The spectrum crunch is dead, long live spectrum demand

Brian Williamson and Sam Wood (*)

July 2015

Abstract

The assessment of future mobile data and spectrum demand is an important policy and business strategy question. The orthodox approach to these linked questions starts from a mobile data traffic projection to infer spectrum demand and value. However, future mobile data demand is uncertain, and spectrum demand and value is sensitive to data demand, since under the orthodox approach either there is a spectrum surplus or a spectrum crunch.

We explore an alternative "bootstrap" approach where mobile data demand and spectrum value are determined simultaneously, without the need for a data traffic forecast. The equilibrium is determined within the model as a function of underlying supply and demand side assumptions. Spectrum demand is found to be less sensitive to supply side assumptions including existing spectrum availability, since an increase in capacity stimulates data demand.

The bootstrap approach eliminates the "spectrum crunch", replacing it with an economic concept of spectrum demand - spectrum value as a function of spectrum availability. The bootstrap model can be used to explore a richer set of strategy and policy questions than the orthodox approach, including the sensitivity of data and spectrum demand to changes in willingness to pay for data.

Key words: Spectrum value, mobile data, spectrum crunch

JEL codes: D40, K23, L50, L96, O33

1 Introduction

The term "spectrum crunch" refers to a pending excess of demand for spectrum for mobile services. The term was used as a rallying call for spectrum reallocation by FCC Chairman Julius Genachowski at successive Consumer Electronics Shows, with this call to arms in 2012:

> *"…America's global leadership in mobile, and the strategic bandwidth advantage so many have worked hard to create, is being threatened by the looming spectrum crunch. At the FCC, we identified the problem and began sounding the alarm about the spectrum crunch almost three years ago – to some debate at the time. But in a world of tablets, ultrabooks, and 4G phones that consume more and more data, the debate has been settled."*[1]

As a call for action the term spectrum crunch has been a success. Around the world governments have released spectrum for mobile, and continue to do so. However, as a way of thinking about and modelling spectrum demand, the notion of a spectrum crunch may have outlived its usefulness. Given

---

(*) Brian Williamson is a Partner at Plum Consulting; Sam Wood is a consultant at Plum Consulting.

[1] January 2012. "Remarks of FCC Chairman Julius Genachowski, 2012 Consumer Electronics Show." https://www.fcc.gov/document/chairman-genachowski-2012-consumer-electronics-show

the growing economic importance of mobile applications[2] and the challenge of clearing spectrum for mobile, placing demand assessment and valuation on a firmer basis is a priority.

The idea evoked by a spectrum crunch - that data demand is growing independent of mobile capacity (i.e. is exogenous), and that mobile capacity is a function of spectrum availability only – isn't a sound basis for thinking about spectrum policy or mobile strategy. Spectrum supply stimulates demand via higher quality of service and/or lower data prices.

The endogeneity of demand, its responsiveness to supply, has been recognised by transport planners since the 1960s in relation to capacity increments to roads.[3] The need to modify the approach in relation to telecommunications was identified by Lanning *et al* (1999):[4]

> *"The usual practice of telecom network planners is to take traffic requirements as inputs and to produce a cost minimizing network. In the case of low demand elasticity, such an approach will reasonably approximate profit maximizing solutions. When technology innovation is fast, as it is in optics, and demand is elastic, as it is in data, then the practice needs to be modified."*

In this paper we explore an approach where mobile supply and demand are integrated via a data price feedback on demand. The paper builds on Williamson (2014) which introduced the approach.[5] We refer to approach as the bootstrap approach.

A data traffic forecast is no longer required since mobile data is determined endogenously within the model, and the notion of a "spectrum crunch" is no longer meaningful given the focus on equilibrium outcomes in terms of data demand and spectrum value.

2 The orthodox approach

Under the simplest orthodox approach spectrum demand is inferred directly from data demand and the costs of meeting demand are not considered (the ITU utilised this approach as an input to the World Radiocommunications Conference in 2015).[6] This approach has no economic dimension – either in terms of data demand or spectrum demand (where demand in an economic sense is a function of price). This is like asking someone how many Bentleys they would like, without asking whether they are prepared to pay for them.

An alternative approach utilises mobile network cost models to infer spectrum value by considering the trade-off between using spectrum and deploying more cellular sites in order to meet demand. This

---

[2] Timothy Bresnahan, Jason Davis and Pai-Ling Yin. 2014. "Economic Value Creation in Mobile Applications." http://www.nber.org/chapters/c13044.pdf

[3] Todd Litman. September 2012. "Generated traffic and induced travel – implications for transport planning." http://www.vtpi.org/gentraf.pdf

[4] Steven Lanning, Shawn O'Donnell and Russell Neuman. September 1999. "A taxonomy of communications demand." http://dspace.mit.edu/bitstream/handle/1721.1/1527/odonnell.pdf?sequence=1

[5] Brian Williamson. June 2014. "Do you need a mobile data forecast to estimate spectrum demand?" http://www.plumconsulting.co.uk/pdfs/Plum_Insight_June_2014_Do_you_need_a_mobile_data_forecast_to_estimate_spectrum_demand.pdf

