	--14.6**	5.19
WtB	-0.817*	0.320
invNMNOs	9.96**	1.63
national	0.332	0.331
preIT	1.79**	0.297
yearD_01	-0.910**	0.250
yearD_0203	-0.640	0.352
yearD_0405	-0.680*	0.301
yearD_0607	-0.936**	0.278
yearD_0809	-0.670	0.342
yearD_1011	-0.711*	0.301
Constant (β_0)	--1.107	0.799

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

Using 2010 explanatory variables (see Table 6 above), the European regression model above produces a predicted licence price €12.6m. When 2011 explanatory variables are applied (see Table 6 above), the lower GDP per capita in 2010 largely motivates the decrease in predicted licence price to €12.2m. This is substantially lower than our European regression model results from 10/71b predicting a licence price of €20.3m illustrating the impact of the recent Danish 900MHz and 1800MHz auctions (uncompetitive) and Swedish 800MHz auction (auction price below sample average, see sub-1GHz and 1800MHz and Europe average benchmarks in Table 3).

Further, we also consider the impact of excluding the year dummies in predicting a licence value thereby ignoring the time trend of spectrum value post the telecoms bubble. This regression is illustrated in Equation 5 below and regression results in Table 20 below.

[47] Less all 2.5/2.6GHz auctions as noted in section 3.2.2 above.

Equation 5: European regression model without year dummies

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \beta_{preIT} \cdot preIT$$

Table 20: Results of European regression without year dummies

Coefficient for	Estimated coefficient	Standard error
GDPpc	0.0000216*	.0000106
ApPop	--17.5**	4.43
WtB	-0.786*	0.310
invNMNOs	11.2**	1.33
national	0.384	0.316
preIT	2.52**	0.213
Constant (β_0)	-2.19**	0.524

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

Excluding the year dummies in the European regression model would yield a predicted licence price of €11.1m, roughly €1m lower than when year dummies are included in the regression model. Therefore the depression in predicted licence values with the inclusion of new auction data (Austria 2.6GHz, Denmark 900 and 1800MHz and Sweden 800MHz) would depress predicted licence values if we do not take into account the time trend of spectrum value.

B.2 Sub-1GHz and 1800MHz auctions

Equation 6: Regression equation for sub-1GHz and 1800MHz auctions

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{PopDen} \cdot PopDen + \beta_{WtB} \cdot WtB + \cdots$$
$$\ldots + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \cdots$$
$$\ldots + \beta_{AFME} \cdot AFME + \beta_{preIT} \cdot preIT + \beta_{year01} \cdot year01 + \cdots$$
$$\ldots + \beta_{year0203} \cdot year0203 + \beta_{year0405} \cdot year0405 + \beta_{year0607} \cdot year0607 + \cdots$$
$$\ldots + \beta_{year0809} \cdot year0809 + \beta_{year1011} \cdot year1011$$

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 bi-annually. For example $year0607$ is 1 if the 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.[48] The results are summarised in the following table.

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

Table 21: Regression analysis using all sub-1GHz and 1800MHz auctions

Coefficient for:	Estimated coefficient	Standard error
GDPpc	0.000044**	0.00000222
PopDen	-0.0000277*	0.0000119
WtB	-1.88**	0.105
invNMNOs	-0.659	0.342
national	0.154*	0.0681
AFME	1.48**	0.0895
preIT	-3.47**	0.223
yearD_01	-4.02**	0.184
yearD_0203	-4.86**	0.196
yearD_0405	-4.36**	0.182
yearD_0607	-4.23**	0.183
yearD_0809	-4.57**	0.187
yearD_1011	-4.17**	0.199
Constant (β_0)	4.53**	0.216

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

Using 2010 explanatory variables (see Table 6 above), the sub-1GHz and 1800MHz regression model above produces a predicted licence price €26.7m. When 2011 explanatory variables are applied (see Table 6 above), the lower GDP per capita in 2010 largely motivates the decrease in predicted licence price to €25.7m. This is substantially higher that our predicted licence price from our "sub-1GHz and 1800MHz regression model" in 10/71b, due mainly to the inclusion of the recently completed Hong Kong auction where the licence prices for 850MHz and 900MHz in the auction were significantly above the sample average (see sub-1GHz and 1800MHz average benchmark in Table 3).

As in the case of the 'Mobile' and 'Europe' regression models, we also consider the impact of excluding the year dummies in predicting a licence value thereby ignoring the time trend of spectrum value post the telecoms bubble within the dataset of sub-1GHz and 1800MHz auctions. This regression is illustrated in Equation 5 below and regression results in Table 20 below.

Equation 7: Sub-1GHz and 1800MHz regression model without year dummies

$$PMHzPop = \beta_0 + \beta_{GDPpc} \cdot GDPpc + \beta_{ApPop} \cdot ApPop + \beta_{WtB} \cdot WtB + \beta_{invNMNOs} \cdot invNMNOs + \beta_{national} \cdot national + \beta_{AFME} \cdot AFME + \beta_{preIT} \cdot preIT$$

Table 22: Results of sub-1GHz and 1800MHz regression without year dummies

Coefficient for	Estimated coefficient	Standard error
GDPpc	0.000032**	0.00000216
ApPop	-0.0000293*	0.0000126
WtB	-2.31 **	0.102
invNMNOs	4.31**	0.319
national	0.267*	0.0669
AFME	0.546**	0.0856
preIT	0.665**	0.165
Constant (β_0)	0.0560	0.124

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

The above regression model yields a predicted licence price of €14.7m substantially lower than in the regression including year dummies.

Excluding the year dummies in the sub-1GHz and 1800MHz regression model causes the coefficient of invNmnos to flip sign hence change in magnitude by about 750%. This is counter intuitive as we expect the value of spectrum to decrease with the number of mobile operators (and hence increase with the inverse of the number of mobile operators). On the other hand, the preIT coefficient has gone from negative to positive which is in line with general expectations though arguable this is less important in this regression model as not many sub-1GHz and 1800MHz licences were sold via auction during the telecoms bubble.

Annex C: Stakeholder responses to minimum price proposals

In this Annex we summarise the responses to ComReg consultations 09/99, 10/71 and 10/105 related to the recommended minimum price and our benchmarking analysis contained in our reports published alongside ComReg's consultations – Part C of 09/99c, 10/71b and 10/105a. For ease of consideration, views of respondents are presented by topic, as expressed in all relevant consultation responses.

