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Vorsprung durch Econometrics: what drives spectrum value?

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Radiospectrum is a vital input in the provision of mobile services. Additional spectrum enhances the coverage and capacity of mobile networks, enabling them to meet the ever-growing demand for mobile data. Yet attaching an appropriate value to spectrum is a perennial problem for regulators and operators – regulators must decide how to allocate spectrum and set reserve prices for spectrum auctions, while operators must decide what the spectrum is worth to them (and so whether to bid at auction). This Insight explores the role of econometrics in spectrum valuation, and discusses some key findings from Plum's econometric modelling work.

What is econometrics?

Econometric analysis is a statistical toolkit that allows us estimate the relationships between a dependent variable and one or more explanatory variables (factors which may explain the variance in the dependent variable).

In the context of spectrum valuation, the dependent variable is spectrum value (usually the value realised at a spectrum auction, on a per MHz basis), while the explanatory variables will include economic and geographic factors and spectrum characteristics. The econometric model will estimate the relationships between spectrum value and the explanatory factors, and these relationships can be used to predict spectrum value in future auctions.

Why use econometrics?

Econometrics offers certain advantages over a simple benchmarking of spectrum auctions in similar countries. First, unlike benchmarking, the set of comparator countries does not need to be specifically chosen, so there is no need to debate what constitutes an appropriate comparator (with econometrics, the more data the better).

Second, econometrics can work better than benchmarking for countries without close comparators. This is because its predictions are made based on an estimated relationship between an explanatory variable (say, GDP) and spectrum value. For example, econometrics could predict spectrum value in a country with a uniquely high GDP using the estimated relationship between GDP and spectrum value. Benchmarking is likely to be less useful in this situation.

Finally, econometrics provides unique insight into which factors drive spectrum value, and their relative importance. Some of these drivers are explored later in the paper.

Where econometrics has been used

Regulators, operators, academics and consultants have all used econometrics to value spectrum. Early work in the field was conducted by Hazlett (2004), who ran an econometric analysis of 42 spectrum awards across 27 countries, and identified various drivers of spectrum value.[1] Ford (2008) used econometric analysis to evaluate the 'unencumbered' value of AWS spectrum in the US to explore the impact of proposed conditions on those licences.[2]

Similar work was carried out for 23 3G spectrum awards (covering 83 individual licences) by Bohlin et al (2010), which found significant impacts from various groupings of explanatory variables: national economic and mobile market conditions, spectrum attributes and network obligations.[3]

More recently, Wallsten (2013) analysed data from 80 auctions conducted by the FCC since 1996 (covering 69,000 spectrum licences)[4] This analysis identifies some key drivers of spectrum value – for example, paired spectrum is found to be about twice as valuable as unpaired – though it is not specifically focussed on mobile broadband.

Econometric modelling has been undertaken by The Telecom Regulatory Authority of India as an input to set a

[1] Thomas Hazlett (2004), "Property Rights and Wireless Licence Values", *AEI-Brookings Joint Center Working Paper No. 04-08* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=519602
[2] George S. Ford (2008), "Calculating the Value of Unencumbered AWS-III Spectrum", *Perspective No.08-01* http://www.phoenix-center.org/pcper.html#2008
[3] Erik Bohlin Gary Madden and Aaron Morey (2010), "An Econometric Analysis of 3G Auction Spectrum Results", *Robert Schuman Centre RSCAS 2010/55* http://cadmus.eui.eu/bitstream/handle/1814/14237/RSCAS_2010_55.pdf?sequence=1
[4] Scott Wallsten (2013), "Is There Really a Spectrum Crisis? Quantifying the Factors AffectingSpectrum License Value", *Technology Policy Institute* http://ssrn.com/abstract=2206466

reserve price for forthcoming spectrum auctions.[5] The TRAI's econometric modelling was discussed and expanded upon in a response by Plum[6]. The Commission for Communications Regulation in Ireland (ComReg) have also made use of econometrics in five sets of spectrum valuation analyses of the 800 MHz, 900 MHz and 1800 MHz spectrum bands.[7] In the US, The CTIA and the CEA used econometrics to estimate the benefits of an additional 120 MHz of mobile broadband spectrum.[8]

Plum's econometric model

The model is based on 247 observed mobile spectrum auctions over the past 10 years, based on data from Plum's spectrum auction database. The explanatory variables used in the model are described in the table below.