[6] ITU. 2014. "Future spectrum requirements estimate for terrestrial IMT." http://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2290-2014-PDF-E.pdf

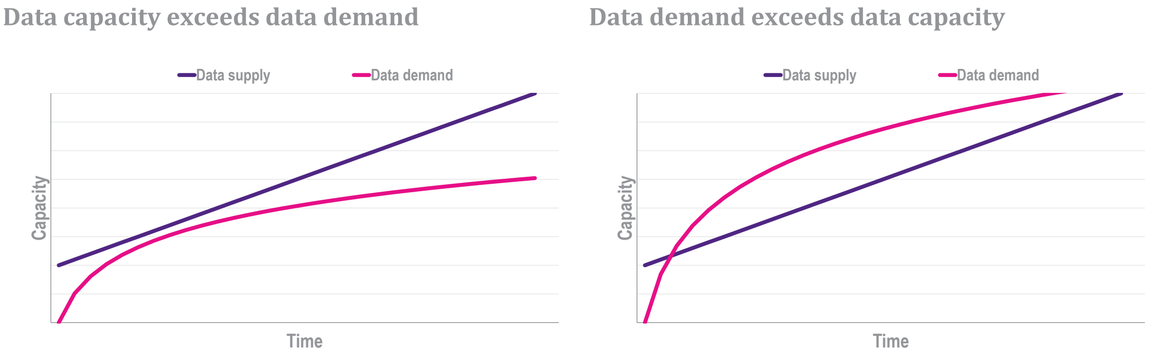
approach was developed to assess the opportunity cost of spectrum for the purpose of spectrum pricing (the "Smith-NERA method") and is often referred to as the avoided cost method.[7]

Further application of the approach was subsequently proposed in the UK,[8] and the approach is now widely utilised internationally as an input to spectrum allocation, bidding decisions and pricing decisions.

Extensions of the Smith-NERA method, which model network expansion over an extended time frame are used to infer a value for spectrum.[9] However, these approaches assume that supply expands to meet an exogenously data forecast irrespective of the level of demand (consumer willingness to pay for data) and the cost of meeting demand.

As illustrated in Figure 1 this approach could imply either an excess of spectrum implying zero spectrum value or a "spectrum crunch", potentially implying high spectrum value.

Figure 1



There is considerable uncertainty regarding future network capacity and future traffic growth, as illustrated by a study for Ofcom by Real Wireless which considered mobile data traffic growth of between 23-fold and 297-fold over the period 2012-2030, a difference of over an order of magnitude.[10]

However, not only is future traffic growth uncertain but spectrum value is highly sensitive to assumed traffic growth under the orthodox modelling approach. Illustrating this, Aetha (2014) found that the net present value of sub-700 MHz spectrum for mobile use in Europe for the period 2015-2029 varied between zero and €10.3 billion based on Ofcom and ITU/UMTS Forum data traffic projections respectively.[11]

---

[7] Smith-NERA. April 1996. "Study into the use of Spectrum Pricing". http://www.ofcom.org.uk/static/archive/ra/topics/spectrum-price/documents/smith/smith1.htm

[8] Martin Cave. 2002. "Review of Radio Spectrum Management." http://www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review/1_whole_job.pdf

[9] Brian Williamson. January 2012. "Mobile data growth – too much of a good thing?" http://www.plumconsulting.co.uk/pdfs/Plum_Insight_Jan2012_Mobile_data_growth_-_too_much_of_a_good_thing.pdf

[10] Real Wireless for Ofcom. April 2012. "Techniques for increasing the capacity of wireless broadband networks: UK, 2012-2030" http://www.ofcom.org.uk/static/uhf/real-wireless-report.pdf

[11] Aetha. October 2014. "Future use of the 470–694MHz band". http://www.aethaconsulting.com/articles/report_econbenefits470694mhz.php

A sense check on traffic growth assumptions can be made by considering their affordability based on network cost estimates. Ericsson[12] and NSN[13] have published analysis showing how falling unit mobile data costs can support traffic growth consistent with profitability for operators. However, this represents an *ex post* check rather than a change in modelling approach.

What is lacking under the orthodox approach is consideration within the modelling of factors that would restore the market to equilibrium, as Clarke (2014) noted:[14]

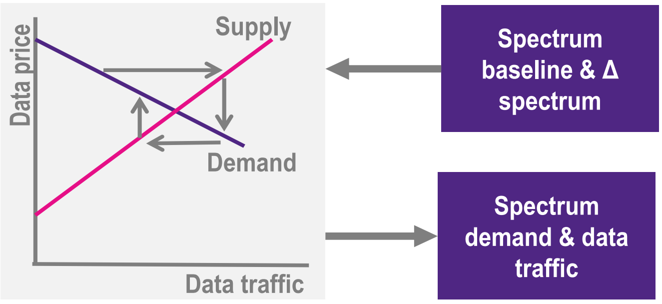
> *"When wireless capacities are tight, data connections will slow down. Either customers will accept slower performance of their mobile applications, or they will discontinue their use, or transfer their use to off-peak periods or locations. It is also possible that they will eschew particularly data-hungry applications in favor of less-desirable substitute applications that have the virtue of reduced data use. Either way, the effective service quality that customers receive will be reduced. Further, it is quite certain that prices will also be a major equilibrator of the market."*

The bootstrap approach explored below aims to overcome these shortcomings by explicitly modelling supply and demand, and by finding the equilibrium.