C.1 Benchmark methodology and modelling issues

Table 23: Respondents' views on the benchmarking methodology

Respondent	View on the benchmarking methodology
H3GI	Welcomes and supports ComReg's proposals to adopt a benchmarking approach to determine the minimum price. However, it considers that: • DotEcon's data is weak because it does not include data from any comparable auctions for liberalised 900MHz spectrum; • DotEcon did not apply a regression analysis to all 3G licences; • DotEcon should have analysed the minimum prices set by regulators in Europe (most notably Arcep for the auction of the fourth French 3G licence) or elsewhere instead of market prices achieved in auctions of 2G and 3G spectrum; • A minimum price should not be set according to the market valuation of spectrum achieved in other countries as the real market price of the spectrum should only be determined by the market at auction; • DotEcon and ComReg have taken too aggressive an approach in relation to the setting of a minimum price.
Eircom Group	• Has a preference for DotEcon's regression benchmarks as apposed to averages benchmark, as it is likely to give a more reliable estimate of the market value because some of the drivers of inter-country differences are taken into account. • Considers that there is no attempt by DotEcon to get good "like for like" comparators and that historic and other country indicators of value are problematic. • Benchmarks from pre-recession auctions are likely to overstate spectrum value today. • Irish 3G licence benchmarks could overstate the minimum price for 900MHz licences. • The minimum price (reserve price plus SUF) should be set at a 50% discount to the auction benchmark.

O2	• Benchmarks can be a useful indicator of what prices should be • However, they can be very unreliable as they depend on obtaining a sizeable sample of comparators. The difficulty in finding this comparator group means benchmarks can have a wide margin of error and should be used cautiously. • If benchmarks were to be used at all, ComReg should have used a benchmark of reserve prices or minimum prices to set the reserve and minimum price in Ireland.
Vodafone	• Does not believe that there is any rationale for seeking to determine a minimum price based on benchmarks because once a minimum price is set such that it deters non-serious or speculative bidders, the underlying value of the spectrum is best elicited through the auction process, not the benchmark value. • It is inappropriate to rely heavily on estimated valuations from historic auction data given the lack of sufficient data.

Table 24: Respondents' views on modelling issues i.e. data inputs

Respondent	Views on modelling issues, margin of error and inputs
O2	O2 consider that there are a number of factors that have either been omitted from the DotEcon benchmark report or taken into account incorrectly and serve to inflate the estimated value of a lot of spectrum in Ireland, namely: 1. That GDP should not be used as a comparison against the referenced countries because GNP is a more relevant comparator due to the large distorting effect of non-national trade in Ireland. GDP in Ireland is greater than GNP therefore serves to inflate the estimated value of a lot whereas GNP is a more relevant comparator for the value of the spectrum licence in Ireland. 2. DotEcon's benchmark produces a direct comparison of the value of a lot of spectrum in Ireland by measuring the price per MHz per head of population. However, this ignores a fundamental fact that larger markets produce higher prices/MHz/pop and DotEcon should have included a correction for the relative size of the Irish market. 3. Spectrum prices are in decline and have been for a number of years therefore older licences will have little in comparison with those that can be expected in 2011. Contrary to the approach that should have been taken, DotEcon has modified its benchmarking report to reduce the impact of more recent auctions, even though they are the most relevant comparators.

	4. In addition DotEcon have used current local conditions incorrectly or have not updated the benchmark report to reflect current local conditions, namely: 1. The impact of the current recession on Ireland and the government actions over the coming years which are set to have a deflationary impact on the economy; 2. That the retail market is increasingly competitive, despite having a population of 4 million there are currently 4 MVNOs (two of which have recently been launched); 3. The DotEcon benchmark is heavily influenced by the expected number of bidders in the auction, and the number used is 5. At the proposed minimum price O2 is of the view that there might well be no more than 4. Dotecon should re-run the model to determine the effect this would have on the recommended price range.
Vodafone	• Questions the merits of relying on estimated valuation ranges based on outcomes of previous spectrum auctions. • Believes that the relatively small number of directly relevant observations (instances of 800MHz and 900MHz spectrum) raises serious doubts about deriving conclusions from the benchmarking analysis. • Considers that the current benchmarking approach should be significantly modified such that: o GNP per capita is used rather than GDP per capita because it is the most appropriate independent variable to use in the benchmarking analysis in the Irish context because GNP is more superior than GDP in terms of reflecting the income actually available to the Irish residents.
H3GI	• Considers that DotEcon's data is weak because it does not include data from any comparable auctions for liberalized 900MHz spectrum; • Includes less comparable frequencies within sample such at the DECT guard band and 1785-1805MHz. • Asserts that DotEcon should have analysed the minimum prices set by regulators in Europe (most notably Arcep for the auction of the fourth French 3G licence) or elsewhere instead of market prices achieved in auctions of 2G and 3G spectrum; • Argues that a minimum price should not be set according to the market valuation of spectrum achieved in other countries as the real market price of the spectrum should only be determined by the market at auction;
Eircom Group	• Considers that there has been no attempt by DotEcon to get good "like for like" comparators and that historic and

	other country indicators of value are problematic. • Argues that benchmarks from pre-recession auctions are likely to overstate spectrum value today. • States that Irish 3G licence benchmarks could overstate the minimum price for 900MHz licences.

C.2 Conservative approach

Table 25: Respondents' arguments in support of a more conservative approach

Respondent	Arguments in support of a more conservative approach to minimum price setting by ComReg
Digiweb	Estimates that ComReg should not have set such a high minimum price.
H3GI	Argues that the minimum price proposed by ComReg is too high. Given that DotEcon itself admits in its revised report that: a) it does not have comparable liberalised 900MHz auction data, b) there are uncertainties over the relative values of 800MHz and 900MHz and the effects of increase supply in the auction, and c) that determining the appropriate sample and benchmark metrics is not an exact science, H3GI is of the view that DotEcon and ComReg have taken too aggressive an approach in relation to the setting of a minimum price.
Eircom Group	• ComReg's proposed minimum price for the award is high by international standards. • The Competition Commission's conclusions regarding Ofcom's decision to base values in 2007 on the results of the auction of 2.1GHz spectrum held in 2000 indicates the need for caution in drawing inferences from auction benchmarks. • The outlook for GDP, and more specifically real disposable income growth, has deteriorated. This might be expected to impact on the expected value of spectrum in Ireland. Therefore, benchmarks from pre-recession auctions are likely to overstate spectrum value today. • Eircom Group notes that DotEcon has attempted to take account of the reduction in GDP in their revised estimates of sub 1GHz band value (10/71b). However, this does not take account of the larger impact of the economic crisis on GNP and the mobile market and the on-going impact of reduced growth forecast over the medium term.