Variable	Description
Constant	Constant term (included as standard in regression analysis)
Bandwidth sold	The quantity of spectrum being auctioned. More contiguous bandwidth is expected to be more valuable.
Licence duration	The length of the licence
GDP per capita	A measure of the country's wealth
TDD spectrum	Dummy variable[9] for time-duplexed spectrum
Region	Dummy variables for regions
Year	Dummy variables for years
Bandwidth per operator	Bandwidth sold per operator (can indicate auction competitiveness)
>3 GHz spectrum	Dummy variable to indicate spectrum above 3 GHz
Population density	The country's population divided by its land area
Spectrum stock	The quantity of spectrum already released for mobile broadband
Cell radius	The maximum cell radius a frequency can support
Supported devices	The number of distinct mobile devices supported by a spectrum band
Auction format	Dummy variables for the auction's format
Mobile market HHI	The Herfindahl-Hirschman Index (HHI) measures market concentration

[5] TRAI (2013), *Consultation Paper No. 06/2013,* Para 3.44-3.53
http://www.trai.gov.in/Content/ConDis/689_1.aspx
[6] Plum (2013), "The value of 1800 MHz spectrum in India",
http://www.plumconsulting.co.uk/pdfs/Plum_Aug_2013_-_Value_of_1800MHz_in_India.pdf
[7] Dotecon for ComReg (2012), *ComReg document 12/23*.
http://www.comreg.ie/_fileupload/publications/ComReg1223.pdf
[8] CTIA and CEA (2011), "Broadcast Spectrum Incentive Auctions White Paper"
http://files.ctia.org/pdf/CTIA_CEA_TV_Spectrum_Whitepaper.pdf
[9] A dummy variable is a binary 1/0 variable – in this case it takes the value of 1 if the spectrum auctioned is TDD spectrum, and 0 if it is not.

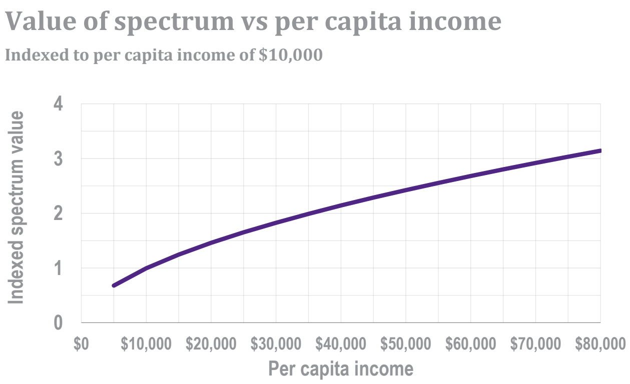
Plum's model is based on a log specification. There are several advantages to this: taking logs can help eliminate or mitigate the statistical problems of heteroscedasticity[10] and skewness[11] that are common with strictly positive variables (such as auction results). Taking logs also narrows the range of a variable, making the model less sensitive to outlying observations.

What are the key drivers of spectrum value?

This Insight explores the impact of some of the model's variables on the value of spectrum below. All findings discussed in this Insight are derived from Plum's econometric model, and were found to be statistically significant at the 5% significance level.[12]

GDP: the wealth of telecommunications

Generally speaking, the richer a country is per capita, the more valuable its spectrum. Wealthier populations are more likely to have a mobile data contract and to have a higher willingness to pay for mobile data. Spectrum thus becomes more valuable to operators in these markets, as it offers a way of meeting that data demand.



Source: Plum Consulting

However, this is subject to diminishing returns – even the richest of people can only use so much data. The model predicts that spectrum will be 47% more valuable in country with a per capita income of $20,000 than one with an income of $10,000. However, raising income a further $10,000 – from $20,000 to $30,000 – will only add an incremental 25% to spectrum value.

[10] Heteroscedasticity occurs when the variance of the error term – the difference between the observed result and the model prediction – differs depending on the value of the explanatory variables. This can affect the standard errors of the model coefficients.
[11] Skewness refers to asymmetry in a statistical distribution. If a distribution is skewed, test of statistical significance can give misleading results.
[12] All findings discussed in this Insight are statistically significant at the 5% significance level. This means that there is a less than 5% likelihood is of obtaining the model's estimate, on the assumption that the variable really does have no explanatory power (a Type I error).

