Do you need a mobile data forecast to estimate spectrum demand?

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Spectrum demand is a key input to decisions over spectrum allocation and assignment. Yet estimates of spectrum demand are sensitive to assumptions regarding future mobile traffic, which are uncertain. In this Insight we consider an alternative approach to modelling the demand for spectrum which dispenses with the need for a data traffic forecast. Instead, the approach iteratively solves an economic supply-demand balance based on assumptions regarding network costs and consumer willingness to pay for data. The approach offers fresh insights into mobile and spectrum demand, and provides a foundation for a deeper understanding of these core questions for policy makers and industry.

What does this Insight set out to address?

The appropriate allocation of radio spectrum is a global priority given the growing economic benefits associated with wireless technologies, most prominently mobile. Decisions over the allocation of spectrum are required at the World Radio Conference in 2015 and at the regional and national level. Operators also need to assess their own future demand for spectrum in deciding whether to seek additional spectrum and how much to pay for it.

Decisions over spectrum allocation depend on mobile demand for spectrum which in turn depends on mobile data demand. They also depend on the alternative use value of spectrum. However, future mobile traffic growth is uncertain and small changes in assumptions can have a large impact on inferred spectrum demand.

Estimates of spectrum demand tend to be knife edge in nature, with either spectrum abundance or spectrum scarcity i.e. a “spectrum crunch”. However, this is artificial as market demand is continuous in nature and depends on price. Indeed in an economic sense it is not meaningful to consider demand independent of price (one might like a Bentley, but how much are you prepared to pay for one?). We also know that network capacity can shape the scale of demand – a phenomenon observed, for example, in road networks where extra capacity induces demand.

This Insight considers the question of mobile spectrum demand from an economic perspective. We consider mobile network supply (taking account of costs) alongside demand (taking account of consumer willingness to pay for mobile data).

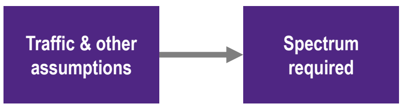
What are the existing approaches?

Existing approaches for estimating the demand for spectrum start from a forecast of mobile data traffic, typically built up from existing trends or a bottom up assessment of device ownership and device consumption (for example, forecasts by Cisco[1] and Ericsson [2]).

Existing approaches then either build on traffic projections by considering network capacity (including spectrum efficiency and the number of sites) to infer the quantity of spectrum required; or they in addition introduce consideration of network costs to infer spectrum demand.

The first of these approaches is illustrated in stylised form below. This approach has been adopted by, for example, Ofcom in their mobile data strategy[3] and by the International Telecommunications Union (ITU).[4]

Technical model



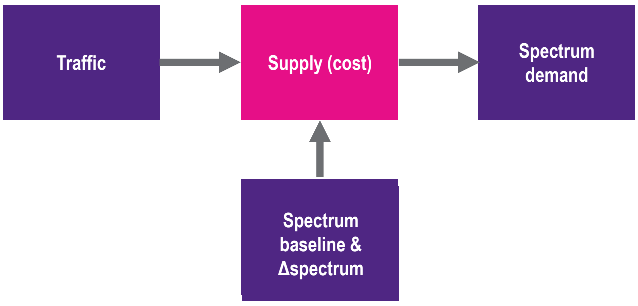
Assessing network capacity is a foundation of all approaches to estimating spectrum demand. However, on its own a purely technical approach does not factor in the economics of supply and demand.

Another class of models introduces network cost and estimates the network site costs avoided with additional

[1] Cisco, February 2014, “Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013–2018” http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.pdf
[2] Ericsson, June 2014, “Ericsson Mobility Report” http://www.ericsson.com/res/docs/2014/ericsson-mobility-report-june-2014.pdf
[3] Ofcom, May 2014, “Mobile data strategy” http://stakeholders.ofcom.org.uk/binaries/consultations/mobile-data-strategy/statement/statement.pdf
[4] ITU-R Recommendation M.1768. https://www.itu.int/rec/R-REC-M.1768/en

spectrum.[5] These models nevertheless continue to rely on an exogenous mobile data traffic forecast, as illustrated below.

Avoided cost model



The approach incorporates supply costs but does not model demand for data in an endogenous way i.e. there is no feedback of price on demand for data and therefore on demand for spectrum. Implicitly mobile data demand is assumed to be entirely price inelastic.