	• Irish 3G licence benchmarks could overstate the minimum price for 900MHz licence. • The supply of spectrum has increased with clarification regarding analogue TV switch off and the proposed combined auction. Expected spectrum supply is therefore greater and uncertainty over value is greater implying a lower spectrum valuation and greater grounds for caution. • The auction format in relation to caps and the move to a second price format has alleviated concerns in relation to tacit collusion, thereby greatly reducing the argument for a high reserve price to prevent tacit collusion. • The economic consequences of a high minimum price leading to unsold spectrum are likely to be much greater than those arising from a low minimum price (potentially resulting in the allocation of spectrum to a user who does not place the highest value on the spectrum).
O2	• Given the uncertainty and margin of error that is inherent in the use of benchmarks and the risk that a high price will deter bidders, it is surprising that ComReg has chosen the upper end of the range when given that this exercise has been undertaken in the context of setting a minimum price. ComReg should have opted for the lower value in the range. • In effect, ComReg is setting the minimum price at what it believes the sale price should be and as a result is inhibiting the auction as a means to determine the price. • If benchmarks were to be used at all, ComReg should have used a benchmark of reserve prices or minimum prices to set the reserve and minimum price in Ireland. • Setting a low but non-trivial reserve price can deter frivolous bidders, particularly if a deposit is required. • The communications sector in Ireland (including mobile) is currently experiencing a significant downturn with mobile revenue in decline. Although profitability is falling, network operators must prepare for a significant increase in investment in order to deliver next generation mobile access. The excessive minimum price will take investment out of the market at a time when it needs that investment to address the explosion of data demand driven by consumer behaviour needs. • ComReg should take into account its experience from 2006 when an auction of spectrum in the 26GHz band was launched and the minimum price of €1m was excessive and proved to deter potential bidders. • Setting the minimum price excessively high could well have the effect of deterring a bidder from entering the auction which is a distortion of competition and runs contrary to ComReg's legal obligations.
Vodafone	Bidders' assessments of spectrum value are forward-looking and the adverse change in economic and financial conditions in

	Ireland is likely to materially reduce expectations for demand and revenues, at least over the medium term, therefore greatly limiting the relevance of previous auction data.
Imagine	Does not agree with the proposed pricing structure as the proposed minimum price is a severe deterrent to new market entry. The benefits of spectrum liberalisation will not be achieved by the amount someone is prepared to pay to acquire this spectrum. Rather, the award process should also test the intent of any alternative bidders to bring competition and increased value to the market. This includes a graded licence fee with significantly reduced licence fees for a new market entrant, which should be used to encourage new market entry.
Ericsson	Does not agree with ComReg's minimum price proposal. Ericsson shares DotEcon's view that it is best to "err on the side of caution" in setting the minimum price. Mobile operators face a very challenging environment in which to produce investment plans for additional network deployment and there is a real risk that, by setting the reserve price in the auction at too high a level, ComReg will choke off demand. In these very uncertain economic times, ComReg should be promoting network investment and therefore setting the reserve price at the level that its advisers DotEcon have recommended would be a sensible first step in that regard.
UPC Ireland	The reserve prices for a new entrant are structurally too high. The key is to get new entrants in and incentivise them to innovate and provide coverage.

C.3 Common minimum price of 800 and 900MHz spectrum and relative minimum price of 1800MHz spectrum

Table 26: Respondents' views on the proposed common minimum price

Respondent	Views on ComReg's proposal to set a common minimum price for both the 800MHz and 900MHz bands
ESBN	Agrees with this proposal, except for the proportion of spectrum to be set aside for utility use. Believes that this spectrum should be priced in a manner to reflect its strategic value.
H3GI	Argues that a common minimum price should not be set for 800MHz spectrum and 900MHz spectrum as these spectrum bands are not substitutable because: • All network equipment and existing GSM or 3G mobile devices currently available can be used with 900MHz spectrum but cannot be used with 800MHz spectrum; • Worldwide harmonisation measures are in place for

	900MHz spectrum but not 800MHz spectrum; and • There is significant clarity as to the future plans of regulators for 900MHz spectrum, however plans remain unclear for 800MHz spectrum. Given the above factors H3GI submits that the 900MHz band is significantly more valuable to operators than 800MHz spectrum. Submits that it is entirely unacceptable for ComReg/DotEcon to justify the proposal of a common minimum price based on the grounds of a lack of evidence to support the relative value of liberalised-use 900MHz and 800MHz spectrum.
RTE and RTENL	Believes that the lower 800MHz block should have its minimum price set higher than the upper 800MHz block and 900MHz blocks to ensure that it is only taken up if demand is particularly high, thus avoiding any unnecessary impact on broadcasting services.
Vodafone	Agrees with ComReg's proposal to set a common minimum price for both the 800MHz and 900MHz bands.
UPC Ireland	Believes that the 800MHz band should have a lower minimum price as the 900MHz band has immediate and existing revenue streams while a network to provide services using 800MHz frequencies will first need to be constructed and will then need to attract subscribers. Additionally, there are standardisation and technical issues with the delivery of voice over LTE that have yet to be overcome and as such therefore these bands are not comparable from a return on investment perspective despite their proximity within the sub 1-GHz band.

Table 27: Respondents' views on the approach to setting a minimum price for 1800MHz spectrum

Respondent	Views on the setting of the 1800MHz minimum price
Eircom Group	Argues that the minimum price for 1800MHz spectrum resulting from the relativity analysis is likely to result in a minimum price that is excessive because of the problems inherent in the benchmarking analysis of sub-1GHz spectrum.
O2	Finds the relativity method for setting the 1800MHz spectrum minimum price to be without credibility. Considers that Tables 6, 7 and 8 in DotEcon report 10/105b prove that there is no consistent and reliable relationship between the price of spectrum above and below 1GHz that could be used to determine the expected price of 1800MHz spectrum in the proposed auction. States that it almost appears that to some extent the model