3 The bootstrap approach

The bootstrap modelling approach treats mobile data demand as endogenous i.e. it is determined within the model. Under the bootstrap approach operators expand network capacity provided there is sufficient willingness to pay for the extra capacity. The bootstrap model is solved iteratively to find the equilibrium between data supply (capacity) and data demand, as illustrated in Figure 2.

Figure 2



This modelling approach is more economically and commercially realistic than the orthodox approach. Spectrum supply can be varied and a new equilibrium found, thereby enabling spectrum to be valued by comparing the two equilibria and calculating the difference in network costs. However, in contrast to the orthodox approach, data traffic responds to changes in supply brought about by changes in

---

[12] Ericsson. 2010. "Mobile broadband - busting the myth of the scissor effect." http://www.ericsson.com/ericsson/corpinfo/publications/ericsson_business_review/pdf/210/210_strategy_mobile_broadband.pdf

[13] NSN. 2010. "Mobile broadband with HSPA and LTE – capacity and cost aspects." http://networks.nokia.com/sites/default/files/document/nokia_mobile_broadband_with_hspa_and_lte_white_paper.pdf

[14] Richard Clarke. September 2014. "Expanding mobile wireless capacity: The challenges presented by technology and economics." *Telecommunications Policy*, Volume 38, Issues 8–9. http://www.sciencedirect.com/science/article/pii/S0308596113001900

spectrum supply or other assumptions including spectrum efficiency (the quantity of data that can be carried by a unit of spectrum).

Because supply and demand are in equilibrium the situation in Figure 1 does not arise. There is always demand for spectrum since it can enable growth, though it is diminishing with supply. Neither will there be a ‘crunch’, since, unlike in the orthodox approach, prices mediate between supply and demand. The fact that data traffic adjusts to supply also gives the model an extra degree of freedom and reduces the sensitivity to other assumptions, in particular spectrum efficiency.

Under the bootstrap approach demand for spectrum and data is always considered in relation to willingness to pay i.e. we consider demand curves involving quantity and price. The Bentley problem mentioned earlier does not therefore arise since demand is conditional on willingness to pay.

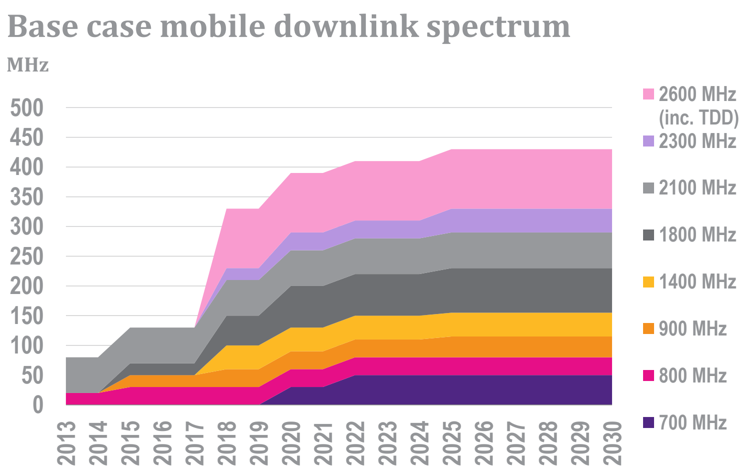
4 Modelling assumptions

The modelling is calibrated for Europe (excluding Russia and Turkey) including base year (2015) traffic based on the Cisco VNI.[15] Further, our modelling relates to spectrum for capacity purposes. Lower frequency spectrum (sub-1 GHz), which allows coverage to be extended at lower cost, has in the past had higher value. However, this may change once sufficient sub-1 GHz spectrum is already available.

On the demand side we assume that individual data expenditure is constant in real terms, that the number of data consumers grows from 60% of the population to 90% by 2020 and that (as a base case) the price elasticity of data demand is -1 (in other words if the price halves, data consumption doubles).

On the supply side we assume that site capacity is determined by spectrum efficiency (which grows from 1 to 2 bits/second/Hertz) and the amount of downlink spectrum available (which we assume grows from 130 MHz in 2015 to 430 MHz in 2030, as illustrated in Figure 3). Note that uplink spectrum is not shown in the figure.

Figure 3



[15] Cisco. May 2015. “VNI”. http://www.cisco.com/c/en/us/solutions/collateral/service-provider/ip-ngn-ip-next-generation-network/white_paper_c11-481360.html

Other harmonised spectrum, including 3.4 to 4.2 GHz spectrum, may also be utilised by mobile over this time period. We in effect model this possibility via our sensitivity analysis of additional spectrum supply.

