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Communications Regulation

Spectrum award – 3.6 GHz band.

Report from DotEcon on 3.6 GHz band reserve prices.

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3.6GHz band reserve prices

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Executive Summary

1. The 3.6GHz band could accommodate a variety of possible uses, including fixed wireless applications, nomadic wireless services, additional capacity for existing mobile operators in high demand locations or even backhaul. Given that 350MHz of spectrum is available in the band, it could sustain a number of operators of different types. Both FDD and TDD systems could potentially be used in this band, but there is currently significant momentum behind the use of the band for TDD LTE, including potentially migration of WiMax networks to LTE for fixed wireless applications.
2. We consider benchmarks of market price from awards of 3.6GHz, 2.3GHz and 2.6GHz spectrum. Few of the 3.6GHz awards occurred in the last five years; bidders in prior awards are unlikely to have factored in future migration to LTE when valuing spectrum. Therefore, 3.6GHz benchmarks may underestimate the current market price. Conversely, the anticipation of LTE use is likely to be factored into 2.3GHz and 2.6GHz benchmarks to a greater extent, though these bands may have better equipment availability and somewhat better propagation characteristics than the 3.6GHz band. Therefore, it is possible that 2.3GHz and 2.6GHz benchmarks could somewhat overestimate the value of 3.6GHz spectrum.
3. We normalise all benchmarks to the equivalent price of a 15-year licence in 2015 prices, considering all fees linked to the licence over its life (e.g. annual fees). On this basis we obtain the following averages across licence prices (after excluding non-competitive auctions and outliers):

	Average licence price per MHz per capita			
	All awards	*European awards*	*Awards from 2010*	*European awards from 2010*
All bands	€0.0236	€0.0142	€0.0715	€0.0386
3.6GHz band	€0.0158	€0.0064	€0.0038	€0.0038
2.6GHz band	€0.0297	€0.0333	€0.0473	€0.0473
2.3GHz band	€0.0279	NA	€0.1125	NA

4. We recommend that ComReg sets a minimum price in the range of €0.015-0.025 per MHz per capita. On this basis, the minimum price for a 5MHz national block would range between around €350,000 and €575,000.
5. We recommend that the minimum price be split equally (in net present value terms) between a reserve price for the auction and annual fees for the duration of the licence. Ignoring inflation, at €0.015 per MHz per capita, this would result in a minimum up-front payment of just above €170,000 and an annual fee of just under €20,000 for a 5MHz national block. At €0.025 per MHz per capita, the minimum up-front payment would increase to just under €290,000 with an annual fee of just above €30,000.
6. We then consider how to set minimum prices for regional licences, using the two regional structures proposed by ComReg. The starting point is to consider the population in each region. However, we then consider an uplift for urban and higher population density regions. The uplift reflects (i) commuting inflows for ComReg's proposed regional structure, which separates urban centres and non-urban centres into separate regions (captured by adjusting population figures to reflect the net population flow in each region); and (ii) the likely value premium for high population density regions, which is likely to lead to lower unit deployment costs (captured by using a higher price per MHz per capita in such regions). Indeed, in other regional auctions urban areas have demonstrated higher prices by a factor of two or more.

1 Introduction

7. In this document we recommend reserve prices for the upcoming award of 15-year licences for the rights to use frequencies in the 3.6GHz band[1] in Ireland. In total, 350MHz will be available for award in two contiguous frequency ranges:

   - 3410-3435MHz; and
   - 3475-3800MHz.

8. Our starting point is to develop conservative estimates of the potential market price[2] of national licences for spectrum in this band. We then make a recommendation on reserve prices based on these estimates. Our recommendation takes into account the uncertainty around these estimates and the risk that reserve prices might be set too high, leading to unassigned spectrum even though there might be demand for it.

1.1 Use of the 3.6GHz band

9. The 3.6GHz band could accommodate a variety of possible uses, including fixed wireless applications, nomadic wireless services, additional capacity for existing mobile operators in high demand locations or even backhaul. Both FDD and TDD systems could potentially be used in this band, but there is currently significant momentum behind the use of the band for TDD LTE; this technology might be used in future by mobile, fixed or nomadic systems. Given the amount of spectrum available in the band, it could sustain a number of operators using the spectrum for rather different purposes.

[1] The 3.6GHz band includes all the available frequencies in the 3.4-3.8GHz range.

[2] Throughout 'market price' should be understood to mean price as established in a competitive process. Notice that this can be expected to be lower than the business case valuation of the winner of a licence, which should exceed the price that it pays. For example, in an open auction process, market price is typically established by losing bids, as opposed to the valuations of winning bids for the lots they receive.

10. Global TD-LTE Initiative (GTI) notes that the two main drivers for the deployment of TDD LTE in the 3.6GHz band are:[3]

    - the increasing need for mobile operators to obtain additional capacity to support the exponential increase of data traffic;
    - the interest from existing FWA operators in the band to migrate their networks to LTE in order to benefit from the growing ecosystem of LTE devices for this band, with the corresponding reductions in equipment costs and greater efficiency.

11. Indeed, Global mobile Suppliers Association (GSA) reports that as of April 2015, eleven TDD LTE networks have been launched using spectrum in the 3.6GHz band[4] (despite the limited device ecosystem in this band at present, as only 26 devices were available as of April 2015).[5] GTI also notes that some WiMax operators had already begun their migration to LTE towards the end of 2013.[6] The main motivation for migration appears to be the superiority of LTE over mature WiMax systems in terms of achieving greater spectral efficiency (i.e. more bits/Hz). Migration to LTE is also likely to become increasingly attractive as the availability of devices for the 3.6GHz band increases and the cost of devices falls.

12. We expect that existing FWA licensees in Ireland will have a similar motivation to migrate to LTE. Therefore, we expect the 3.6GHz band to be used for TDD LTE in the long run, even if used for fixed or nomadic services.

[3] GTI, 2013, The emerging ecosystem for LTE TDD networks at 3.5/3.6GHz: http://lte-tdd.org/upload/accessory/20139/201391311577882263.pdf.

[4] GSA, 2015, Spectrum used currently in 393 commercially launched LTE networks: http://www.gsacom.com/cgi/redir.pl5?url=http://www.gsacom.com/downloads/pdf/Spectrum_used_in_commercially_launched_LTE_networks_090415.php4

[5] GSA, 2015, 4G market and technology update April 9 2015: http://www.gsacom.com/downloads/pdf/Snapshot_LTE-TDD_extract_GSA_Evolution_to_LTE_report_090415.php4

[6] ibid.

1.2 Benchmarking the market price for licences in the 3.6GHz band

13. To estimate the market price for spectrum licences in the 3.6GHz band we consider two groups of international benchmarks. First, we consider awards of frequencies within the 3.6GHz band, though most of these occurred some time ago and are unlikely to reflect the value arising from the possibility of using these bands for TDD-LTE. Second, we consider awards of unpaired spectrum licences in similar bands (2.6GHz and 2.3GHz) that, although at somewhat different frequencies, are used for TDD-LTE. As we explain below, the first group of benchmarks is might understate the current market price of a 3.6GHz licence, whereas the second group might overstate it.

Benchmark data from awards of 3.6GHz spectrum

14. The most direct comparators are spectrum licences for any frequencies within the 3.6GHz band (identified by the EC as bands 42 and 43).[7]

15. A key factor underpinning the value of spectrum is the expected revenue from the services that can be offered with the spectrum. The expected revenue will depend on expected data traffic and prices (which in turn depend on expected competition in the downstream market). On the one hand, demand for data traffic has increased materially over the last few years; on the other hand, the landscape of the downstream market also changes over time (especially with convergence of communications services). For this reason, more recent awards are likely to provide better information for forecasting the value of spectrum, as the expectations from bidders in more recent auctions are probably a better reflection of future possibilities. However, most of the available benchmarks are quite old (only three

[7] EC Decision 11(06) designated this frequency range for mobile/fixed communications networks on a non-exclusive basis. 3GPP identified this frequency range for TDD use – bands 42 (3.4-3.6GHz) and 43 (3.6-3.8GHz) in 2012.

of the available auction benchmarks took place in the last five years).