	involves a degree of reverse-engineering the methodology to produce a result, which is within an acceptable range. This risks giving the impression that rather than considering and consulting in proper detail the means of setting a minimum price for 1800MHz spectrum, ComReg is seeking to rush through the consultation so that the 1800MHz band can be included in the auction already planned for spectrum in the 800MHz and 900MHz bands. Using the recent example where 1800MHz spectrum was sold as part of a multi-band auction in Germany in 2010, O2 calculated an implied final sale price, when adjusted for population, of €1m for a lot of 1800MHz spectrum in Ireland. This is significantly less than ComReg's proposal to set the minimum price for the auction in Ireland at €12.5m. Suggests that DotEcon could produce a benchmark report showing the relevant reserve or minimum prices that have been set for the various auctions in their database. Notes the reserve prices set in the recent Switzerland (€8.9m for 800MHz and €2.9m for 1800MHz spectrum, when adjusted for population) and Hong Kong auctions (€1.7m for 800/900MHz spectrum, when adjusted for population).
Vodafone	Considers that given that the proposed minimum price for 1800MHz spectrum is based on the benchmarking of sub-1GHz spectrum and the serious shortcomings in the practical implementation of the benchmarking approach for sub-1GHz spectrum identified by Vodafone mean that the current proposed 1800MHz minimum price is also inappropriately high. Does not believe that the relativity analysis used is a valid basis for setting a minimum price for 1800MHz spectrum lots because Vodafone considers that it is inappropriate to draw conclusions about a reasonable relative valuation of 1800MHz spectrum from the very limited amount of international data available for benchmarking purposes. Therefore as a precautionary measure to the risk of setting the minimum price above the efficient level ComReg should set the price at a very low level. Hence, Vodafone considers that if the minimum price of 1800MHz spectrum blocks were set relative to sub-1GHz spectrum then it should be no higher than 30% of the price of sub-1GHz spectrum.

C.4 Considerations for choosing an appropriate minimum price based on ComReg's objectives

Respondent	Views on choosing the appropriate minimum price
O2	The minimum price set by ComReg bears no correlation to some of the criteria for setting the minimum price set out by ComReg including to deter frivolous bidders, reflect social option value and

	cover the administrative cost of running the auction. ComReg has offered no analysis on the correlation of minimum price levels and collusive outcomes. With regards to managing collusion incentives, O2 notes in its response to 10/71 that a minimum price of "€25m would offer no greater efficacy than €18m" in preventing collusion. Such a high minimum price proposed by ComReg would leave spectrum inefficiently assigned contrary to ComReg's statutory objectives. ComReg has not justify why the collusion objectives carries greater weight than the objective of not choking off demand.
Digiweb	Ofcom should not set such a high minimum price. Considers that a lower minimum price of €5m should deter frivolous bidders.
Ericsson	Collusion concerns alleviate with the inclusion of 800MHz spectrum in the joint award hence the minimum price should be set at the bottom of the €18m to €26m proposed range.
Vodafone	In its response to 10/71 (10/103R), Vodafone concludes that if a benchmarking approach is to be used, ComReg's statutory objectives will be most effectively achieved if a minimum price were to be set at the lower end of the estimated valuation range of €18m-€26m for 2x5MHz of sub-1GHz spectrum.
Eircom	In Eircom's response to 10/105, it considers that it is not clear from ComReg's consultation document that ComReg believes the selected minimum price would assist in meeting its listed objectives including managing collusion concerns, reflecting social value, deterring frivolous bidders and covering the administrative cost of running the auction. Further it notes that the chosen minimum price of ComReg is so high that it will impede the achievements of the objectives pursed by ComReg.

C.5 Dealing with collusion risks in the auction

Respondent	Views on dealing with collusion risks in the auction
H3GI	The risk of collusion would be sufficiently dealt with by (i) the threat of expulsion from the award process; (ii) prosecution under the Competition Act, 2002 for entering into an agreement or concerted practice contrary to Section 4 o f the Act. DotEcon nor ComReg has proven that the Irish market might be prone to collusion.
O2	The auction mechanism itself should be sufficiently robust to prevent collusive behaviour rather than setting an excessive reserve or minimum price to mitigate weaknesses in the auction

	mechanism. DotEcon has referred to a large number of spectrum auctions in other countries and noted that common practice is to have a low reserve price. ComReg has not presented any evidence (other than that there might not be a large number of bidders) to explain why a spectrum auction in Ireland is more likely to involve collusion than an auction in any other country. Competition law in Ireland and the EU should be well placed to deal with bidders' collusive behaviour.
UPC	Other means rather than a high minimum price could mitigate collusion concerns and deter frivolous bidders such as higher down payments packaging the spectrum such that bidders will focus their biddings.
Digiweb	It is unclear to Digiweb how ComReg concluded that its choice of a higher minimum price would be superior to a lower one in dealing with collusion concerns in the auction. It *"didn't understand how the potential tacit agreement will be neutralized by 'just' €8m"*.
Vodafone	The CCA format and sub-1GHz spectrum cap of 2x20MHz would effectively address ComReg's concerns around potential scope and incentives for tacit collusion. Therefore there is no clear rationale for ComReg to set the minimum price using a benchmarking process to deal with these issues.
Eircom	The larger spectrum cap (sub-1GHz and overall cap) is expected to increase competitive pressure in the auction and reduce the risk of tacit collusion, thus a high minimum price is not justified.

Annex D: DotEcon's response to stakeholders' comments

In this Annex we consider the responses to ComReg consultations 09/99, 10/71 and 10/105 that relate specifically to the benchmarking analysis that DotEcon has undertaken and used as a basis for recommending a suitable minimum price range for spectrum in multiple bands in the upcoming auction in Ireland. We first present the background to which we designed our benchmarking analysis in accompanying reports 09/99c, 10/71b and 10/105a respectively. We then summarise and address respondent views on (i) using the benchmarking methodology and modelling issues, (ii) setting the minimum price at a more conservative level, (iii) setting a common minimum price for 800MHz and 900MHz spectrum and setting the minimum price for 1800MHz spectrum to be 50% of that of sub-1GHz spectrum.

Annex C above presents summary tables of respondent view on these topics.

D.1 Background

141. In 2009, as part of the advice provided by DotEcon to ComReg on aspects of a 900MHz award process in Ireland (09/99c), DotEcon undertook a benchmarking analysis which produced a lower bound estimate of the market value of liberalised 900MHz spectrum. This estimate was used to provide a recommendation for a minimum price (consisting of an upfront payment plus annual usage fees) for 900MHz spectrum. The results of this analysis were published in Part C of DotEcon's report (09/99c) accompanying ComReg's consultation on its approach to liberalising 900MHz and 1800MHz spectrum published in December 2009 (*'Liberalising the future use of the 900 MHz and 1800 MHz spectrum bands'* (09/99)).

142. In Part C of that report, we discussed a number of key issues that we considered to be important when setting minimum prices in general. We also discussed the key issues to be considered in the context of ComReg's objectives, including its objective to ensure the efficient use of spectrum.

143. Taking into account these objectives, we considered that the significant concerns over low competition scenarios, in particular those arising from potential strategic behaviour within an award for 900MHz spectrum, pointed to the setting of a minimum price that reflected market value to manage bidders' strategic incentives.[49] Such collusion concerns were also reflected in the decision to use a second price sealed bid combinatorial auction format that encouraged truthful bidding.