A cost per site of €70,000 is assumed. We assume a continuous distribution of traffic across sites (of the form $y = ax^b$) normalised such that 20% of sites initially carry 50% of traffic. Maximum site utilisation is 50%, and busy hour traffic is assumed to be 7% of daily traffic.

When solving for the equilibrium data traffic growth path, we assume that traffic growth declines each year towards a value reflecting long-run income and mobile productivity growth, and allow the actual traffic path to be determined endogenously, consistent with the assumption regarding willingness to pay for data. We reach an equilibrium based on a data price calculated from costs and traffic, and utilise a real discount rate of 7% and model the period 2015 to 2030.

The modelling approach differs fundamentally from the orthodox approach in that an assumption regarding consumer willingness to pay for data is required (expressed in expenditure and elasticity terms), whilst an assumption regarding data traffic is not required.

The approach also differs in it models economic decision making – operators choose whether to invest in network capacity or not, and consumers choose to buy data or not (rather than operators always investing in capacity irrespective of returns and consumers consuming data consistent with the forecast irrespective of cost).

5 Modelling results

To compare the orthodox and bootstrap approaches we first standardise base case data traffic growth between the two models. To do this we calculate traffic growth utilising the bootstrap model and then use this traffic as an input to the orthodox model.

The data growth predicted under the bootstrap base case of constant user data expenditure is broadly comparable with forecasts by Cisco (5-fold growth by 2019) and Ericsson (9-fold growth by 2020).[16] This suggests that these forecasts are economically plausible.

We then use the bootstrap model to proxy the orthodox approach by setting the price elasticity of data demand to zero. We can then compare the sensitivity of the models to changes in input assumptions on a like for like basis.

5.1 Supply side sensitivity

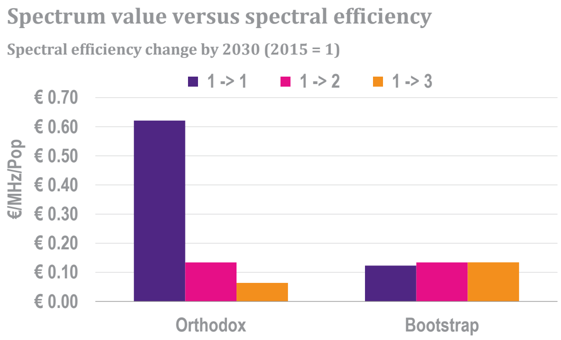
Spectrum value is less sensitive to supply side changes with the bootstrap approach versus the orthodox model. The reason for this is that increases in capacity via higher spectrum efficiency (the amount of data carried per MHz) or additional spectrum increase traffic, thereby partially offsetting the impact of additional capacity on the incremental value of spectrum.

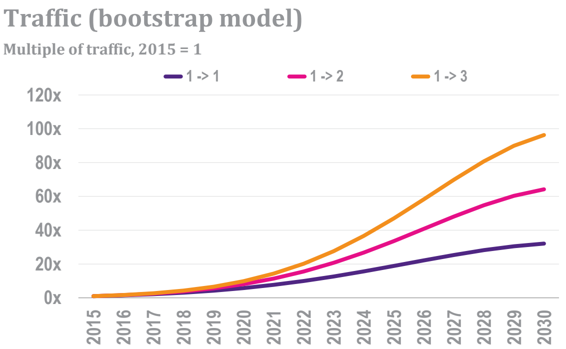
The sensitivity to changes in spectrum efficiency are illustrated in Figure 4, with spectrum value normalised to € per MHz per population (€/MHz/pop). The bootstrap values are broadly comparable

[16] Ericsson. June 2015. "Mobility Report". http://www.ericsson.com/mobility-report

with auction outcomes for spectrum for capacity, for example, those in Germany in June 2015 which were in the range €0.1-0.3 per MHz/pop.[17]

Figure 4

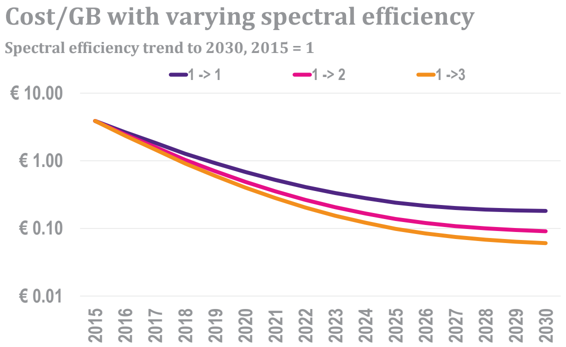




The sensitivity to a change in spectrum efficiency is negligible under the bootstrap approach, since data traffic changes in response to additional capacity and lower unit costs. For the base case 64-fold data growth by 2030 corresponds to an average annual compound rate of growth of 32% over fifteen years.

Figure 5 (log scale) shows the reduction in unit costs accompanying increased spectrum efficiency, availability and network utilisation. It is the fall in unit costs, alongside assumed subscriber growth from 60% to 90% by 2020, which drives data growth consistent with constant real user expenditure.