16. Another key factor for spectrum valuations is the technology available (or expected to be available) for using the spectrum. In this regard, the value of 3.6GHz spectrum is likely to have increased given the possibility to use LTE in this band, which is a fairly recent development both in terms of spectrum harmonisation and equipment availability.[8]

17. Given that the benchmarks available relate to awards that predate both the harmonisation of this band[9] and the development of TDD-LTE for this band, it is unlikely that bidders in these awards would have based their valuations for 3.6GHz licences based on the future use of the spectrum for TDD-LTE (and even if such future use were anticipated, it might have been heavily discounted to reflect the uncertainty about this possibility). Therefore, while we expect 3.6GHz benchmarks based on historic awards to provide estimates of market price that would be achieved amongst pre-existing modes of use (mostly FWA, BWA or WiMax), these might understate the current market price by not reflecting the impact of competition from LTE users.

Benchmark data from awards of spectrum in other bands

18. Given that we expect the 3.6GHz band will be used for TDD-LTE, other bands used for TDD-LTE may also be used as a benchmark for estimating the market price of the 3.6GHz band, provided that they do not have materially different characteristics (as for instance, signal propagation). In particular, we consider that the 2.6GHz band (Band 38) and the 2.3GHz band (Band 40) might be a good comparator. However, we expect the current value of licences in the 2.3GHz and 2.6GHz bands to be higher than that of licences in the 3.6GHz band for a number of reasons:

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[8] The first commercial TDD-LTE network in these bands was launched by UK Broadband in February 2012 (see for example http://www.ukbroadband.com/about-us/press-releases/press-release-1).

[9] Discussions for the harmonisation of the 3.6GHz band for mobile use will not take place until WRC-15.

- The 2.3GHz and 2.6GHz bands have somewhat better propagation characteristics than the 3.6GHz band. In particular, the main proposed use for the 3.6GHz band at the moment is high-bandwidth small cell use, whereas the 2.3GHz and 2.6GHz bands may be used for both macro and small cell deployment. While more recent trials such as that conducted by NBN Co in Australia suggest that 3.6GHz spectrum may be used for both macro and small cell deployment,[10] we expect the technical value of spectrum at 2.3GHz and 2.6GHz to be higher than that of spectrum in the 3.6GHz band.
- There is greater TDD-LTE equipment availability in these bands (GSA reports as of April 2015 that there are 696 devices available for 2.6GHz spectrum and 606 for 2.3GHz spectrum, compared to just 26 devices for 3.6GHz spectrum).[11]
- The process of harmonisation towards TDD-LTE use in these bands is more advanced than in the 3.6GHz band, which provides greater certainty for bidders in terms of technological development and device availability.

1.3 Overall approach

19. Benchmarks from relatively old awards of 3.6GHz spectrum might have limited value for forecasting the likely market price of spectrum in the 3.6GHz band at present, particularly given that the possibility of using TDD-LTE for the 3.6GHz band is relatively recent. In contrast, benchmarks from awards of 2.6GHz and 2.3GHz might overstate the market price of 3.6GHz spectrum, in that these bands have greater

[10] See http://www.ericsson.com/news/150301-nbn-co-and-ericsson_244069647_c

[11] GSA, 2015, 4G market and technology update April 9 2015: http://www.gsacom.com/downloads/pdf/Snapshot_LTE-TDD_extract_GSA_Evolution_to_LTE_report_090415.php4

equipment availability[12] and superior propagation characteristics (to some extent). Therefore, our estimate for the market price of 3.6GHz licences lies between these two sets of benchmarks.

20. Once we have formed an estimate of the market price of a national licence for 3.6GHz spectrum we consider what would be a reasonable level for reserve prices. Our recommendation of reserve prices is below our estimate of market price, with the aim of mitigating the risk of potentially ending up with unsold spectrum as a result of chocking off demand. We also discuss how the fees for 3.6GHz spectrum might be split between a minimum up-front payment, implemented as a reserve price in an auction, and on-going annual licence fees.

21. Having formed a view on an appropriate range for the minimum prices expressed on a per MHz per capita, we use this as the basis for recommending minimum prices for regional licences, following the two options for regional lot structures proposed by ComReg. As a starting point, we use raw population in each region calculate the minimum price for each region. However, this is likely to understate the minimum price for urban centres, which see population inflows during the day. We therefore make some adjustments to account for net population flows in each region. We then propose using a higher price per MHz per capita when calculating minimum prices for regions with higher population density, as higher density is likely to reduce unit network costs and improve capacity utilisation.

2 Available international benchmarks

22. Below we present average licence prices per MHz per capita for licences of unpaired spectrum in each of the 3.6GHz, 2.6GHz and 2.3GHz bands. By ‘licence price’ we shall mean the Net Present Value (NPV) of the various fees required for a licence over its life from the perspective of a hypothetical operator. These fees include the upfront payment required when the licence is awarded, any deferred payments and annual licence fees (as all these fees can be anticipated by

[12] Particularly in the 2.6GHz band, which has been a key mobile expansion band for some time.

the licensee when acquiring its licence). For calculating the NPV of fees we use a nominal[13] discount rate of 8.63% (which corresponds to the nominal, pre-tax WACC estimated for the mobile telecommunications sector in Ireland in 2014).[14] We note that ComReg has not determined a cost of capital for the FWALA sector. However, we only use benchmarks as an indication when recommending minimum prices, and therefore our conclusions are not sensitive to the particular assumption made about this discount rate.

23. Licence prices are adjusted so that they are comparable across licences as follows:

- **currency differences**: licence prices are converted to 2015 Euros using Purchasing Price Parity (PPP) exchange rates and inflation using US CPI data;
- **licence duration**: licence prices are normalised to a 15-year licence assuming that licences have a constant nominal value per year over their duration;
- **licence bandwidth**: licence prices are normalised to a per MHz price by dividing them by the bandwidth for the licence; and
- **population covered**: licence prices are divided by the population covered by the licence so that licences are presented on a per capita basis.

24. All licence prices in this document are reported as the NPV of all the licence fees that would be applicable if the licence term was fifteen years. When discussing benchmarks, we expressed these in terms of 2015 Euros per MHz per capita.

25. For each award we calculate the average licence price per MHz per population across all licences assigned in the

[13] When considering deferred and annual fees, we do not update these in line with inflation. Therefore, by also using a nominal rather than real discount rate we implicitly assume that any deferred fees in our benchmarks would not have been increased in line with inflation, which may not always be the case. However, note that if fees were increased to take account of inflation this would yield a higher NPV that calculated under our implicit assumption. Therefore, our approach should, if anything, understate actual licence prices.

[14] ComReg, 2014, Cost of Capital, Document 14/136 and D15/14: http://www.comreg.ie/_fileupload/publications/ComReg14136.pdf.

award. To do this, we first calculate the licence price that would correspond to each lot sold in the award. Then, we calculate the average licence price across all lots sold in the award, weighted by the population covered by each lot, so that in awards in which at least some spectrum was offered as regional licences we give more importance to licences with greater population coverage.[15]

26. We also calculate average licence prices across awards, first separately for each of the 3.6GHz, 2.6GHz and 2.3GHz bands, and then across all bands. Where the sample size allows for it, we also consider the sub-sample of European-only awards, or separate our sample between awards before 2010 and after 2010 (which helps us to assess the impact of the availability of LTE and harmonisation on the value of licences).

27. Our sample consists of awards of unpaired spectrum in the 3.6GHz, 2.6GHz and 2.3GHz bands, with 23, 10 and 7 observations respectively. We only consider auctions in which the prices were determined by bidders, and thus only those in which spectrum was allocated above reserve prices. The data in our sample is provided in Annex A.

28. When calculating average licence prices across different awards we exclude outliers within the sample, in order to ensure that our sample statistics are not skewed by extreme values associated with atypical outcomes. We identify outliers within each sample using two common methods:

    - if the observation lies more than three standard deviations away from the sample mean; or
    - if the observation lies beyond the 'outer fence' of the sample, with the outer fence calculated as three times the interquartile range (distance between the 75th and 25th percentiles) from the 75th percentile.

    We consider an observation to be an outlier if it is identified by either of these criteria.

[15] Under this approach, a lot with national coverage has the same per MHz weight as the combination of lots that would be required to achieve the same coverage on the basis of regional licences.