144. While it was apt to set a minimum price reflective of market value, we were mindful that such a minimum price should not be so high that it risks

[49] See paragraphs 480 – 487 and 471-475 in Part C of DotEcon report 09/99c for a discussion of the recent trends and why setting a low but non-trivial minimum price would not be appropriate in Ireland.

the participation efficiency of the auction and chokes off demand of bidders with serious business cases for the spectrum. Therefore, we undertook a benchmarking analysis both of simple averages and regression analysis in order to produce a conservative range of market values for 900MHz spectrum, which could then be used by ComReg to set a minimum price for this spectrum.

145. Given that historically 900MHz spectrum in many countries was assigned administratively rather than auctioned, very little data is available on the market value of 900MHz spectrum and in particular liberalised 900MHz spectrum. In order to increase the robustness of our results, we included other mobile frequencies licences, which had been auctioned internationally over the past 10 years, within our dataset. We considered liberalised 900MHz spectrum to be of relatively high value given its propagation merits compared to higher frequency spectrum, and the liberalised nature of the spectrum meant that it could be used for 3G and possibly even 4G or LTE in the future. Hence, benchmarks of the average mobile licence value including both sub-1GHz spectrum, most of which has been licensed on an unliberalised basis, and higher frequency spectrum would present a lower bound estimate to the market value of liberalised 900MHz spectrum.

146. Following our December 2009 report, in 2010 we were commissioned by ComReg to consider the merits of including 800MHz spectrum in the 900MHz auction and the mechanics of how such a joint award would operate in practice, including how the minimum price for 800MHz spectrum should be set. Our proposals were reported to ComReg and published in September 2010 (10/71b) accompanying ComReg's consultation on the subject (10/71). We concluded in this report that it was appropriate to set a common minimum price for spectrum in the 800MHz and 900MHz bands, setting this minimum price based on market values calculated using the same benchmarking methodology as that used in our previous report (09/99c).

147. We noted in this report that the setting of a common minimum price does not imply that 800MHz spectrum is of identical value or is a perfect substitute to 900MHz spectrum, nor does it suggest that the final auction outcome would necessarily reflect this price parity. Rather, the setting of a common minimum price for 800MHz and 900MHz spectrum reflects the similarities between the two bands in terms of propagation characteristics and the uncertainties over the relative valuation of spectrum in these two bands given the current lack of data available on this relativity. It was considered that in the absence of evidence that these values differ substantially, it was prudent to set a common minimum price for these bands as long as this value does not choke off efficient demand. Any residual uncertainty regarding the differing values of lots of spectrum between the bands particularly in the near term given the non-equivalent availability of LTE equipment in these bands should be reflected in the

use of a more conservative approach to setting the common sub-1GHz minimum price.[50]

148. In this report we also updated prices to May 2010 terms as well as updating geographic and demographic inputs such as GDP and population data. Our updated GDP data (which was17.3% lower than the 2008 GDP data used in 09/99c) allowed us to some extent take into account of the possible negative effect of the recession on the market value of the spectrum.

149. Following this, we were asked to consider the modifications necessary for the inclusion of 1800MHz spectrum in the planned sub-1GHz award. Our findings on the modification necessary for the auction design were published in December 2010 as ComReg document 10/105a. Simultaneously, we considered how the minimum price for 1800MHz spectrum would need to be set in order to ensure that competition was not distorted and that the auction outcome would not be affected by the minimum prices. Our findings in this regard were set out in a report also published by ComReg (10/105b) in December 2010. In this paper, we noted that there was good reason to expect that lower frequency spectrum (spectrum under 1GHz) to be more valuable than higher frequency spectrum such as that in the1800MHz band due to network savings associated with the superior propagation characteristics and more effective in-building coverage of this spectrum. This point is consistent with technical studies. Therefore, we noted that we would expect the value of the 1800MHz spectrum to be lower than the 800MHz and 900MHz spectrum to be auctioned in Ireland.

150. Therefore, in setting the minimum price of 1800MHz spectrum we had to ensure that this was set so as not distort bidders' choices between bands. If we had taken the same benchmarking approach for setting the sub-1GHz minimum price we would not have calculated a conservative lower bound estimate of the value of 1800MHz spectrum consistent with the lower bound estimate achieved for spectrum in the 800MHz and 900MHz bands. This is because the conservative range of values for 800MHz and 900MHz spectrum was achieved by benchmarking against a dataset with competitive and uncompetitive auctions of lower value spectrum than that of 800MHz and 900MHz frequencies to be awarded for liberalised use. However, using the same dataset to produce an estimate of value of 1800MHz spectrum would have produced a central estimate of the market value of 1800MHz spectrum and could have potentially overestimated the value of 1800MHz spectrum.

151. For these reasons, we applied an alternative methodology to estimate an appropriate minimum price for the 1800MHz spectrum in Ireland, investigating the relative valuations of sub-1GHz and 1800MHz spectrum from international benchmarks and deriving a suitable minimum price for 1800MHz relative to the minimum price set for sub-1GHz spectrum. This

[50] See paragraphs 10-15 of DotEcon report 10/71b for a further discussion on implications of including 800MHz spectrum on the appropriate minimum price.

approach was considered appropriate because it ensured that the minimum prices of the various bands to be auctioned in the single award are all based on a conservative lower bound market value, therefore reducing the risk of choking off demand and distorting bidders' choices in the auction.

152. In addition, we noted that it was not necessary to precisely identify the relative valuations of sub 1-GHz spectrum and 1800MHz spectrum; rather a good approximation of relative value was sufficient so long as the minimum price derived for 1800MHz was not so high as to risk choking off demand of serious bidders for 1800MHz spectrum. By ensuring that demand was not choked off in the award we could ensure that the relative values could be reflected in different prices of sub 1-GHz and 1800MHz spectrum achieved in the auction itself.

153. We considered a range of information about the relative values such as the relative band value achieved in previous auctions where sub-1GHz and 1800MHz spectrum were awarded in a joint auction; separate auctions for sub-1GHz spectrum and 1800MHz spectrum auctioned in the same country but in separate awards; and a number of studies on the network costs associated with the different spectrum bands. From this set of information we considered that an accurate approximation for the relative value of 1800MHz to sub-1GHz spectrum was consistently around 45%-60%.

D.2 Benchmark methodology and modelling issues

D.2.1 Respondents' views on benchmarking methodology

154. In their consultation responses, Digiweb and Vodafone communicated that they were not in favour of a benchmarking approach to setting minimum prices. Vodafone questioned the rationale for setting a minimum price based on a benchmarking model. It considered that as long as the minimum is set high enough to deter frivolous bidders the auction would determine the market value instead and therefore there was no benefit in approximating a market value.