What is the alternative?

In practice data traffic might be expected to respond to network capacity (and therefore to spectrum availability, spectrum efficiency and site costs) via changes in quality of service and/or the incremental price of mobile data. Data traffic should be treated as endogenous, not exogenous.

This situation is analogous to induced demand in road traffic planning where it has been found that between 50% and 100% of additional capacity may be relatively rapidly used up through stimulation of additional road traffic.[6] A 1999 paper identified a need to modify the approach to modelling in relation to the telecommunications industry when capacity and cost change substantially:[7]

"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. Demand response (elasticity) is the input and planned traffic and pricing is added to the usual solution of when, what and where to install network elements under consideration."

[5] Plum Insight, 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

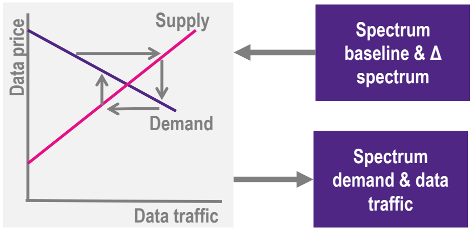
[6] Litman, September 2012, "Generated traffic and induced travel – implications for transport planning" http://www.vtpi.org/gentraf.pdf

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

We adopt this approach, building on capacity and avoided cost models. We allow mobile data traffic to be determined endogenously within the model by solving iteratively for the equilibrium of data supply and demand taking account of network costs and consumers' willingness to pay for data.

Both mobile data traffic and spectrum demand are outputs of the model, and mobile data is not fixed but is responsive to other assumptions including spectrum availability and spectrum efficiency. We call this the bootstrap approach since mobile data traffic is determined iteratively within the model, as illustrated below.

Bootstrap model



How does the bootstrap model behave?

We compare the bootstrap and avoided cost modelling approaches by first running the bootstrap model to generate a base case data traffic path, and then using this path as an input to the exogenous traffic avoided cost model.

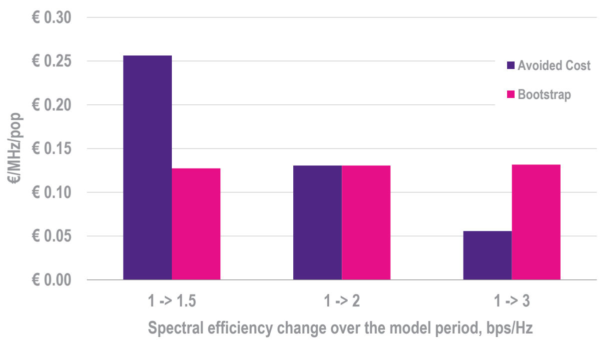
Our bootstrap model is calibrated for Western Europe. We assume that consumers' individual mobile data expenditure is the same in 2030 as today and that the number of mobile data customers increases from 60% to 90% of the population (supply side assumptions are summarised at the end of this Insight).

We then vary other model parameters in both models and compare their behaviour. We report the results of three simulations below: the impact of varying network capacity (via changes to assumed spectrum efficiency); the impact of varying consumer willingness to pay for data and the impact of changing site costs over time.

We represent mobile spectrum demand in terms of €/MHz/population calculated based on avoided cost (calculated for a spectrum increment in 2020). A spectrum demand curve could be built up by repeating the calculation for different spectrum baselines. The quantity of spectrum demanded or allocated for mobile would in turn depend on the demand for spectrum in the next best alternative use (not considered here).

We find that variations in network capacity driven by changes in spectrum efficiency have a strong impact on spectrum demand in the avoided cost model, but only a modest impact on spectrum demand under the bootstrap approach (see below).