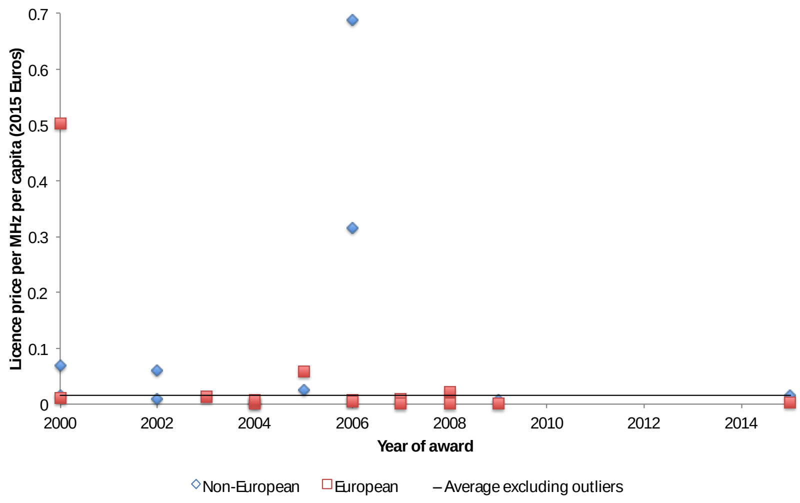
29. Where available, we also look at the licence renewal fees paid by operators using their licence for TDD-LTE as a cross-check. Note that this does not provide an indication of the market price (as these fees are set by the regulator). However, renewal fees (where paid by the operator) indicate a price at which demand (from that specific operator) was not chocked off.

2.1 Licence prices for 3.6GHz spectrum

30. We have a sample of 23 auctions of 3.6GHz licences, fifteen of which correspond to European countries. However, we have only one observation in the last five years (the Slovakian 3.7GHz auction in 2015), with the remaining 22 awards having taken place prior to 2010. (Most of the sample consists of awards of FWA, BWA or WiMax licences.)

31. Figure 1 below plots average licence prices for the award in the sample over time.

Figure 1: 3.6GHz licence prices

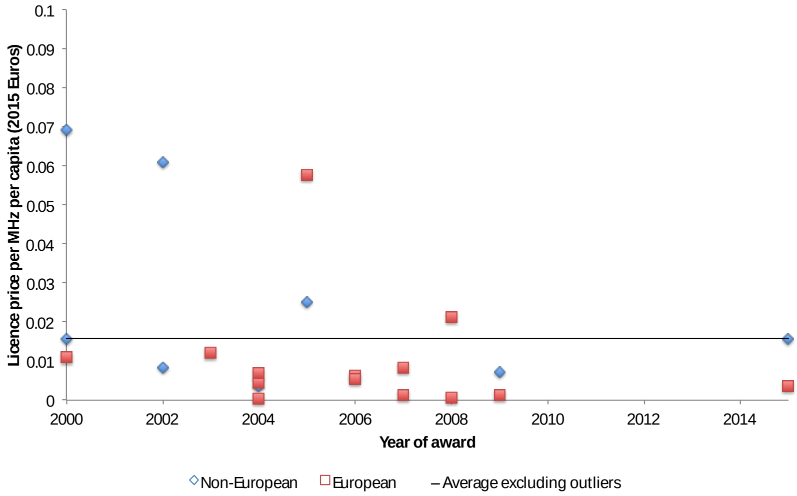


32. There is great variance of licence prices in the sample, with licence prices ranging from €0.0005 (Austria 2004) to €0.6875 (Jordan, 2006). However, this appears to be cause by three very high licence price observations, which we identify as outliers:

- Switzerland 2000;[16]
- Jordan 2006; and
- Bahrain 2006.

Excluding these outliers from the sample greatly reduces the variance across licence prices. The licence prices remaining in the sample after excluding outliers are plotted in Figure 2. The average of licence prices when excluding outliers is €0.0158 (€0.0792 if we include outliers).

Figure 2: 3.6GHz licence prices excluding outliers



33. Licence prices for European countries appear to be below the average (despite more than half the sample being European auctions), with only Switzerland 2000 (identified as an outlier in the whole sample), Italy 2008 and Bulgaria 2005 above the sample average. When considering a European-only sample (the European sample), the Swiss and Bulgarian auctions are identified as outliers. The average of licence prices across European auctions excluding these outliers is €0.0064 (€0.0429 if we include outliers), which is less than half the average for the full sample.

34. When looking at the sub-sample of awards from 2010, we only have one observation (Slovakia, 2014), in which the licence price is €0.0038. In practice, some 3.6GHz spectrum licensees have already launched TDD-LTE networks: Menatelecom (Belgium, awarded 2006); ABC

[16] The Swiss auction is the only European auction outlier. Licences prices in the Swiss auction in 2000 may have been inflated due to the telecoms bubble at the time of the auction.

Communication (Canada, 2004); Neo Sky (Spain, 2000) and UK Broadband (UK, 2003). We also understand that a number of operators are planning to launch TDD-LTE networks: DBD (Germany, 2006) and Milmex (Poland, 2005). However, these licences were awarded before harmonisation of the band for LTE and prior to the development of the LTE equipment.[17] Therefore, the prices for these licences are unlikely to reflect the value from using the spectrum for TDD-LTE.

35. We can use the renewal fee paid by UK Broadband (UKBB) in 2013 for its 3.6GHz licence in the UK as a cross-check.[18] The renewal fee was set by Ofcom with reference to the prices achieved in the 2003 auction, so it is also unlikely to reflect the value of using this band for TDD LTE. Therefore, while the fee paid by UKBB in 2013 provides a lower bound on the value UKBB attributes to its licence, it might still understate the market price of the licence.[19] The fee paid by 2013 by UKBB, adjusted to a 15-year term and 2015 Euros, is €0.0089 per MHz per capita, which is higher than the European sample average and higher than the licence prices achieved in the only auction from 2010, but below the full sample average. We note that UKBB's licence will be amended to an indefinite licence after the current term expires (in 2018) with annual fees set based on Administrative Incentive Pricing principles.[20] However, it is not yet clear what UKBB will be required to pay in annual fees.

[17] See footnote 7.

[18] http://www.ofcom.org.uk/static/archive/ra/topics/pfwa/3-4ghz/3-4-index.htm

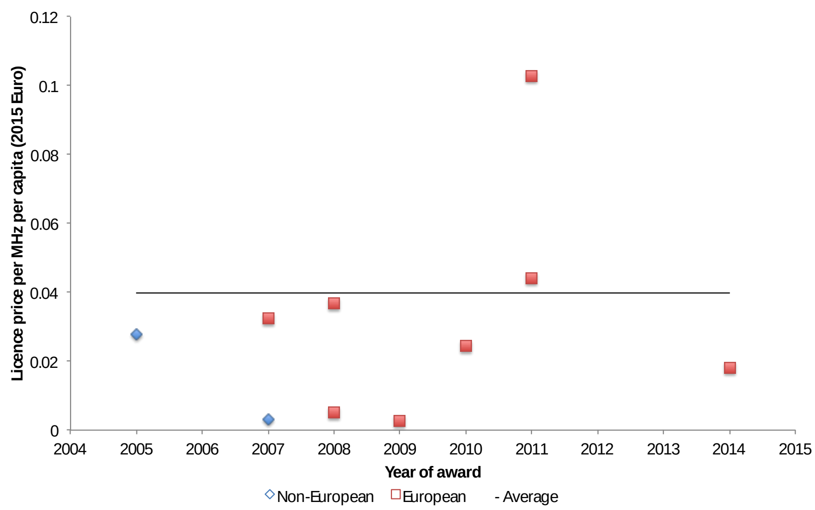
[19] The spectrum licensed to UKBB was initially assigned by auction in 2003 for a 5-year licence term (UKBB won spectrum in several regions in the auction and subsequently acquired the other two winners from the auction to amalgamate a national licence). Its licence was renewed in 2007 and again in 2013 (for another 5 years), for a renewal fee set on the basis of the 2003 auction prices.

[20] Ofcom, 9th October 2014, Variation of UK Broadband's 3.4GHz licence: http://stakeholders.ofcom.org.uk/binaries/consultations/uk-broadband-licence/statement/UK_Broadband_Statement.pdf

2.2 Licence prices for unpaired 2.6GHz spectrum

36. There are ten auctions in the sample, eight of which are for European countries. Four of the auctions took place from 2010, and therefore are likely to reflect the possibility of using the spectrum for TDD-LTE.