Figure 5



We note that in the absence of demand growth induced by lower prices and an outward shift in the data demand curve – declining unit costs would result in a revenue contraction for the mobile industry. The demand stimulus from growth in the use of applications offsets the impact of declining unit costs due to spectrum efficiency, utilisation and increased spectrum availability.

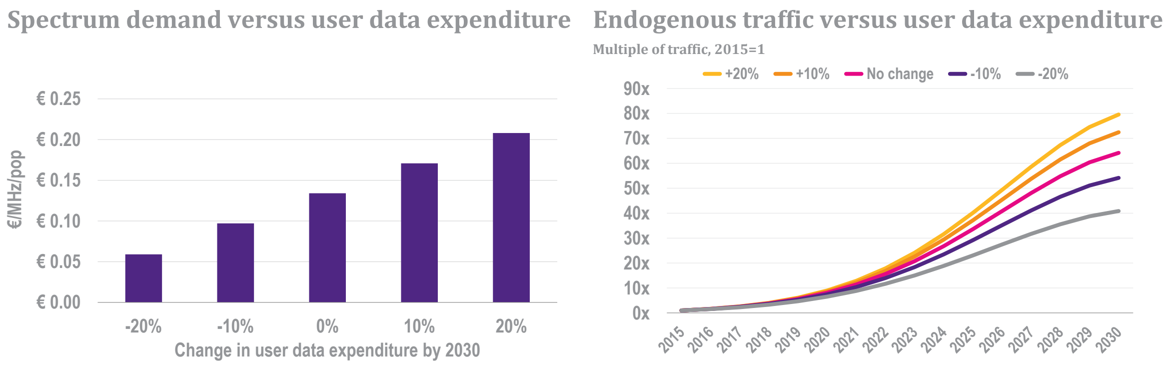
[17] Bundesnetzagentur. 19 June 2015. “Spectrum auction in Mainz finished.” http://www.bundesnetzagentur.de/cln_1432/SharedDocs/Pressemitteilungen/EN/2015/1500617_Frequnezversteigerung.html?nn=404422

5.2 Demand side sensitivity

The consumer demand side is not modelled under the orthodox approach, rather a fixed exogenous data traffic forecast is utilised. The following results therefore apply only for the bootstrap model.

We allow user data expenditure to vary by +/- 10% or 20% by 2030 versus the base case (constant real expenditure assumption). We obtain the spectrum values and corresponding data traffic profiles in Figure 6.

Figure 6



Both spectrum value and data traffic are seen to move together as user data expenditure varies. Further, the increase in traffic as a function of assumed data expenditure is subject to diminishing returns (the increments in the data growth curves get smaller as assumed expenditure is increased). We tested a much larger increase in data expenditure of 100%. Traffic increased 115-fold or 37% per annum compound versus 64-fold and 32% per annum compound for the base case.

We note that movement in individual data expenditure over time is ambiguous, even if willingness to pay for mobile data is increasing. The reason for this is that growth in willingness to pay (an outward shift in the demand curve) may be offset by a downward shift in the mobile data supply curve (due to capacity-productivity gains), depending on the price elasticity of data demand (movements along the demand curve in response to price changes).

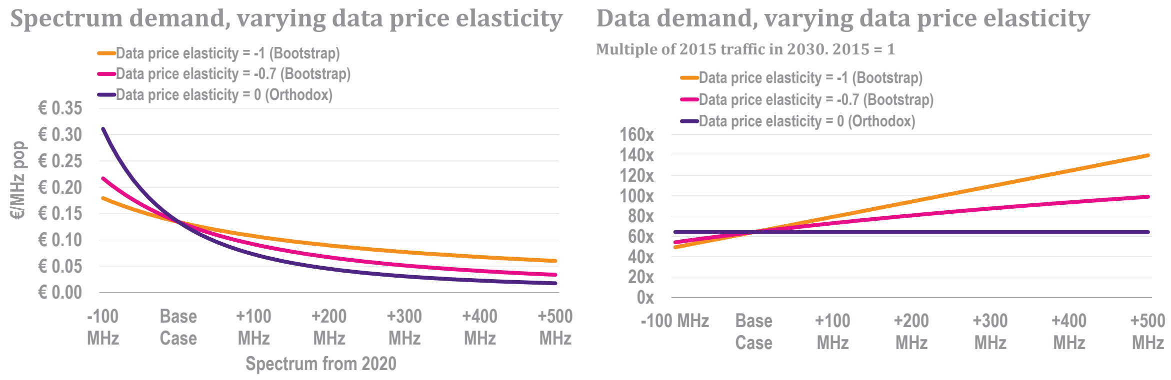
We consider it plausible that real data expenditure will increase over time, which would imply both higher data growth and higher spectrum value than our base case analysis.

5.3 Spectrum demand curves

By progressively adding increments of spectrum we utilise the bootstrap model to construct spectrum demand curves (incremental value as a function of spectrum quantity). The curve shows the sensitivity to spectrum availability.

