Optimizing spectrum assignments to deliver expansive 5G connectivity

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What have spectrum auctions ever done for us?

The first batch of radio frequencies released for mobile services in the United States were awarded by lottery during the 1980s. At the time it was chosen as a preferred option to replace the 'command and control' or 'beauty contest' process which was deemed to be too slow, costly, fictitious, subjective and not transparent. The lottery offered 643 licenses[3] and attracted over 400,000 applicants[4], the majority of who were small time rent seekers with the intention of 'flipping' the license rather than ever building a network. It was a calamitous process that lasted six years, delaying the launch of mobile services and doing nothing to serve the public interest.

In 1993 that the United States Congress allowed auctions to be held for non-broadcast spectrum. The 1994, simultaneous, multiple round auction for 30 MHz lasted four months and netted USD 7.7 billion which covered the historical cost of the Federal Communication Commission. Its success led US lawmakers to make auctions mandatory in 1997.

Beauty contests ruled the roost across much of the world until the turn of the century at which point applying economic theory to the assignment of spectrum, accompanied by a move towards liberalisation and competition, took hold. Auctions soon became the norm with only a few countries bucking the trend and maintaining 'command and control'.

While auctions can be much more efficient than other assignment processes, when poorly designed, they can have a net negative impact, particularly when artificially inflated prices impair the balance sheets of firms that have won the right to exploit the scarce resource.

The father of spectrum economic theory, Ronald Coase, argued that for spectrum, "the delimitation of [property] rights is an essential prelude to market transactions." Once there is legal certainty around a spectrum property, to assign it, "employ the price mechanism, as this allocates resources to users without the need for government regulation." It took policy makers in the US 34 years to act on the message and implement spectrum auctions. Coase believed that with the market mechanism, "the aim should be to maximize output" of spectrum.[5] This is achieved when the right conditions are in place for the resource to be fully exploited by spectrum owners who require the necessary incentives to deploy high quality and extensively available services.

High spectrum prices realised at auction have always been a sore point amongst bidders, especially in the mobile sector. Such complaints tend to reach a crescendo when a new generation of technology – at present 5G – imposes high investment demands, and they are further compounded by the more expansive political targets for the sector.

This note argues that, while complaints about excessive prices can be fully justified in some circumstances, competitive auctions, amplified in various ways, should still play a major role in initial spectrum assignments and their design should not distort investment incentives. Further, initial assignments should be complemented by secondary trading of licences along with the ability to sub-lease amounts of spectrum to third parties. The note concludes with some practical auction assignment guidelines to ensure that spectrum output is maximised.

Auctions are desirable because they introduce competition into the assignment process. Spectrum gravitates to those who can bid more for it, which tend to be those who can use it most efficiently. Alternative 'command and control' assignment mechanisms, such as 'beauty contests', rely on judgements made by spectrum regulators which may be subjective and can be subject to gaming by the operators concerned. Indeed, one of the main drivers of spectrum auction's wide uptake and success has been down to 'beauty contests' not delivering on the planned outcome.

Despite the failings of the vast majority of 'beauty contexts' there are circumstances when they can generate good outcomes, when they are conducted in a constructive manner, which drives the market to deliver the output policy makers desire, e.g. in terms of coverage, capacity and competition. Both China and Japan do not charge upfront fees for spectrum but instead judge whether the deployment commitments of firms match the country's policy objectives and assign spectrum accordingly. Both countries currently enjoy more expansive connectivity than their global peers. Measured by the number of installed 4G base stations per person, mobile networks in China and Japan are around four times as dense as those in larger European countries and the United States. In Latin America, Chile has historically adopted a 'command and control' spectrum assignment process and its networks are around three times as dense as those in Argentina, Brazil, Columbia and Mexico.