Figure 3: Unpaired 2.6GHz licence prices



37. We do not identify any outliers in the sample of 2.6GHz awards. However, the prices reached in the Spanish award in 2011 appear materially higher than the rest of observations in the graph, which could have a material effect on the sample average. Therefore, we also calculate averages excluding the Spanish auction from the sample

38. The full sample average is €0.0297, and the average when considering only European countries is €0.0333. When excluding the Spanish auction, the full average falls to €0.0216, while the average for the European sample falls to €0.0234.

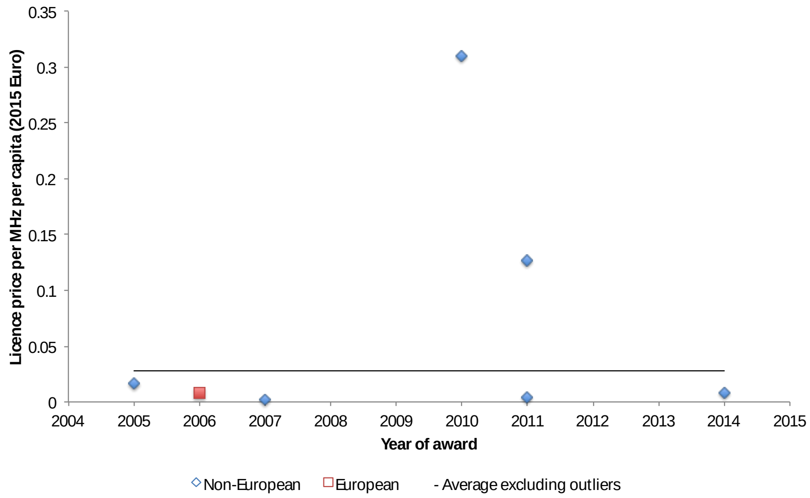
39. When looking only at awards from 2010, we have four observations, all of them from European countries. The sample average for this sub-sample is €0.0473, and falls to €0.0289 when excluding the Spanish auction.

2.3 Licence prices for unpaired 2.3GHz spectrum

40. The sample of licence prices in awards of unpaired 2.3GHz spectrum contains seven auctions, only one of which is for a European country (Norway 2006). Three of these took place

before 2010 and are therefore unlikely to reflect the value of spectrum for LTE use. Figure 4 below plots the average licence prices for the awards in the 2.3GHz sample over time.

Figure 4: Unpaired 2.3GHz licence prices



41. We identify the 2010 award in India as an outlier. Prices in Hong Kong are also relatively higher than the rest. However, Hong Kong is not identified as an outlier. The average of licence prices when excluding India as an outlier is €0.0279 (€0.0682 if we include India).

42. We only have one observation for Europe, which took place before 2010 (Norway 2006). The average licence price achieved in this auction is €0.0084.

43. Several operators who won spectrum in 2.3GHz auctions after 2010 deployed LTE networks in this band within two years of winning their licence, including NBN co (Australia), China Mobile (Hong Kong) and Bharti Airtel and Aircel (India) while Bitflux Communications (Nigeria) is planning to deploy an LTE network. Therefore, licence prices from these more recent spectrum auctions may already reflect the value of spectrum for LTE. If we focus only on these awards after 2010, India is not identified as an outlier. However, given the very few observations available and the relatively extreme licence price in India, we also consider the average when excluding this award. The average of licence prices for awards is €0.1125, which falls to €0.0468 if we exclude the Indian auction.

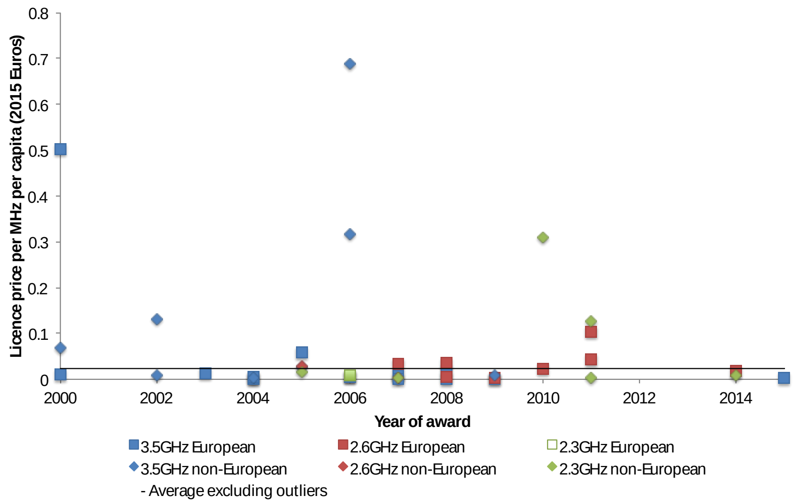
44. We can obtain another benchmark for the market price for 2.3GHz licences from the renewal fee paid by Optus

Australia, which has rolled out LTE in this band. Optus' 2.3GHz licence fee was set by ACMA on the basis of international auction benchmarks.[21] The renewal fee, adjusted to a common 15-year licence term in 2015 Euros, is €0.03 per MHz per capita. This fee would have been below Optus' valuation, and is aligned with the average licence prices obtained above.

2.4 Summary of average licence prices across bands

45. Figure 5 below plots the average licence prices for the awards in all three licences over time, colour coded according to frequency band.

Figure 5: Unpaired 3.6GHz, 2.6GHz and 2.3GHz licence prices



46. When looking at the full sample including all bands together we identify the following outliers:

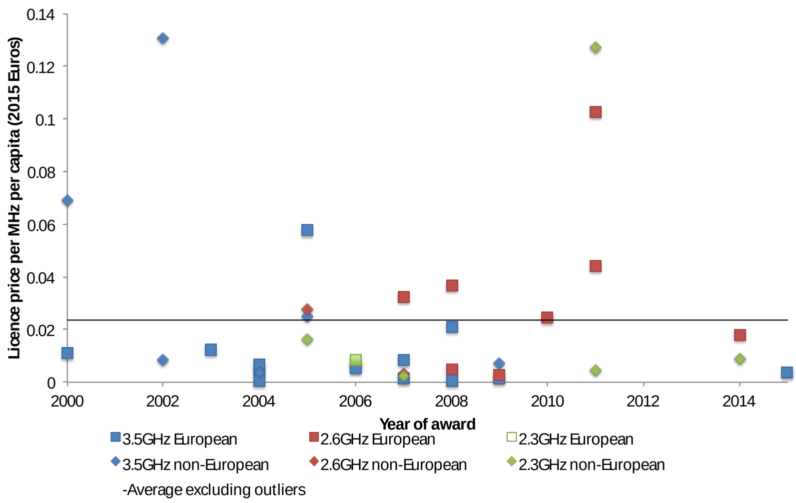
- Switzerland 2000 (3.6GHz);
- Bahrain 2006 (3.6GHz);
- Jordan 2006 (3.6GHz); and
- India 2010 (2.3GHz).

47. Figure 6 below plots the average licence prices for the awards remaining in the sample after excluding outliers.

[21] See https://www.communications.gov.au/what-we-do/spectrum/spectrum-licences

The overall picture suggests that the value of spectrum in these three bands is not dissimilar, in the sense that there is more variation within prices for each band than there is across the averages for individual band.

Figure 6: Unpaired 3.6GHz, 2.6GHz and 2.3GHz licence prices, after excluding outliers



48. When looking at the full sample across the three bands we identify the following outliers:

- Switzerland 2000;
- India 2010;
- Jordan 2006; and
- Bahrain 2006.

The average of licence prices across the three bands when excluding outliers is €0.0236 (€0.0667 if we include outliers).

49. When looking only at European awards across the three bands, we identify the following outliers:

- Switzerland 2000; and
- Spain 2011.

The average of licence prices across the three bands is €0.0142 (€0.0383 if we include outliers).

50. If we focus on awards from 2010, we do not identify any outliers. The average of licence prices across the three bands when looking only at awards from 2010 is €0.0715. We also identify no outliers if we restrict our attention to European awards from 2010. For this sub-sample, the average of licence prices is €0.0386.

51. Restricting the attention to awards from 2010 has a noticeable impact on the averages, which are materially

higher relative to when also including older awards. This effect appears to be driven by an increase in licence prices for 2.6GHz and 2.3GHz licences following LTE developments in these bands.