Curves can then be generated which illustrate the impact of other factors on the supply or demand side. Figure 7 shows spectrum demand curves calculated for data price elasticities of 0, -0.7 and -1; and the accompanying endogenously determined data growth paths (we adjust data expenditure to normalise the base case values as the elasticity varies).

Figure 7



Spectrum value is subject to diminishing returns as supply is increased, but value falls less steeply the higher the elasticity. In the zero elasticity (orthodox) case, spectrum value is much more sensitive to what has already been released, meaning that the timing of spectrum release can be a crucial factor under the orthodox approach.

Figure 7 also illustrate how endogenously determined data growth feeds back on spectrum value as spectrum supply is increased for varying assumptions regarding the data price elasticity of demand. With a data price elasticity of demand of zero there is no feedback, so data growth does not change with spectrum availability and incremental spectrum value declines more steeply.

6 Implications

The bootstrap approach allows a fresh perspective, but also allows questions to be considered that could not be assessed using orthodox modelling. We discuss examples below.

6.1 Benefits of spectrum and spectrum allocation decisions

The bootstrap model provides an estimate of both the productivity gains from additional spectrum and the extent of additional demand (market expansion). It is possible therefore to obtain an estimate of the overall economic benefit.

We calculate the benefits of the spectrum increase from 60 MHz of downlink spectrum in 2015 to 430 MHz in 2030 (with the 60 MHz base case assuming no new spectrum post the allocation of 2.1 GHz in Europe). We utilise a social discount rate of 4%,[18] since we are interested in an overall economic benefit estimate rather than a private spectrum value. The expansion of spectrum supply results in productivity benefits for mobile service provision. The net present value of these benefits from additional spectrum to 2030 is €110 billion.

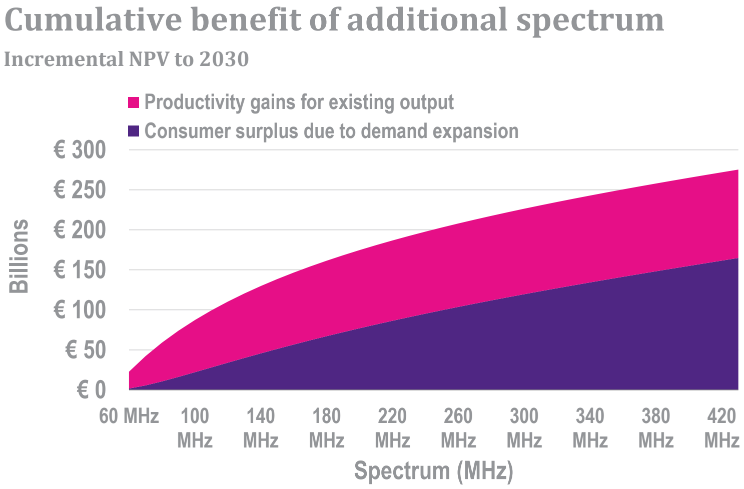
In addition to productivity gains the benefits of additional demand stimulated by price reduction also need to be calculated. Under the bootstrap modelling approach the expansion of spectrum supply stimulates an increase in data growth from 12-fold by 2030 to 64-fold.

[18] European Commission. January 2009. “PART III: Annexes to Impact Assessment Guidelines.” http://ec.europa.eu/smart-regulation/impact/commission_guidelines/docs/ia_guidelines_annexes_en.pdf

For this increase in data traffic the additional consumer surplus is 150% of the productivity gains for an isoelastic demand curve with a data price elasticity of -1.[19] Note that under the orthodox modelling approach the implicit data price elasticity of demand is zero, there is no change in data traffic, and this calculation is not be possible.

Allowing for the increase in output the overall benefit is €275 billion in present value terms for Europe. Figure 8 shows the cumulative impact of spectrum release in terms of productivity gains and demand expansion.

Figure 8



We note that the benefits of all spectrum would be substantially larger, since the benefits above are incremental to an initial 60 MHz. Whilst value continues to rise with additional spectrum it is subject to diminishing returns. At some point the opportunity cost of competing use value and spectrum clearance costs would offset the benefits of further reallocation.

6.2 Spectrum allocation, reassignment and pricing

Spectrum allocation decisions, in particular between broadcasting and mobile broadband, involve an assessment of the trade-off between the value of the two uses and the costs of reallocation. The debate tends to be dominated by a discussion of whether mobile "needs" additional spectrum given conflicting views of future traffic growth. The bootstrap approach allows the discussion to be recast in terms of the declining incremental value of spectrum for mobile versus the value of broadcast use and clearance costs.

In relation to spectrum reallocation the bootstrap model could be used to inform the setting of reserve prices and ongoing fees. The advantage of using spectrum demand curves is that it explicitly shows how value, and therefore the appropriate reserve price and/or spectrum price, declines with increasing spectrum availability. This suggests that past benchmarks may overestimate appropriate reserve prices and fees.