155. On the other hand, a number of respondents stated a preference for a benchmarking approach to setting minimum prices; however, some of these respondents considered that the inputs used in the benchmarking approach were problematic and made suggestions for the use of other input data such as the use of GNP instead of GDP. O2 and H3GI suggested that a more suitable benchmark for setting minimum prices would be a benchmark of the minimum prices set by other authorities rather than the final prices achieved in the relevant auctions.

156. Addressing first the choice of a benchmarking approach to setting minimum prices, we discussed above that given ComReg's concerns over low competition scenarios, it was appropriate to set a minimum price reflective of market value of spectrum to manage the strategic incentives of bidders. Therefore, in our benchmarking exercise, we set out a benchmark that represented a conservative lower bound of the market value of liberalised 900MHz spectrum in DotEcon report 09/99c and, subsequently, liberalised sub-1GHz spectrum value in DotEcon report 10/71b.

157. The proposed addition of 800MHz and, separately, 1800MHz spectrum within the same auction lowered but did not eliminate the low competition concerns for the proposed auction. Hence it was still apt to set a minimum price reflective of market value. Reflecting the decrease in magnitude of the concerns over anti-competitive behaviour in the auction, and the increased uncertainty over the relative value of 900MHz and 800MHz spectrum and sub-1GHz and 1800MHz spectrum, we concluded that where collusion concerns are not strong, the chosen minimum price should be relatively more conservative to ensure the efficiency of the auction process. [51]

158. Furthermore, although previously the trend for many NRAs was to set low but non-trivial minimum prices in spectrum auctions, there has increasingly been a deviation from this approach to set higher minimum prices. For example, in the Swedish 2.6GHz auction in 2008, the reserve price for a 2x5MHz lot was SEK2.75 million whereas the reserve price for the recently concluded 800MHz auction in Sweden was SEK150 million per 2x5MHz lot. In addition, in its consultation on the upcoming UK 800MHz and 2.6GHz auction, published in March 2011, Ofcom stated that it is deviating from its long-standing approach of setting low but non-trivial minimum prices, and is considering the setting of reserve prices that reflect the market value of spectrum so as to manage strategic incentives of potential bidders.

159. Addressing then the suggested approach of benchmarking minimum prices instead of licences values, we note that when considering the appropriate minimum price for a particular award, each National Regulatory Authority (NRA) takes into account its own objectives for that award. ComReg's objectives for a multi-band spectrum award have led to the setting of a minimum price that is reflective of market value of liberalised sub-1GHz and 1800MHz spectrum. However, the objectives of other NRAs in setting minimum prices may not have led to the setting of minimum prices for spectrum in relevant auctions internationally to be reflective of market value. Therefore, it would not have been appropriate for ComReg to have set minimum prices for a multi-band auction based on minimum prices set by other NRAs with different objectives in mind.

160. Confronting then the issues raised with the variables used in benchmarking analysis, we opted to use GDP as an independent variable in our regression analysis rather than GNP as it is a better reflection of the domestic income levels within Ireland. If we consider domestic income levels as a proxy of willingness to pay for mobile communications services within a country, as well as other factors such as the level of development within a country that affects the value of spectrum, then we consider GDP to be a better explanatory variable than GNP in our regression model.

161. In summary, we do not consider that these responses affect our choice of approach in benchmarking the value of spectrum in Ireland as detailed in our various reports on the subject.

[51] See Section 2 of 10/71b and Section 7.4 of 10/105a.

Respondents' view on modelling issues

162. Many of the respondents to ComReg's various consultations have argued that the dataset used in the benchmarking analysis is weak because the auction data in the benchmarking dataset and the upcoming Irish auction of 800MHz, 900MHz and 1800MHz cannot be considered as 'like for like' and that therefore the benchmarking analysis has a large margin of error.

163. Addressing the issue over the dataset used in our benchmarking analysis, in all three DotEcon reports on the subject of benchmarking (09/99c,[52] 10/71b and 10/105a) we acknowledged that the auction data used in our benchmarks were not 'like for like' with that of the spectrum to be auctioned in Ireland. However, this was not considered a problem per se because the aim of the benchmarking exercise was not to predict the exact market value of the spectrum to be auctioned but rather to produce a range of conservative market values, which could then be used to set a conservative, market-based minimum price, therefore ensuring that the actual market value could be derived in the auction itself. Hence, it was not necessary to have data that was considered 'like for like' per se but rather that the data used should have similar characteristics whilst at the same time producing a conservative market value range.

164. As discussed above, the data used in the benchmarking of sub-1GHz spectrum was that of a collection of auctions where a wide range of spectrum bands for mobile and 3G services had been auctioned, which were considered to be less valuable than the liberalised 800MHz and 900MHz spectrum. This meant that this dataset could most usefully be used to produce a conservative market value for 800MHz and 900MHz spectrum. Subsequently, the results from the relativity analysis for 1800MHz spectrum based on the benchmarking of 800MHz and 900MHz spectrum also produced an estimate that is likely to be a lower bound of the market value of 1800MHz spectrum (discussed further in sub-section D.4.2 below).

165. H3GI has commented that some of auctions included in the sample are not comparable to 900MHz spectrum, namely, the 1900-1905MHz band in Sweden and 1785-1805MHz in the UK and Ireland and DECT guard band in the UK. While these frequencies were not eventually used to implement national GSM systems, the available applications such as local area mobile networks are substitutes, even if only weak substitutes to wide area mobile services. Therefore the opportunity cost of these frequencies is relevant in constructing a conservative lower bound estimate of sub-1GHz spectrum, particularly as these frequencies are considered to be of lower value compared to 800MHz or 900MHz spectrum.

166. H3GI has also questioned why an "All 3G Licences" regression analysis was not included. In this respect, we note that:

[52] See in particular paragraph 466 of DotEcon report 09/99c.

- 3G auction results are taken into account in two out of our three regression analysis data sets – in "All mobile" and in the "Europe" regression data set; and
- A narrower dataset of "All 3G Licences" dataset would only add incremental informative value to the conservative lower bound estimate of liberalised sub-1GHs spectrum if certain aspects of 3G spectrum valuations might be more reflective of sub-1GHz values as compared to other bands. If 3G licence values are affected by factors other than the value of services that could be deployed using the spectrum, such as the influence of the telecoms bubble, a regression analysis on a data set including only these licences will not add incremental informative value.

167. Therefore, given the account already taken of 3G licences and the documented effects of the telecom bubble affecting licence prices around 2000, we consider that an "All 3G Licences" dataset would not add much informative value to deriving a conservative lower bound estimate of sub-1GHz spectrum over and above the regression results we derived from the regression analysis on the three datasets currently used - "All mobile", "Europe" and "Sub-1GHz and 1800MHz".