52. The averages for each band and across bands are summarised in Table 1.

Table 1: Average licence price per MHz per capita for the 3.6GHz, 2.6GHz and 2.3GHz bands

	Average licence price per MHz per capita *(sample size excluding outliers)*			
	All awards	*European awards*	*Awards from 2010*	*European awards from 2010*
All bands	€0.0236 (36)	€0.0142 (22)	€0.0715 (9)	€0.0386 (5)
3.6GHz band	€0.0158 (20)	€0.0064 (13)	€0.0038 (1)	€0.0038 (1)
2.6GHz band	€0.0297 (10)	€0.0333 (8)	€0.0473 (4)	€0.0473 (4)
2.3GHz band	€0.0279 (6)	NA	€0.1125 (4)	NA

3 Implications for the reserve price of a national licence

53. TDD-LTE use in the 3.6GHz band is still in its early stages, and many of the awards for which 3.6GHz licence prices are available predate any developments for using TDD-LTE use in this band. For this reason, licence prices in our sample may understate the current market price of this band. Nonetheless, subject that this proviso, these estimates are still useful in providing an indication of a lower bound for the likely market price for the 3.6GHz band.

54. The auction price of unpaired 2.6GHz spectrum and more recent 2.3GHz auctions may provide an indication of the market price of high frequency spectrum for TDD-LTE use. However, using the licence price of 2.6GHz licences as an estimate for the price of 3.6GHz licences might overstate the

value of 3.6GHz licences, as the value of these frequency bands is likely to be higher than that of 3.6GHz spectrum.

55. Setting reserve prices that are reflective of likely market price reduces the potential gains from strategically withholding competition in an auction, which helps to mitigate the risk of inefficient auction outcomes. At the same time we need to ensure that reserve prices are set acknowledging uncertainty about estimates of market price, so that the risk of demand being inefficiently choked off is controlled.

3.1 Market prices from benchmark auctions

56. Table 1 summarises the available benchmarks for licence prices. On the basis of these benchmarks:
    - benchmarks from the 2.6GHz and 2.3GHz bands suggest that setting a minimum price above €0.03 (per MHz per capita) would run some risk of choking off demand in the 3.6GHz band, as we expect the value of spectrum in the 2.6GHz and 2.3GHz bands to be above the value of spectrum in the 3.6GHz band; and
    - 3.6GHz benchmarks provide an overall average of around €0.016, but this may understate the value of spectrum.

57. When looking at the impact of LTE developments in the 2.3GHz and 2.6GHz band, licence prices appear to have increased after 2010. Therefore, it would seem to be reasonable to expect a similar effect for 3.6GHz licence prices. If the value of 3.6GHz spectrum were to roughly double as a result of LTE harmonisation, then a reasonable estimate for its market price might be around €0.03.

3.2 Existing FWALA charges

58. We now compare these possible minimum prices with the existing annual fees for a FWALA licensee are summarised in Table 2 below.

Table 2: FWALA fees

Channel size	*Annual fee*
Over 2×14MHz and up to 2x28MHz	€2,800
Up to 2×14MHz	€2,000
Up to 2×7MHz	€1,500

Source: ComReg Statutory Instrument No. 79 of 2003

59. The 3.6GHz band consists of channels from 10MHz to 50MHz (2x25MHz):[22]

- A licence for a 10MHz channel (hence less than 2×7MHz) would be subject to an annual licence fee of €1,500; therefore the annual fee per MHz applicable to a 10MHz channel would be €150.
- A licence for a 50MHz channel (2×25MHz) would be subject to an annual licence fee of €2,800; therefore the annual fee per MHz applicable to a 50MHz channel would be €56. This would appear to be the cheapest option given the fee structure.

Therefore, the applicable annual fees for an existing 3.6GHz FWALA licensee should range from around €56 per MHz to €150 per MHz. Notice that the fees actually paid by different licensees depend on their specific licence; however, the average licence fee paid across all licensees would fall within this range. We also note the majority of licences (172 out of the 198 current FWALA licences) are for over 2x14MHz, and therefore would have an applicable fee between €56 per MHz (for a 50MHz licence) to somewhere under €100 per MHz (for smaller licences still over 28MHz); therefore, the average fee per MHz paid across all licensees is likely to be towards the lower half of the €56 to €150 range.

[22] ComReg, 20012, 06/17R7, Revised Guidelines to Applicants for FWALA Licences: http://www.comreg.ie/_fileupload/publications/ComReg0617R7.pdf

60. The coverage of FWALA licences is defined by a radius of 20km. Therefore, a FWALA licence covers a total area of 1,257km^2. The total area for the Republic of Ireland is slightly over 70,000Km^2, about 56 times greater than the coverage area of a FWALA licence. In practice, given that FWALA licences have a coverage area defined as a circle, obtaining nationwide coverage for the whole country on the basis of FWALA licences would require a greater number of partially overlapping licences.[23] Therefore, one might need at least 67 FWALA licences to achieve nationwide coverage. Using this minimum bound, we approximate the minimum annual licence fee that an operator would need to pay to achieve nationwide coverage on the basis of FWALA licences as 67 times the cost of an individual FWALA licence. Therefore, such a minimum annual licence fee for nationwide coverage could range between around €3,800 per MHz and €10,100 per MHz, depending on its bandwidth.

61. Assuming constant annual licence fees over 15 years, the NPV of annual fees for achieving national coverage on the basis of FWALA licences for a period of 15 years would range between around €34,000 and €90,000 per MHz. Given the country population,[24] this corresponds to a licence price per MHz per capita ranging between €0.007 and €0.020. Notice that this does not provide an indication of a likely competitive price for the spectrum (as the fees for FWALA licences were set administratively), but simply an indication that there is demand for these licences at these prices.

62. The value to an operator using this spectrum for LTE is likely to exceed the existing amounts paid in annual fees. The Imagine Group, which is using the spectrum to provide near

[23] Covering a large area with many small circles optimally (keeping the overlap to a minimum while still not leaving any gaps) will result in the covering circles having a total area of about $(3\sqrt{3})/(2\pi)$ times the area covered (in the limiting case as the covering circles become small). Therefore, due to overlaps, the total area of covering circles will be about 21% greater than the area being covered. (See Kershner, R. "The Number of Circles Covering a Set." Amer. J. Math. 61, 665-671, 1939).

[24] We use a population of 4,588,252, as reported in the 2011 Census (the latest official figures available) provided by the Central Statistics Office Ireland (CSO).

nationwide services have indicated that they are planning to roll out a TDD-LTE network.

3.3 Minimum price for a national licence

63. There is a considerable degree of uncertainty about the likely market price of the 3.6GHz band. Nevertheless, we can be reasonably certain that setting the minimum price at the average licence price from international benchmarks for awards of 3.6GHz spectrum (€0.016 per MHz per capita) is unlikely to choke off demand. This price would also fall within the current range of FWALA licensing fees obtained above (see paragraph 61).

64. On the basis of the benchmarks obtained from unpaired 2.3GHz and 2.6GHz spectrum, we consider that the competitive price could be around €0.03 per MHz per capita. However, at this level we could not rule out the possibility that demand might be choked off. Therefore, we would recommend setting the minimum price below this level.

65. **We propose that minimum prices should be set in the range €0.015 to €0.025 per MHz per capita**. At the lower endpoint of €0.015 (just below the average licence price of international benchmarks for awards of 3.6GHz spectrum) there is less risk of choking off demand for spectrum, which would be aligned with ComReg's objectives for this award. Setting higher minimum prices, towards €0.025, might involve a marginally greater risk of choking off demand, thought this might have the advantage of discouraging collusive bidding and gaming behaviour in the auction.

66. Given the Irish population,[25] a minimum price of €0.015 per MHz per capita would imply a minimum price of just under €350,000 for a 5MHz block nationally; while a minimum price of €0.25 per MHz per capita would imply a minimum price of just under €575,000 for a 5MHz block nationally.

[25] Ibid.

3.4 Up-front payment vs. annual fees

67. Given a particular minimum price, we have a choice about whether this is recovered through a minimum up-front price (i.e. a reserve price in the auction) or on-going annual fees. The previous Multi Band Spectrum Award (MBSA) split the recovery of the minimum price 50:50 between the up-front price and annual fees.