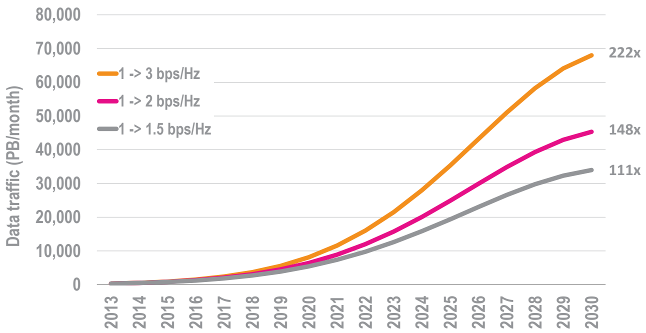
Sensitivity of spectrum demand to spectral efficiency



Source: Plum Consulting

The intuition for the difference in the sensitivity of spectrum demand to an increase in spectrum efficiency is that additional capacity generates additional mobile data traffic under the bootstrap approach, thereby offsetting the decrease in spectrum demand. The response of the data traffic paths generated endogenously under the bootstrap approach illustrates the linkage to spectrum efficiency (the model is calibrated to initial traffic levels for Europe).

Endogenous traffic with different spectral efficiencies



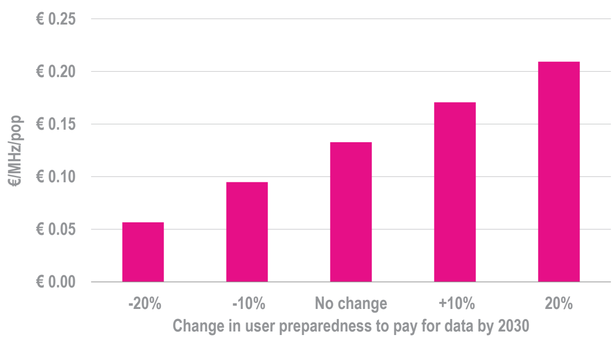
Source: Plum Consulting

We found similar results with variations in baseline spectrum availability. In contrast to the avoided cost approach, in the bootstrap approach incremental spectrum demand is not that sensitive to existing spectrum availability i.e. the demand curve is comparatively flat. Another way of thinking about this is that spectrum demand is no longer a knife edge phenomenon.

Next we consider the sensitivity of the bootstrap model to variations on the consumer demand side, namely to variations in what consumers are assumed to be prepared to pay for data (this is not a relevant consideration under the avoided cost approach since traffic is fixed outside the model).

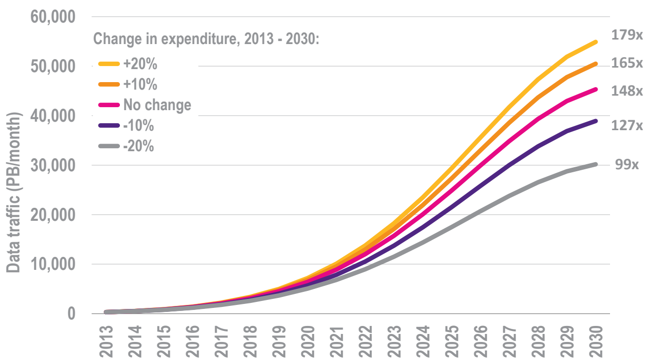
We find that both spectrum demand and data traffic are sensitive to the assumption regarding what consumers are prepared to pay for data (under our base case we assume individual data expenditure is constant to 2030). Also note that data traffic growth exhibits diminishing returns to user expenditure, as rising costs choke off demand.

Sensitivity of spectrum demand to user preparedness to pay



Source: Plum Consulting

Endogenous traffic with different data expenditure

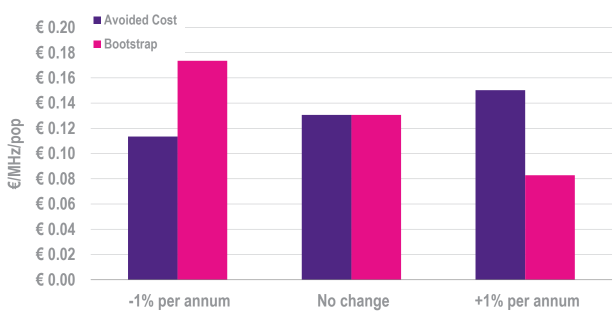


Source: Plum Consulting

Making the modelling approach "more economic" has reduced the sensitivity of spectrum demand to network capacity assumptions such as spectrum efficiency, eliminated the need to utilise a traffic forecast and highlighted the sensitivity of spectrum demand to consumer willingness to pay for mobile data.