168. Separately, a number of respondents have argued that the use of pre-recession auction data is likely to overstate the current and future value of spectrum in Ireland because national income and growth expectations have fallen in Ireland since the onset of the recession therefore negatively affecting the value of spectrum at least in the medium term.

169. Addressing this, country and market differences were taken into account in the benchmarking analysis by controlling for differences in population, GDP and mobile market concentration. The use of population data meant that we could adjust prices to reflect the fact that Ireland has a lower population than other larger countries in our sample. GDP per capita is used to reflect country differences in national income, which can have an effect on the value of spectrum. In all of our benchmarking reports we used the most recent GDP data available for Ireland take into consideration the possible negative effect of the recession on the value of the spectrum in Ireland. Specifically, between our analysis in 09/99c where 2008 GDP per capita was used and the current update benchmark analysis where 2010 GDP per capita is used, GDP per capita has dropped by nearly 20%.

170. In addition, O2 argued that more weight is placed on past auctions while older licences are less comparable to current licence values, and that more weight should be placed on recent auctions instead as they may be more reflective of current market value and expectations. O2 also suggests that our benchmarking analysis should be re-run taking account that there is unlikely to be more than four bidders given the proposed minimum price of €25m per 2x5MHz of sub-1GHz spectrum proposed at the time.

171. Our benchmarking analysis does not place more weight on past auctions. Rather as explained in Section 3.2.2, more recent auctions have a greater impact on our predicted licence price as compared to older auctions as they influence the coefficient of the year_1011 dummy which is one of the explanatory variables for our predicted licence price. As the year

dummies controls for the time trend element of licence prices our predicted licence price does reflect current market value and expectations.

172. In sub-section 3.2.2, we present a sensitivity analysis on the 'winners to bidders' ratio (WtB) as an independent variable in our regression model. We consider that the sensitivities we ran cover the possible likely competitive scenarios in the upcoming auction given the specific market conditions in Ireland. A less competitive auction (resulting in a higher 'winners to bidders' ratio) would indeed have an impact on the predicted licence value in our regression model. However, we note that the sample average winners to bidders ratio has increase from 0.86 previously to 0.77 currently and this has been taken into account in our estimates. We consider this to be inline with O2's comments on producing an estimate that reflects current market sentiments particularly given that it is unknown how many bidders will actually take part or what the competitive scenario for the upcoming auction would be. ,However, even in the case of four bidders (and four winners) we consider the predicted licence values from our sensitivity analysis to be within our recommended range of minimum prices.

D.3 Conservative approach

D.3.1 Respondents' views on the level of minimum prices set by ComReg

173. Many respondents have argued that the approach taken by ComReg and/or DotEcon in setting minimum prices, in their view, has been too aggressive and therefore minimum prices have been set too high. Imagine has also argued in favour of a price structure that encourages new market entry. Other respondents have argued that ComReg should choose the bottom end of the benchmark range given the possibly large margin of error and the dangers of choking off demand in the auction therefore possibly leading to unsold spectrum.

174. In addition, many respondents have argued that there exists a large degree of uncertainty about the value of spectrum in Ireland because of the fall in economic growth and output in Ireland, therefore depressing the value of spectrum to operators. Further, mobile operators have argued that they face a very challenging environment in which to produce investment plans for additional network deployment and therefore there is a risk that, by setting the reserve price in the auction at too high a level, ComReg will choke off demand.

175. Addressing the view that a more conservative approach should be adopted in setting minimum prices, we note from above that in DotEcon report 09/99c we considered setting minimum prices reflecting market value to be in line with ComReg's objective of managing strategic incentives of bidders in the auction. Nevertheless, we designed our benchmarking approach to yield a conservative lower bound range of the likely market value of 900MHz spectrum. Subsequently, when we proposed a common minimum price for 800MHz and 900MHz spectrum in September 2010, we considered that any uncertainty in relative valuations of 800MHz and 900MHz spectrum and the decreasing risk of collusion given the greater availability of spectrum should motivate the setting of a common minimum price for sub-1GHz spectrum more conservatively.

Specifically, it was considered that in the absence of evidence that these values differ substantially, it was prudent to set a common minimum price for these bands as long as this value does not choke off efficient demand and that any residual uncertainty regarding the differing values of lots of spectrum in these two bands should be reflected in the use of a more conservative approach to setting the common sub-1GHz minimum price.[53] Similar arguments were then re-iterated with the proposed inclusion of 1800MHz spectrum in a joint auction of 800MHz and 900MHz spectrum in Section 7.4 of DotEcon report 10/105a. In calculating a suitable minimum price for 1800MHz spectrum in this report, we note the importance of setting a minimum price on the same conservative lower bound basis as that of sub-1GHz spectrum.

176. Furthermore, as explained above, although the outlook for growth and national income has deteriorated in Ireland we considered that this was reflected in our reports as we have consistently sought to ensure that the most recent GDP levels have been used. The use of lower GDP levels in 10/71b and this report have reduced the value of the range of market values produced by the benchmark analysis, therefore allowing us take into account the possible negative effect of the recession on the market value of the spectrum. In this updated benchmarking analysis, we also have in our dataset spectrum auction results of recent auctions that would be reflective of the current economic climate.

177. We consider that while there is a degree of uncertainty as to our estimates, as with any data analysis, our approach to calculating a conservative lower bound value of sub-1GHz and 1800MHz spectrum provides extra headroom in setting an appropriate minimum price that reflects market value but is not so high as to risk participation efficiency of the auction. In addition, the consistency cross checks against recent competitive auctions of liberalised sub-1GHz and 1800MHz results in Section 4 above suggests that our current recommended minimum price range is in line with current market value of the spectrum concerned. We note further that taking into account recent spectrum auction results has lowered our benchmark range as compared to that presented in 10/71b. We also re-iterate in this report the point mentioned in previous reports 10/71b and 10/105a that reductions in concerns over strategic behaviour and uncertainties over relative valuations of 800MHz, 900MHz and 1800MHz spectrum particularly in the near term given the lack of LTE equipment availability in these bands should be reflected in a more conservative approach in setting minimum prices in the upcoming auction.

[53] See paragraphs 10-15 of DotEcon report 10/71b for a further discussion on implications of including 800MHz spectrum on the appropriate minimum price.