68. Overall, the considerations affecting this split are similar for this award as for the MBSA:[26]

- setting higher annual fees may encourage efficient use of spectrum by encourage licensees not making use of spectrum to return it to ComReg. Arguably, as spectrum trading is possible, the current licensee will face an opportunity cost if there is a more valuable use of that spectrum. However, arguably paying an annual licence might encourage efficient use more strongly on account of it being an actual cost, rather than opportunity cost which only reflects a notional foregone opportunity;
- deferring part of the overall cost of licence by increasing annual fees (which should create a corresponding reduction in the auction price provided that those future annual fees are anticipated by bidders and factored into the valuation of spectrum) may encourage weaker and less well-resourced bidders, potentially increasing participation and strengthening competition within the auction;

[26] DotEcon for ComReg, 2012, 12/24, Issues relating to the award of spectrum in multiple bands in Ireland: http://www.comreg.ie/radio_spectrum/consultations_and_associated_documents.713.1096.html#sthash.Sftl9QXm.dpuf

and

DotEcon for ComReg, 2011, 11/58, Issues relating to the award of spectrum in multiple bands in Ireland: http://www.comreg.ie/radio_spectrum/consultations_and_associated_documents.713.1096.html#sthash.Sftl9QXm.dpuf

- conversely, if annual fees are set too high, this could increase the risk of default from winners and could encourage gaming in the auction, as the immediate up-front payment is modest relative to deferred costs.

69. Broadly similar considerations apply here. Whilst it is the case the framework for spectrum transfer is now longer established than at the time of the MBSA,[27] there is still some value in ensuring that spectrum fees are sufficient to encourage return of spectrum where it is clearly not being efficiently used. It is also likely that this award would attract a range of bidders, not just well-resourced MNOs, and participation could be encouraged by deferring some the cost of a licence through annual fees. Given this, we see no rationale for reducing the relative importance of annual fees within the overall minimum price for this award. Accordingly, we suggest maintaining a 50:50 split of the minimum price between an up-front price and annual fees.

70. Using a 50:50 split for the minimum price between an up-front payment and annual fees we obtain the minimum up-front payment and annual fees shown in Table 3 below. We assume that annual fees would be updated year-on-year to reflect inflation. To calculate initial annual fees, we use a discount factor of 8.63% (as for calculating licence prices in Section 2).[28] We show cases of 0% inflation and 1.5% inflation[29] over the life of the licence. Annual fees are rounded to the nearest Euro, whilst minimum prices and minimum up-front payments to the nearest thousand Euros.

Table 3: Upfront payments and annual fees for a 5 MHz national licence

Price per MHz per capita (€)	*Minimum price for 5MHz (€)*	*Minimum up-front payment (€)*	*Annual fee (€) for first year at 0%*

[27] Statutory Instruments, SI no.34 of 2014, Wireless Telegraphy (Transfer of Spectrum Rights of Use) Regulations 2014: http://www.comreg.ie/_fileupload/publications/ComRegSI34of2014.pdf

[28] Subsequent annual fees will increase in accordance to CPI.

[29] This is the inflation rate assumed for estimating the nominal, pre-tax WACC in ComReg, 2014, Cost of Capital, Document 14/136 and D15/14: http://www.comreg.ie/_fileupload/publications/ComReg14136.pdf.

			inflation (at 1.5% pa inflation)
0.015	344,000	172,000	19,216 (17,773)
0.025	574,000	287,000	32,064 (29,656)

4 Regionalisation of reserve prices

71. We now turn to the question of how to calculate minimum prices for regional licences. ComReg is currently minded to use a regional structure and is considering two different options:

- **Option 1** consists of five regions, namely:
  - *Borders (including Counties Donegal, Leitrim, Cavan, Monaghan and Louth)*
  - *Connaught less county Leitrim and the CSO boundary for Galway City and Suburbs*
  - *Leinster less counties Louth and Dublin*
  - *Munster less the CSO boundary for Limerick City and Suburbs and Cork City and Suburbs*
  - *Dublin County*

- **Option 2** consists of nine regions, namely:
  - *North West (Counties Donegal, Leitrim, Sligo, Mayo, Roscommon and Galway excluding the Galway CSO City and Suburb region)*
  - *North East (Counties Cavan, Monaghan, Louth, Longford, Westmeath, Meath, Offaly, Laois, Kildare, Wicklow and Dublin excluding Dublin CSO City and Suburb region).*
  - *South East (Counties Kilkenny, Carlow, Wexford, the legal boundary of South Tipperary and Waterford, excluding Waterford City and Suburbs)*
  - *South West (Counties, Clare, Limerick excluding Limerick CSO City and*

Suburbs, Kerry, Cork excluding Cork CSO city and Suburbs, and the legal boundary for North Tipperary)

- *Dublin CSO boundary for City and Suburbs*
- *Cork CSO boundary for City and Suburbs*
- *Limerick CSO boundary for City and Suburbs*
- *Galway CSO boundary for City and Suburbs*
- *Waterford CSO boundary for City and Suburbs*

4.1 Regional population under both options

72. In order to calculate minimum prices from our recommended range of minimum prices per MHz per capita we need population figures for each region. We use national population figures from the 2011 Census (the latest official figures available) provided by the Central Statistics Office Ireland (CSO). Table 4 shows populations for the five regions considered for Option 1.

Table 4: Population for the regions under Option 1

Region	*Population*	*Proportion of total population*
Borders	449,498	10%
Connaught (less County Leitrim)	510,749	11%
Leinster (less Counties Dublin and Louth)	1,108,848	24%
Munster	1,246,088	27%
Dublin County	1,273,069	28%

73. The populations for the nine proposed regions under Option 2 are given in Table 5.

Table 5: Population for the regions under Option 2

Region	*Population*	*Proportion of total population*
North East	1,232,502	27%
North West	626,906	14%
South East	446,059	10%
South West	753,825	16%
Dublin CSO city and suburb	1,110,627	24%
Galway CSO city and suburb	76,778	2%
Limerick CSO city and suburb	91,454	2%
Cork CSO city and suburb	198,582	4%
Waterford CSO city and suburb	51,519	1%

4.2 Differences in the value per capita across regions

74. We expect urban regions to command a higher spectrum price than other regions. Therefore, we propose to use an uplift to the price for licences in urban regions relative to non-urban areas. This is a common approach when licences are offered on a regional basis. In Annex B, we present some evidence on premia for urban areas achieved in auctions of regional licences.

75. There are two reasons to expect higher value for the spectrum in urban regions:

- first, urban areas often have a population inflow above the residential population;
- second, population density is higher in urban areas, which is likely to reduce the unit costs of providing capacity in these regions.

Adjusting for population flows

76. Option 1 does not separate urban and non-urban areas into different regions. Therefore, we do not expect flows between urban and non-urban areas to involve material flows across regions, except between Dublin County and neighbouring regions. However, as explained below, we already propose to treat Dublin County differently on the grounds of its higher population density. Therefore, we do not propose to make adjustments to reflect population flows under Option 1.

77. Conversely, the effect of population flows between regions are likely to be material under Option 2, under which urban centres constitute separate regions. We model this effect by adjusting population figures in each region using data on commuting between regions. This requires applying an upward adjustment to urban regions and a downward adjustment to non-urban regions.

78. The urban regions considered under Option 2 are Dublin, Galway, Limerick, Cork and Waterford.[30] Table 6 shows the net inflow of commuters for each region under Option 2, along with adjusted population figures (calculated as the population plus net inflow for each region)**Error! Reference source not found.**. The five urban regions command a large incoming population for work (ranging from 7% to 21% of the residential population). Conversely, non-urban regions have a net outflow of commuters, especially the North East (from which Dublin is carved out) and the South West (from which Cork is carved out).

[30] All urban region include the corresponding city and suburb.

Table 6: Population inflows for urban regions

Region	*Residential population (proportion over total population)*	*Net inflow of commuters (percentage change over residential population)*	*Population, adjusted for uplift (proportion over total population)*
Dublin CSO city and suburb	1,110,627 (24%)	81,904 (7%)	1,192,531 (26%)
Galway CSO city and suburb	76,778 (2%)	15,845 (21%)	92,623 (2%)
Limerick CSO city and suburb	91,454 (2%)	13,681 (15%)	105,135 (2%)
Cork CSO city and suburb	198,582 (4%)	26,504 (13%)	225,086 (5%)
Waterford CSO city and suburb	51,519 (1%)	7,640 (15%)	59,159 (1%)
North East	1,232,502 (27%)	-73,044 (-6%)	1,159,458 (25%)
North West	626,906 (14%)	-18,138 (-3%)	608,768 (13%)
South East	446,059 (10%)	-13,235 (-3%)	432,824 (9%)
South West	753,825 (16%)	-42,039 (-6%)	711,786 (16%)

Adjusting for differences in population density

79. Table 7 and Table 8 show population and population density figures for each region under Option 1 and Option 2 respectively. Under Option 1, Dublin County can be clearly identified as having much higher density than all other regions. Under Option 2, all urban regions have much

higher density than non-urban regions, with Dublin city and suburb being notably more dense than the rest.