Population density: the streaming millions

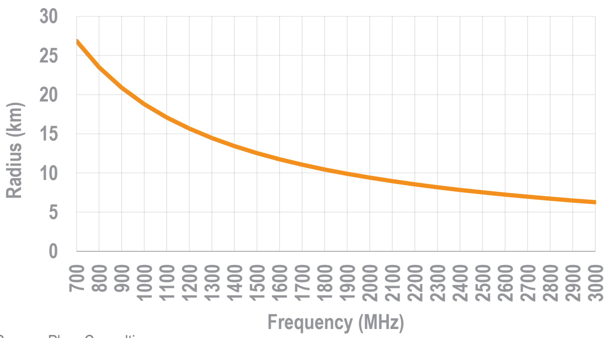
The model suggests that more densely populated countries have more valuable spectrum. Denser countries are more likely to have lots of capacity-constrained cells, making additional spectrum an attractive means of expanding cell capacity. Doubling a country's population density is predicted to add 12.5% to spectrum value.

However, this effect also exhibits diminishing returns – increasing population density only has a marginal effect on spectrum value if the density is already high. This may be because at certain density, other methods of meeting data demand – such as small cells – start to become viable.

Spectrum characteristics – we've got it covered

In general, lower frequency spectrum can be used to run a network with a larger average cell radius. so fewer cells are needed to provide the same level of coverage. In consequence, mobile operators tend to value lower frequency spectrum (such as the 800 MHz band) more highly. The econometric model confirms the link between the cell radius and spectrum value – the lower the frequency, the larger the cell radius and so the higher the spectrum value.

Maximum cell radii, by frequency band



Source: Plum Consulting

However, this is only part of the story. Not every frequency band is supported by every mobile device, making 'common' mobile bands – such as the 1800 MHz band – more valuable. The model predicts that a band's value increases by 5% for every hundred different device models supported.[13]

Moreover, once coverage layer is achieved with lower frequency spectrum, increasing capacity becomes the main motivator for buying spectrum. The premium commanded by sub-1 GHz spectrum is therefore likely to shrink after the first tranche is released.

Finally, the model predicts that, all else being equal, time division duplexed (TDD) spectrum is 57% less valuable than frequency division duplexed (FDD) spectrum, as it is still a developing technology.

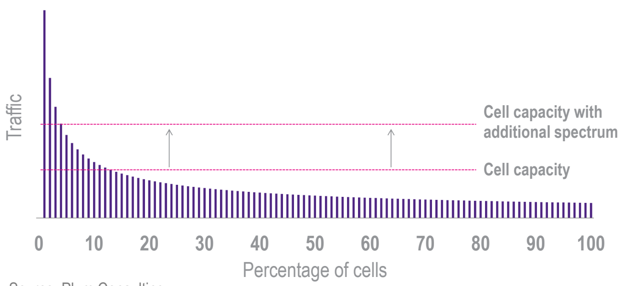
Spectrum stock: too much of a good thing?

The model supports the hypothesis (advanced in Plum's iterated cost model[14]) that – once a coverage layer is achieved – spectrum is subject to diminishing returns: the more one has, the less attractive additional spectrum becomes.

This is because data traffic is unevenly distributed across cells – a typical distribution, in which 20% of cells carry 50% of traffic, is shown below.[15] Additional spectrum increases the capability of each cell to carry traffic. However, each incremental tranche of capacity spectrum will benefit fewer and fewer cells (at least in the short term). For very congested cells, small cells might prove a more cost-effective method of expanding capacity than acquiring more spectrum.

An example mobile network traffic distribution

20% of cells carry 50% of traffic



Source: Plum Consulting

It is also likely that consumers' willingness to pay for additional data decreases with the amount of data consumed.[16] This may lower the expected benefits of expanding the capacity of mobile networks.

The model suggests that doubling the stock of previously released mobile spectrum will reduce the value of additional spectrum by roughly 50%.

[13] Based on data from the GSA. This is an imperfect measure, as some mobile device models are much more common than others. Nevertheless, this measure does provide an indication of the relative importance of different spectrum bands in the provision of mobile services.