D.4 Common minimum price of 800MHz and 900MHz and relative minimum price of 1800MHz spectrum

D.4.1 Respondents' views on a common minimum price for 800MHz and 900MHz spectrum

178. Whilst Vodafone agreed with the decision to set a common minimum price for 800MHz and 900MHz spectrum, a number of respondents have argued that a common minimum price should not be set. Both UPC Ireland and H3GI have argued that these frequency bands are not substitutes and in particular that 800MHz spectrum is less valuable than 900MHz spectrum and should therefore have a lower minimum price to reflect this. In addition, H3GI submits that it is unacceptable to justify setting a common minimum price based on the fact that there is little data available on the relative values.

179. As expressed in DotEcon report 10/71b[54] and further mentioned in DotEcon Report 10/105a and in this report, we do not view 800MHz and 900MHz spectrum as perfect substitutes, nor do we predict that they will sell at identical prices in the planned auction. In fact, in DotEcon report 10/71b, we considered that the 800MHz and 900MHz spectrum could have different values for different bidders in the auction. An incumbent could, for example, have a higher valuation for liberalised 900MHz (especially in the first time slice) spectrum compared to 800MHz frequencies due to the value it places on ensuring short-run business continuity.

180. However, it was considered at the time and remains appropriate that, a common minimum price should be set for these spectrum bands as spectrum in both of these bands will be licensed for liberalised use. As such, 900MHz spectrum may be used for LTE during the licence period despite GSM-related business continuity issues, and the market value of liberalised 900MHz spectrum should therefore reflect this flexibility. Therefore, taking a longer-term view of these frequency bands suggests that they will be more substitutable in the future. There are good reasons to expect, therefore, that the market value of these bands to be comparable in the long term hence for a common minimum price to be set for these frequencies in the upcoming auction.

181. Nevertheless, we recognise that it is important that in doing so, the common minimum price set does not choke off demand from serious bidders in the auction, thereby allowing the auction process to determine relative demand for these frequencies. We note in DotEcon report 10/71b that in doing so, any residual uncertainty over the relative value of 800MHz and 900MHz spectrum should be taken into account by adopting a more conservative approach to setting the common minimum price.[55]

[54] Section 2 of the DotEcon report 10/71b.

[55] See paragraphs 12 and 15 of the DotEcon report 10/71b.

D.4.2 Relative minimum price for 1800MHz spectrum

182. In terms of the approach taken by DotEcon in setting the minimum price for 1800MHz spectrum, a number of respondents have expressed concerns over this approach adopted. Both Eircom and Vodafone expressed the view that the minimum price for 1800MHz spectrum resulting from a relativity analysis is likely to result in a minimum price that is excessive because of the problems believed to be inherent in the benchmarking analysis of sub-1GHz spectrum. In addition, both Vodafone and O2 questioned the credibility of the relativity analysis because of the limited amount of international data available for benchmarking purposes. Therefore, as a precautionary measure to insure against the risk of setting the minimum price above the efficient level, Vodafone considers that if the minimum price of 1800MHz spectrum blocks were set relative to sub-1GHz spectrum then it should be no higher than 30% of the minimum price of sub-1GHz spectrum.[56]

183. The dataset of available joint auctions of sub-1GHz and 1800MHz spectrum and countries which have auctioned both sub-1GHz and 1800MHz spectrum is small as GSM spectrum was commonly awarded administratively rather than via auction. In addition, in some cases, there has been a need to interpret the auction data that is available to judge if it is fully reflective of competitive market value of frequencies concerned, particularly in the context of the frequencies to be made available in the upcoming auction. For instance, we do not consider auctions where licences were awarded at reserve prices to be fully reflective of relative competitive market value. Further, in the case of the German multi-band auction in 2010, we consider that the 1800MHz licence values from that auction are not fully reflective of competitive market valuations of 1800MHz spectrum due to the incumbents' existing locations within the band as discussed in paragraph 204 of DotEcon report 10/105a.

184. Of the data points that we do have that illustrate relative competitive market value of sub-1GHz versus 1800MHz spectrum, we find that these yield a consistent relationship between the relative values of these frequencies. Further, the relative competitive market value of 1800MHz to sub-1GHz spectrum of 45% to 60% derived from our analysis is consistent with that implied by technical studies based on the relative propagation characteristics of sub-1GHz and higher frequency mobile spectrum.

185. In addition, as noted above and in 10/105a, it is not necessary for our analysis to predict the exact relative valuation of sub-1GHz and 1800Mhz spectrum; rather, a good approximation of relative value will be sufficient so long as the derived minimum price for 1800MHz is not so high as to risk choking off demand of serious bidders for 1800MHz spectrum. By ensuring that demand is not choked off before the first round of the auction, the relative values would be reflected in different prices of sub 1-GHz and 1800MHz spectrum achieved in the auction itself. Any residual

[56] See Annex C for further details on the respondents' comments.

uncertainty about the relative value of sub-1GHz and 1800MHz spectrum should be reflected in a more conservative approach in setting minimum prices.

D.5 Considerations for choosing an appropriate minimum price and managing collusive behaviour in the auction

186. Respondents are of the view that a high minimum price proposed by ComReg does not reflect or fulfill its objectives. Particularly with reference to the effectiveness of a higher minimum price in preventing collusion.

187. Specifically, several respondents commented that with Combinatorial Clock Auction format and the liberal sub-1GHz spectrum cap of 2x20MHz per bidder and overall cap of 1800MHz per bidder sufficiently deals with collusion concerns in the auction. Further Irish and EU competition law should also tackle collusive behavior. Hence there is no justification for ComReg to set high minimum prices on grounds of collusion concerns particularly since there is no proof that a high minimum price reduces collusion. Rather many respondents supported the use of low but non-trivial minimum prices instead.

188. We note in Section 4.4 above that despite the auction format and spectrum caps, operators could still have incentives to collude particularly in the 900MHz band in the first time slice. In addition to concerns of collusive behavior within the auction, operators could also have incentives to engage in pre-auction pooling which may not fall foul under competition law. These incentives need to be managed so that low but non-trivial minimum prices are not suitable. High minimum prices reflecting market value alongside the CCA format and liberal spectrum caps reduce the risks of anti-competitive behavior as higher minimum prices will reduce bidders' pay off from collusive behavior. While the eventual impact of minimum prices imposed on collusive activity is not necessarily conclusive, we consider that it is important to manage bidders' incentives to collude in the auction.

189. In terms of meeting its statutory objectives, the benchmarking produces a conservative lower bound estimate of market value hence a minimum price set in this regard should have low risk of resulting in inefficiently unsold spectrum. Therefore, while a minimum price set at the lower to mid range based on a 'lower bound estimate' methodology is proposed, it is unlikely that this will result in an auction outcome that is contrary to ComReg's statutory objectives.