Table 7: Population and population density for the regions under Option 1

Region	*Population*	*Population density (population per km²)*
Borders	449,498	44
Connaught (less County Leitrim)	510,749	49
Leinster (less Counties Dublin and Louth)	1,108,848	62
Munster	1,246,088	52
Dublin County	1,273,069	1,378

Table 8: Population and population density for the regions under Option 2

Region	*Population*	*Population density (population per km²)*
Dublin CSO city and suburb	1,110,627	3,498
Galway CSO city and suburb	76,778	1,438
Limerick CSO city and suburb	91,454	1,610
Cork CSO city and suburb	198,582	1,206
Waterford CSO city and suburb	51,519	1,163

North East	1,232,502	72
North West	626,906	38
South East	446,059	48
South West	753,825	38

80. We do not have a simple means to relate population density to unit costs and spectrum valuations (in fact, this relationship is likely to be different in nature for different types of operators). Instead, we simply model this effect by using a slightly higher price per MHz per capita for calculating the minimum price for these regions (albeit within the range proposed in Section 3) when calculating the minimum price for urban regions. Specifically, we consider that it would be safe to calculate minimum prices for urban areas using the highest value in the proposed range (€0.025 per MHz per capita), as this is still at a level that is unlikely to choke off demand; conversely, we suggest using a lower price per MHz per capita to calculate the minimum prices for the remaining regions. Given the higher population density for Dublin city and suburb under Option 2, ComReg could contemplate using an even higher price per MHz per capita for this region if it thinks that further differentiation between urban regions is needed.

4.3 Proposed minimum prices for regional licences

81. We start by calculating our recommended minimum prices under Option 2, which has a clear separation between urban and non-urban regions. We calculate these using the adjusted population figures (to reflect commuting flows) for each region. We use a price of €0.015 per MHz per capita for non-urban regions and a price of €0.025 per MHz per capita for urban regions. This yields the proposed minimum prices per region, with the corresponding reserve prices and annual fees, shown in Table 9. Using these minimum prices, a national licence for a 5MHz block would have a total price of €427,000, corresponding to an average price per MHz per capita of €0.0186.

Table 9: Proposed minimum prices, reserve prices and annual fees under Option 2

Region	*Adjusted population*	*Minimum price per MHz per capita (€)*	*Minimum price for 5MHz (€)*	*Minimum up-front payment for 5MHz (€)*	*Annual fee for 5MHz (€) for the first year at 0% inflation (at 1.5% p.a. inflation)*
North East	1,159,458	0.015	87,000	43,500	4,860 (4,495)
North West	608,768	0.015	46,000	23,000	2,570 (2,377)
South East	432,824	0.015	32,000	16,000	1,788 (1,653)
South West	711,786	0.015	53,000	26,500	2,961 (2,738)
Dublin CSO city and suburb	1,192,531	0.025	149,000	74,500	8,323 (7,698)
Galway CSO city and suburb	92,623	0.025	12,000	6,000	670 (620)
Limerick CSO city and suburb	105,135	0.025	13,000	6,500	726 (672)
Cork CSO city and suburb	225,086	0.025	28,000	14,000	1,564 (1,447)
Waterford CSO city and suburb	59,159	0.025	7,000	3,500	391 (362)
All regions	***4,588,252***	***0.0186***	***427,000***	***213,500***	***23,853 (22,062)***

82. Differences across regions are less pronounced under Option 1. However, Dublin County still has clearly higher population density that other regions, more aligned to the population density of urban regions under Option 2 than to the population density of the remaining regions under Option 1. Therefore, we propose to calculate minimum fees using the same price per MHz per capita as for urban regions under Option 2 (€0.025). We calculate the minimum prices for the remaining regions using a common, averaged price per MHz per capita. Specifically, we use the average price per MHz per capita that yields the same total cost for a 5MHz block across all regions as under Option 2. This average price per MHz per capita for the remaining regions is €0.0162. This yields the proposed minimum prices per region, with their corresponding reserve prices and annual fees, shown in Table 10.

Table 10: Proposed minimum prices, reserve prices and annual fees under Option 1

Region	*Population*	*Minimum price per MHz per capita (€)*	*Minimum price of 5MHz (€)*	*Minimum up-front payment for 5MHz (€)*	*Annual fee for 5MHz (€) for the first year at 0% inflation (at 1.5% p.a. inflation)*
Borders	449,498	0.0162	36,000	18,000	2011 (1,860)
Connaught (less Leitrim)	510,749	0.0162	41,000	20,500	2,290 (2,118)
Leinster (less Dublin and Louth)	1,108,848	0.0162	90,000	45,000	5,027 (4,650)
Munster	1,246,088	0.0162	101,000	50,500	5,642 (5,218)

Dublin County	1,273,069	0.0250	159,000	79,500	8,882 (8,215)
All regions	***4,588,252***	***0.0186***	***427,000***	***213,500***	***23,852[31] (22,061)***

[31] This is the sum across all regions of rounded values shown in the table, which is slightly different to that obtained for Option 2 due to rounding.

Annex A: 3.6GHz, 2.6GHz and 2.3GHz benchmarks

3.6GHz

Country	Year	Award	Average licence price per MHz per capita
Australia	2000	3.4GHz Auction	€ 0.0693
Austria	2004	WLL 2004 Auction	€ 0.0005
Austria	2008	3500 MHz (BWA)	€ 0.0007
Bahrain	2006	NFWS auction	€ 0.3163
Bulgaria	2005	Broadband Wireless Auction	€ 0.0578
Canada	2004	2300 & 3500 MHz Auction	€ 0.0038
Canada	2005	Residual 2300 & 3500 MHz Auction	€ 0.0251
Canada	2009	Residual Spectrum Licences in the 2300MHz and 3500MHz bands	€ 0.0073
Denmark	2004	FWA Auction	€ 0.0044
Denmark	2007	National FWA	€ 0.0083
Germany	2006	3.4-3.6 GHz	€ 0.0062
Greece	2000	3.5 GHz and 26 GHz FWA	€ 0.0111
Italy	2008	WiMax auction	€ 0.0212
Jordan	2006	Fixed Broadband Wireless Access	€ 0.6875
New Zealand	2002	Auction 5 WLL and LMP and Cellular	€ 0.0082
Nigeria	2002	FWA 3.5GHz – (five consecutive auctions for	€ 0.0610

		regional licences, averaged in to a single award in our sample)	
Norway	2004	3.5GHz Auction	€ 0.0068
Slovakia	2015	3.7GHz auction	€ 0.0038
Slovenia	2006	3.4-3.6GHz	€ 0.0054
Sweden	2007	3.6-3.8GHz	€ 0.0013
Sweden	2009	3.7GHz Auction	€ 0.0014
Switzerland	2000	WLL 3.4 GHz & 26 GHz	€ 0.5026
United Kingdom	2003	PFWA 3.4 GHz Auction	€ 0.0123

2.6GHz

Country	***Year***	***Award***	***Average licence price per MHz per capita***
Finland	2009	2.6GHz	€ 0.0027
Germany	2010	800MHz, 1800MHz, 2.1GHz and 2.6GHz bands	€ 0.0244
Greece	2014	800MHz and 2.6GHz	€ 0.0182
Italy	2011	4G Auction	€ 0.0441
New Zealand	2007	2.3 and 2.5 GHz auction	€ 0.0030
Norway	2007	2.6 GHz	€ 0.0323
Norway	2008	Residual 2.6GHz	€ 0.0051
Singapore	2005	Wireless Broadband Auction	€ 0.0278
Spain	2011	Second 4G auction	€ 0.1026

Sweden	2008	2.6GHz	€ 0.0369

2.3GHz

Country	***Year***	***Award***	***Average licence price per MHz per capita***
Australia[32]	2011	Residual 2.3GHz auction	€ 0.0044
Hong Kong	2011	2.3GHz Auction	€ 0.1271
India	2010	BWA Auction	€ 0.3098
New Zealand	2007	2.3 and 3.5GHz Auction	€ 0.0024
Nigeria	2014	2.3GHz Auction	€ 0.0088
Norway	2006	2.3GHz Auction	€ 0.0084
Singapore	2005	Wireless Broadband Auction	€ 0.0164

[32] We do not have population data available for all lots sold in this auction. The estimates are only based on the lots for which we have this data.