[19] With isoelastic demand $Q = k.P^{-1}$ the additional consumer surplus from an increase in data from Q_1 to Q_2 is:

$$\frac{\ln(Q_2.Q_1^{-1}) - (Q_2 - Q_1).Q_2^{-1}}{(Q_1^{-1} - Q_2^{-1}).Q_1}$$

Finally, in relation to ongoing fees designed to promote spectrum efficiency, we note that opportunity cost modelling rests on the assumption that the network operator faces a trade-off in meeting demand growth between spectrum and sites. This being the case spectrum prices would not be expected to promote efficient use (since the operator already faces the opportunity cost of spectrum holdings irrespective of fees[20]). The rationale for fees for commercial use when spectrum is scarce is not therefore clear cut.

6.3 "Off-loaded" traffic

Under the orthodox approach the mobile traffic forecast used for modelling spectrum demand is after allowance for "off-load". Under the bootstrap approach traffic is generated endogenously based on the costs of providing, and demand for, mobile capacity.

Wi-Fi traffic is therefore additional to mobile traffic rather than "offloaded" from a fixed exogenous overall traffic forecast. In other words the low or zero incremental user cost of Wi-Fi can be thought of as resulting in additional data consumption.

Wi-Fi may however impact on willingness to pay for mobile data. This impact would be modelled under the bootstrap approach by reducing (if Wi-Fi is primarily a substitute) or increasing (if Wi-Fi is primarily a complement) assumed data expenditure over time.

6.4 Small cells

The use of small cells may increase capacity and address urban coverage not-spots. Focussing on capacity, small cells may increase spectrum efficiency, enhance the overall capacity of macro cells and lower the costs of meeting incremental demand.

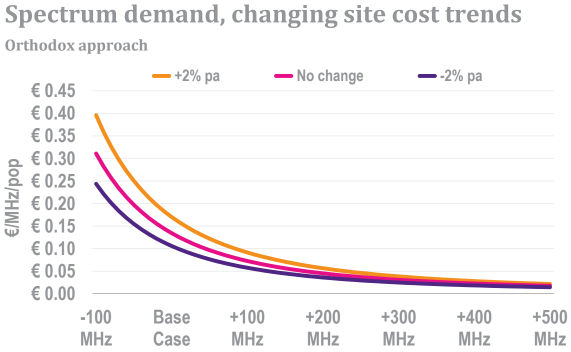
The impact of small cells could therefore be proxied under the bootstrap approach by continuing to utilise the same underlying cost model but with modified inputs regarding spectrum efficiency and changes in site costs over time. We considered the sensitivity to assumed growth in spectrum efficiency earlier in this paper and found that increased spectrum efficiency growth increased data growth but had little impact on spectrum value.

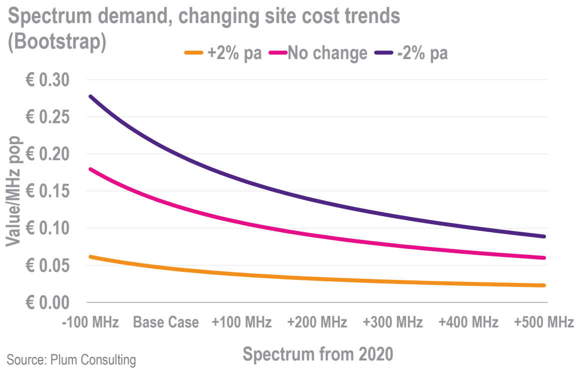
Below we consider the impact of a change in site costs over time (which could be due to, for example, changes in planning constraints or to the increasing use of small cells as a means of offering capacity at lower cost).

Under the orthodox and bootstrap approaches not only is the sensitivity to changes different, the sign of the impact is reversed (the spacing of the spectrum value curves, but also their order, differs between the two cases shown in Figure 9).

[20] Brian Williamson, Phillipa Marks and Yi Shen Chan. January 2014. "Annual licence fees - you cannot have your cake and eat it." http://www.plumconsulting.co.uk/pdfs/Plum_Jan2014_ALF_-_you_cannot_have_your_cake_and_eat_it.pdf

Figure 9





Under the orthodox approach, given that data traffic demand is fixed, additional spectrum means fewer sites need be built to meet demand. The benefit of spectrum in terms of avoided network cost therefore increases if sites are becoming more costly over time. The spectrum demand curve shifts up or down in line with the assumed trend in site costs.

Under the bootstrap modelling approach the opposite happens (and with increased sensitivity). The reason for this reversal is that site cost changes impact on data demand growth. Cheaper sites mean lower data prices and therefore higher data demand, therefore more sites are built. In this scenario additional spectrum is more valuable, since there are more sites that benefit from additional capacity. Conversely, high site costs choke off data demand, and the data market remains in a low-quantity high-price equilibrium.