Although network densification may be attributed to multiple factors, not least favourable planning rules and low passive infrastructure access costs, an operator's balance sheet that is not stretched through excessive spectrum payments will play a role. As noted elsewhere, network densification is a key element for the successful realisation of an expansive version of 5G and should be an increasingly important consideration for all spectrum assignment policy objectives and be reflected in how spectrum auctions are designed.[6]

[3] The Cost of Rent-Seeking: Evidence from Cellular Telephone License Lotteries, 1993, Thomas W. Hazlett and Robert J. Michaels
[4] The Political Spectrum, 2017, Thomas W. Hazlett
[5] Ronald H. Coase, "The Federal Communications Commission," Journal of Law and Economics, Vol 2 (Oct. 1959).
[6] How disruptive is 5G? Martin Cave, Telecommunications Policy Volume 42, Issue 8, September 2018, Pages 653-658. See: www.sciencedirect.com/science/article/abs/pii/S0308596118301654

Auction design evolution

The vast majority of high value spectrum auctions are contested by firms proposing to offer similar services with the spectrum on offer. However, similar approaches apply when competition is between firms providing different services, for example broadcasting and mobile communications, or fixed and mobile broadband services.

The basic mode of operation of a spectrum auction can be described as follows. An individual firm bidding independently for a spectrum licence can be conceived as forming a conjecture as to how the downstream market will develop over the licence period in terms of growth of demand, industry structure, level of competition and other factors. On that footing it estimates the revenues it might earn and its costs of supply (including a cost of capital but excluding spectrum costs). The difference between the two is the maximum it would bid for the spectrum – although it would hope to pay much less. On this basis, firms which expect to be more efficient bid higher and have a greater prospect of success in the auction.

Over the past twenty-five years, giant strides have been made in the range of auctions formats available. This is the result of huge and successful advances in the field of mechanism design. There is evidence that firms are willing to bid higher in auctions with more sophisticated designs which insulate them from some auction risks.[7]

As with the case of other natural resource rights owned by the state, such as oil and gas extraction rights, auctioning the rights to spectrum allows the state to extract the scarcity value or rents of the asset without having to operate the business itself. Absent government abuse of its monopoly power on the supply side of this process (see below), this is a non-distortive way of gaining revenue which can then be used to pursue government objectives. In deciding how to spend it the government must make a trade-off between its broader social objectives such as education, health and defence, and more focussed sectoral objectives such as extending connectivity.

Experience shows that auction processes can be adapted to further such wider social and economic objectives in the mobile sector as equitable geographical coverage and the maintenance of competition in mobile service markets. Thus, some licences can be associated with an obligation to extend network coverage into so-called 'non-commercial' areas. In addition, to maintain a competitive downstream market in mobile communications, a cap can be placed on the amount to spectrum acquired by individual large firms. Both types of condition have been widely applied, without apparent detriment to the ability of the auctions to close satisfactorily.[8] In each case, the government is sacrificing some revenue from the auction for wider coverage or more competition.

Some possible problems with auctions

Auctions can go wrong for a variety of reasons. One arises when the seller of the spectrum – i.e. the government or other relevant authority – exploits its own market power to increase auction revenues. Most simply, this can be done by hoarding spectrum which is available for release. An equally crude method is to sell all the available spectrum in one lot: the highest bidder is thus gifted market power in the downstream market, which – when valued by the method described above – generates a larger prize for that bidder. More subtly, a tranche of spectrum for release can be packaged such that only two firms can acquire significant quantities.[9] Such 'duopolists' should be capable of maintaining prices above the competitive level, but to a somewhat lesser degree than a single firm. Each of these outcomes have adverse effects on coverage, quality and price. This lowers take up of the service, restricts connectivity, and stunts economic growth and the higher government tax receipts which go with it.

If this happens, there is an association between higher spectrum prices and higher service prices, but the former are not causing the latter. The causation is the other way round: it is the expectation of the high profits caused by manipulation of the spectrum market which generates the higher bids. Some empirical evidence on this question is discussed below.