[14] See Brian Williamson and Sam Wood (2014), "Do you need a mobile data forecast to estimate spectrum demand?" We are not aware of any other attempt to test this hypothesis econometrically.

[15] This distribution has been observed by Ericsson (2009) "Don't worry – Mobile broadband is profitable". Nokia Networks (2014) also assume that 15% of sites carry 50% of traffic as a modelling assumption.

[16] There is some evidence to suggest that marginal willingness to pay for fixed line speeds decreases as the speed increases. See Chart 6.4, https://www.communications.gov.au/sites/g/files/net301/f/Cost-Benefit_Analysis_-_FINAL_-_For_Publication.pdf

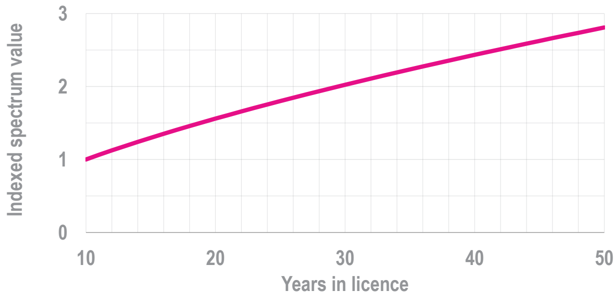
Licence duration: a periodic tale

As might be expected, the model predicts that the longer the licence the more valuable it is. However, this too is subject to diminishing returns: doubling the licence duration adds 56% to the licence value.

This reflects uncertainty about the future – it may be that improvements in spectral efficiency (the amount of information that can be carried by the spectrum) make additional spectrum less vital in meeting future demand for data.

Value of spectrum vs. years in licence

Indexed to a 10-year licence



Source: Plum Consulting

Country-specific factors

Sometimes there may be country-specific factors which affect spectrum value. For example, a country's citizens may have more of a culture of mobile broadband use, or it may have specific policies to encourage the use telecommunications services, or its telecoms market may be more fiercely competitive than the HHI would suggest. It may also be more difficult to split cells or build new network infrastructure in some countries, making additional spectrum the best option for increasing network capacity.

These factors are all likely to increase the value of spectrum to operators, but are hard to reflect with the available data. Fortunately, econometrics provides a method for controlling for these types of factors: the fixed effects model.

This approach includes aggregating the auctions by country – rather than treating each auction as a separate event, they are grouped. Time-invariant factors for each country are included in the model, allowing it to control for unobserved country-specific factors.

This enables the model to produce tailored predictions for individual countries, improving the model's predictive power. For instance, Thailand and Taiwan are found to have positive fixed effects: spectrum is likely to be more valuable here than the other explanatory variables would suggest. This will adjust the model's predictions for future spectrum auctions in Thailand and Taiwan.

Applying econometrics

To successfully conduct econometric analysis, an appropriate data set is needed. As with all data analysis, the quality of the conclusions depends on the quality of the data inputs: the larger and more accurate the dataset the more reliable the conclusions will be.

It's also important that the appropriate statistical tests are run on the econometric model to ensure its validity. Statistical artefacts like collinearity and heteroscedasticity can impact the reliability of any conclusions drawn from the model. All too often these artefacts aren't compensated for, or testing for them is completely neglected.

For spectrum valuation and spectrum allocation decisions, econometric analysis is perhaps best used in conjunction with other valuation methods. Some factors that are likely impact spectrum value (notably, strategic considerations by mobile network operators) are hard to capture in a model; on the other hand, benchmarking can lack the quantitative rigour of econometrics. The use of a variety of methods can help to compensate for the shortcomings of each particular valuation method.

Conclusion

Used appropriately, econometrics can be a valuable tool in assessing the value of spectrum, and is capable of producing a vital input into spectrum allocation decisions. Econometrics also has the advantage of being able to offer unique insights into the key drivers of spectrum value – insights which can be used to develop future analysis.

About Plum

Plum has conducted numerous assessments of spectrum value for operators and regulators around the world. These studies have employed a variety of valuation methods including benchmarking, network cost modelling and econometric analysis. Plum has also reviewed econometric models developed by others, and given advice on how they could be improved.

Plum's econometric modelling is based on Plum's comprehensive spectrum auction database, which collates the results of over 400 mobile spectrum auctions held around the world.

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