Annex B: Approach to urban premia in other auctions

83. In terms of setting reserve prices for regional licences, international practice varies on whether to differ reserve price per MHz per capita across different regions:
    - in the Norwegian 3.5GHz auction in 2004, reserve prices were more or less constant across different regions;
    - in the Spanish auction in 2011, regional unpaired 2.6GHz lot reserve prices per MHz per capita did vary across different regions, though these reserve price did not vary according to population or population density of the regions, it is unclear how relative reserve prices across the regions were set;
    - the 3.5GHz lots in the Canadian 2.3GHz and 3.5GHz auction in 2004 had two "tiers" of reserve prices, with regions with population of 300,000 or more having a reserve price per MHz per capita that was roughly three and a half times that of regions with populations of under than 300,000; and finally
    - the Australian 3.4GHz auction in 2000 did set higher reserve prices per MHz per capita for cities such as Sydney, Melbourne and Brisbane. Less populous cities and the remaining regions (five were defined, dividing the remaining land area but cutting out the cities) commanded lower reserve prices per MHz per capita. The reserve price per MHz per capita for the three 'top tier' cities were about 2-2.5 times that of the other cities and regions.

84. However, auction outcomes do typically demonstrate premia for more urban areas. Norway (2004), Australia (2000) and Canada (2004 and 2005) auctioned off regional 3.4GHz/3.5GHz licences. Licence prices from these auctions are presented in the figures below and we have classified the data points in each auction into three tiers based on population covered.

85. Unfortunately the available auction data here provides limited clarity on the relationship of spectrum value across regions of different population. In particular, in Norway and Australia, there was a great variation in prices even within

regions and the two Canadian auctions were not particularly competitive, with many licences allocated at reserve prices. Therefore final relative prices reflected relative reserve prices (that were set in two tiers). Therefore the analysis below is subjected to considerable uncertainty. Nevertheless, these auction results paint a reasonable consistent picture of relative prices between different tiers of regions demonstrating premia for urban area.

86. In Norway, the price of the Oslo licence, the most populous city in Norway was relatively low compared to the rest of the sample. Excluding Oslo presents a clearer structure of relative prices across regions with different populations. Figure 7 below summaries the average prices in each tier for these auctions and presents the relative prices across tiers. These auctions suggests that the spectrum value in top tier cities may be 1 to 2 times that of middle tier cities and against bottom tier regions, 3 to 5 times more.

Figure 7: Norway 3.5GHz licence prices

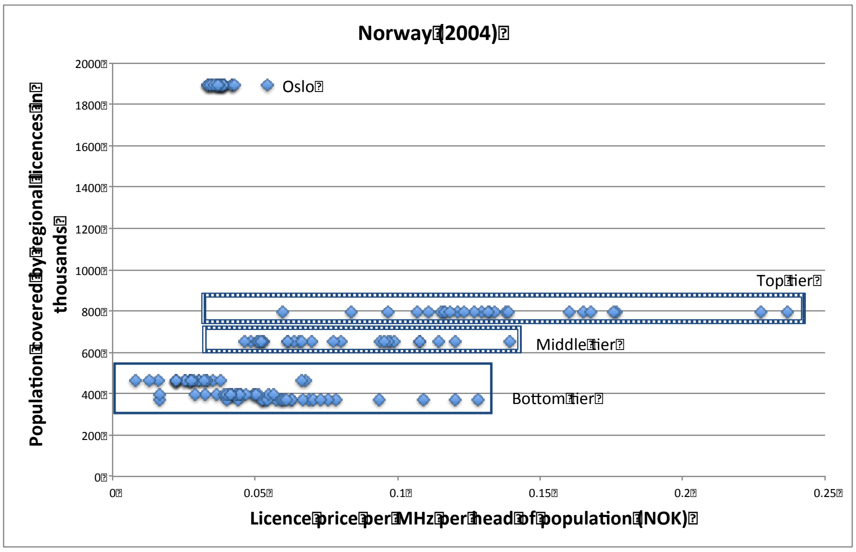


Figure 8: Australia 3.4GHz licence prices

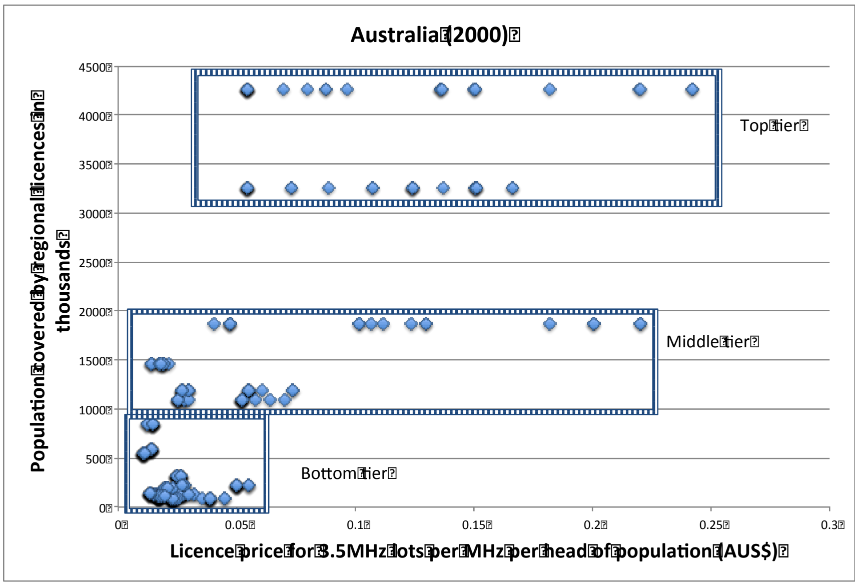


Figure 9: Canada 3.5GHz licence prices

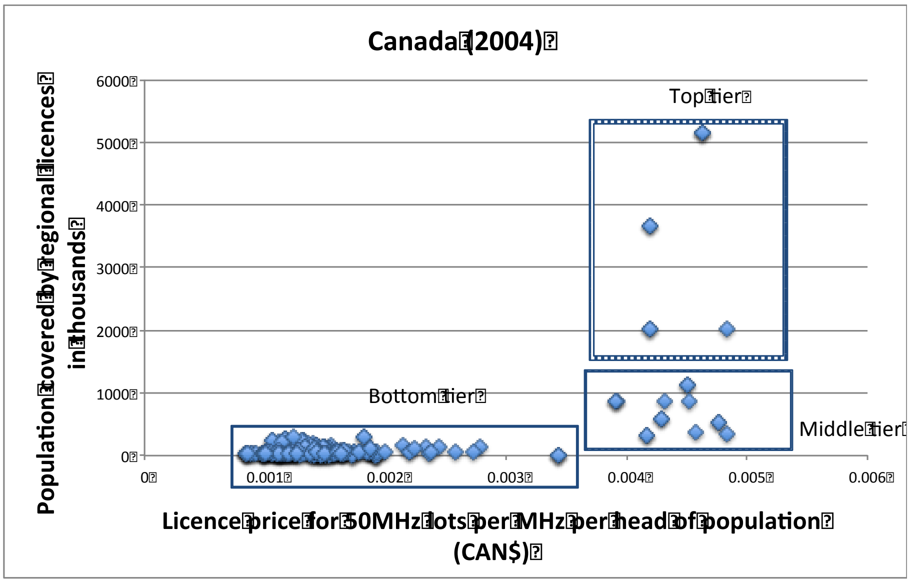


Table 11: Relative prices between tiers in Norway, Australia and Canadian 3.4/3.5GHz auctions

	Norway (excludes/includes Oslo)	*Australia*	*Canada*
Top tier population	Above 700k	Above 3m	Above 2m

Middle tier population	500k-700k	1m-3m	300k-2m
Bottom tier population	Less than 500k	Less than 1m	Less than 300k
Average prices in top tier over middle tier	1.7/1.1	2.1	1.0
Average prices in top tier over bottom tier	2.9/1.9	5.1	3.1