6.5 Data tax (as proposed in Hungary)

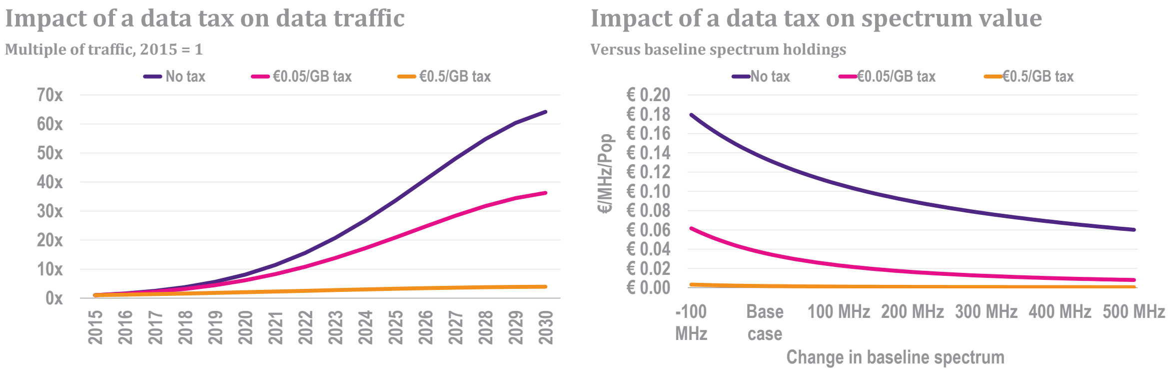
Other policy options can also be assessed based on their impact on data demand and on spectrum value by utilising the bootstrap model. For example, a data tax of 150 forints per gigabyte (around €0.50) was proposed in Hungary in October 2014[21], a proposal that is now being reappraised after public opposition.

At a general level the Diamond and Mirlees (1971) result shows that input taxes are inefficient.[22] In this specific instance the proposed fixed level of tax would have driven a wedge between the cost of supply and the price consumers would face. The bootstrap model can be readily modified to model the effects of the tax. The results are shown in Figure 10 for data traffic and spectrum value (based on the model scaled for Europe as a whole).

[21] http://www.reuters.com/article/2014/10/22/us-hungary-internet-tax-idUSKCN0IB0RN20141022

[22] Mirless Review. September 2011. "Tax by design." Section 6.1.1. http://www.ifs.org.uk/docs/taxbydesign.pdf

Figure 10



The impact of the €0.50 per gigabyte levy on data demand becomes proportionately larger over time as technology and spectrum supply reduce incremental costs. The growth of data demand is therefore choked off at a low level and spectrum value is substantially reduced. A low growth industry and substantial consumer harm would be the result, with little tax revenue to show for it.

6.6 Mobile substitution for fixed broadband

Mobile is the broadband platform for the majority of consumers globally. However, where fixed access networks exist the question of mobile substitution has policy and strategy implications.

With 4G coverage improving and 4G speeds sufficient for many applications mobile data capacity, as opposed to speed or availability, may be the key constraint on substitution for fixed access. If so, then if mobile unit data costs fall, faster than overall internet traffic growth an increasing proportion of consumers may opt for mobile only.

Further, data consumption is skewed, with 5% of consumers accounting for 50% of overall data consumption.[23] We estimate that many consumers have data traffic well below the average (median) level, which increases the scope for substitution.

Under the bootstrap model mobile unit data costs fall at an average compound rate of 34% from 2015 to 2019. This is faster than the compound average growth in fixed traffic forecast by Cisco for Western Europe of 21% per annum to 2019. Considering mobile capacity versus fixed traffic growth alone therefore suggests that mobile substitution may grow from the existing level (7% of households had mobile internet access but no internet connection at home in January 2014[24]).

7 Conclusion

The bootstrap modelling approach, which incorporates an explicit demand side and seeks a simultaneous solution in terms of mobile data demand and spectrum value, offers fresh insights over the orthodox approach to mobile cost and spectrum demand modelling.

[23] Ofcom. Infrastructure Report 2013. http://stakeholders.ofcom.org.uk/binaries/research/telecoms-research/infrastructure-report/IRU_2013.pdf

[24] Eurobarometer. March 2014. "E-Communications and Telecom Single Market Household Survey." http://ec.europa.eu/public_opinion/archives/ebs/ebs_414_en.pdf

A mobile data demand forecast is not required. Whilst a judgement is required over how consumer willingness to pay and data expenditure will change over time, this is arguably easier to judge than long-term data growth for which projections vary by an order of magnitude.

The bootstrap model responds in a qualitatively different manner than an orthodox model: increases in network supply stimulate increased data demand. This feedback loop changes the sensitivity, and even the sign, of the relationship to changing input assumptions.

The bootstrap approach is much less sensitive to supply side capacity changes, spectrum efficiency and availability, than the orthodox approach. Under the orthodox approach, small changes in assumed network capacity can make the difference between a “spectrum crunch” and a “spectrum surplus”, given a fixed traffic forecast. The bootstrap approach removes the notion of a “spectrum crunch”, replacing it with the economic concept of a spectrum demand curve.

Finally, the bootstrap approach allows a wider range of policy issues to be analysed and points to a different research agenda to better understand the variables which spectrum value and mobile data demand are sensitive to; namely consumer willingness to pay, the price elasticity of demand for mobile data and changes in future supply costs of mobile data.