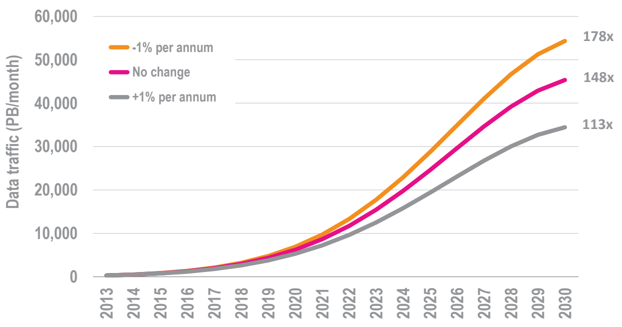
We finally consider the impact of allowing site costs to change over time, see below.

Sensitivity to trend in site costs



Source: Plum Consulting

Endogenous traffic with different site cost trends



Source: Plum Consulting

We find in this case that not only is the sensitivity of spectrum demand between the two approaches different, but that the direction of impact on spectrum demand differs between the two approaches.

The impact on traffic is as might be expected, namely that falling costs stimulate traffic growth since users can afford to consume more data for a given expenditure. The impact on spectrum demand is perhaps less intuitive.

With traffic fixed under the avoided cost approach the number of sites is not a function of site cost, and a reduction in site costs therefore simply reduces the avoided cost estimate with an increment of spectrum i.e. lower site costs reduce spectrum demand.

However, when traffic can vary under the bootstrap approach a change in site costs impacts data costs directly (via the per site cost) and indirectly (via data demand and the number of sites). Falling individual site costs result in more traffic and more sites. This means that there are more sites to benefit from additional spectrum, resulting in higher avoided costs. The net impact is that falling site costs increase spectrum demand.

What have we learned?

When an economic feedback from costs and data demand to traffic is introduced, different underlying model behaviour is observed. In particular, spectrum demand under the bootstrap model is relatively insensitive to assumptions regarding the spectrum baseline and spectrum efficiency which impact network capacity, since capacity induces additional data traffic offsetting the change.

The bootstrap model introduces a direct linkage to consumer behaviour and willingness to pay for mobile data, making this a central assumption. This highlights the importance of research on consumer willingness to pay for mobile data in order to better understand spectrum and data demand.

The bootstrap model also inverts the relationship between site costs and spectrum demand compared to the avoided cost model with exogenous traffic. Further work would be required in order to understand whether this result holds if the linkage between data costs and data traffic were weakened somewhat. However, it illustrates how qualitatively different results may be obtained with the bootstrap approach.

The modelling also illustrates that exogenous traffic forecasts produced by vendors, for example by Cisco and Ericsson, are economically plausible. Under our constant consumer expenditure assumption data growth is somewhat higher than the Cisco and Ericsson forecasts over the corresponding period. Growth is supported by an increase in the number of data customers and a decline in data costs – to around €0.1 per gigabyte by 2030 under our modelling assumptions.

The bootstrap approach also brings fresh, and sometimes different, qualitative insights which we illustrate in relation to Wi-Fi offload. The quantity of Wi-Fi offload is not an input to the bootstrap approach since traffic is not an input to the bootstrap approach. However it is not clear that Wi-Fi traffic is "offloaded" from an otherwise given traffic projection. Wi-Fi traffic may be additional traffic that would not otherwise have been carried over mobile. Further under the bootstrap approach Wi-Fi could be assessed in terms of the potential impact on willingness to pay for mobile data.

Conclusion

The bootstrap approach discussed in this Insight provides another tool in the toolkit for assessing spectrum demand, one that does not require a prior mobile data forecast. The bootstrap approach has provided insights that further work to integrate engineering and economic approaches to modelling spectrum demand could build on.

Bootstrap model base case cost assumptions

We assume a three sector base station, spectrum efficiency of 1 b/s/Hz rising to 2 b/s/Hz by 2030 per sector, busy hour traffic of 10% and utilisation of 40% and downlink spectrum availability increasing five-fold. We also assume an average of 3.5 operators with 2 sharing per site. We assume a continuous traffic distribution of form $y = ax^b$ by sites distributed with 15% of sites carrying 40% of traffic. Site costs of €70,000 per annum per site are assumed & a discount rate of 7% utilised. The model is scaled for Europe with starting point traffic of 325 PB per month based on Cisco.