Another possible problem with auctions is that they may generate overbidding, consequent on a systematic tendency for at least some operators to harbour optimistic projections of the future and thus bid more than the spectrum is worth. When this occurs, the over-bidder might seek to retrieve the situation by raising service prices. But this would require similar action by all suppliers in the market, which is not likely to be forthcoming. Also, bidders for mobile spectrum are typically large international operators with access to appropriate advice and familiarity with the risk of the so-called winner's curse, although the curse may have prevailed in the recent German auction where the reaction of winners was sour.[10]

[7] P Koutroumpis and M Cave, 'Auction design and auction revenues,' Journal of Regulatory Economics, June 2018, Volume 53, Issue 3, pp 275–297 See: link.springer.com/article/10.1007/s11149-018-9358-x

[8] M Cave and R Nicholls, 'The use of spectrum auctions to attain multiple objectives: policy implications,' Telecommunications Policy, 2017

[9] Italy's recent 3.6-3.8 GHz provides an example where asymmetric lots [2 x 80 MHz and 2 x 20 MHz] drove record prices of €0.35 MHz/pop, some 7 times higher than the Spanish auction, held a few months earlier, for the same amount of spectrum in a comparable band.

[10] "Network rollout in Germany has suffered a significant setback…operators now lack the money to expand their networks," Dirk Wössner, DT Board member. It's a "disaster for Germany," Hannes Ametsreiter, CEO Vodafone. With the available supply cut by 25% and a new entrant enticed into the bidding process on favourable terms, the auction went on for 497 rounds. The final round had the same allocation of spectrum blocks as round 191 but with highly inflated prices.

Supply and demand

Price is a function of supply and demand. In spectrum auctions, the logic suggests that all thing being equal, greater spectrum supply will lower the price paid. As the first wave of 5G auctions plays out in Europe and the United States, the amount of spectrum supplied to the respective markets is at an extreme contrast.

The US President has declared that "the race to 5G is a race that America must win" and to give its industry the best shot, the Federal Communications Commission (FCC) has been flooding the market with spectrum and consequently spectrum licences are being sold at historically low prices.[11]

FCC Chairman Ajit Pai says "we're taking an aggressive, all-of-the-above approach: we're freeing up high, mid, and low-band spectrum for 5G. Looking high we've…made available to the private sector a combined 1,550 megahertz of spectrum." And they are not stopping there. A third spectrum auction in 2019 "will be the largest in American history, releasing 3,400 megahertz of spectrum into the commercial marketplace."[12]

Compared to the American flood, the pace of European spectrum supply is more of a trickle. The primary 5G pioneer band in Europe is 3.4–3.8 GHz and a deadline of end-2020 has been set for member states to "reorganise and allow the use of sufficiently large blocks of the 3.4–3.8 GHz band".[13]

Europe's track record on meeting such deadlines is a cause for concern and the continent can ill afford a re-run of the 4G race that saw other regions accelerate out of the blocks and assume an unassailable lead. Whereas the US had auctioned off 84 MHz of digital dividend spectrum in 2008, by 2013 only nine of 27 EU member states had come good on their spectrum release commitments and consequently the US had 10 times as many 4G subscribers.[14] Little wonder that the externalities associated with the app economy accrued to the US, where they contribute some USD 100 billion per annum to the economy,[15] but struggled to take hold in Europe.

As the table below shows, the current approach to 5G spectrum assignment in Europe is mixed. There is a high variance in prices paid that correlate closely to the amount of spectrum made available. Efficient competitive 5G auctions are currently leading problematic auctions 4-3. The margin of victory is narrow, and the game is still young.

Overview of recent 5G spectrum auctions for the 3.4 - 3.8 GHz band

Country	Supply (% of 400 MHz)	Price per MHz pop (€ cents)	Comments
Italy	50%	36	Asymmetric lots providing just two bidders with sufficiently large blocks
Germany	75%	16.8	100 MHz set aside for non telco use, new entrant enticed to bid
UK	37.5%*	13	120 MHz still on the shelf. 140 MHz was already assigned
Austria	97.5%	6	Policy goal to promote a rapid rollout of 5G infrastructure
Ireland	87.5%	5	Designed to enable national and regional footprints
Spain	50%	5	The remaining 50% of the band was acquired during the auction from an incumbent holder
Finland	97.5%	4	Policy approach and auction design cited favourably by France

*Does not include 120 MHz owned by incumbent UK Broadband (acquired by Three)

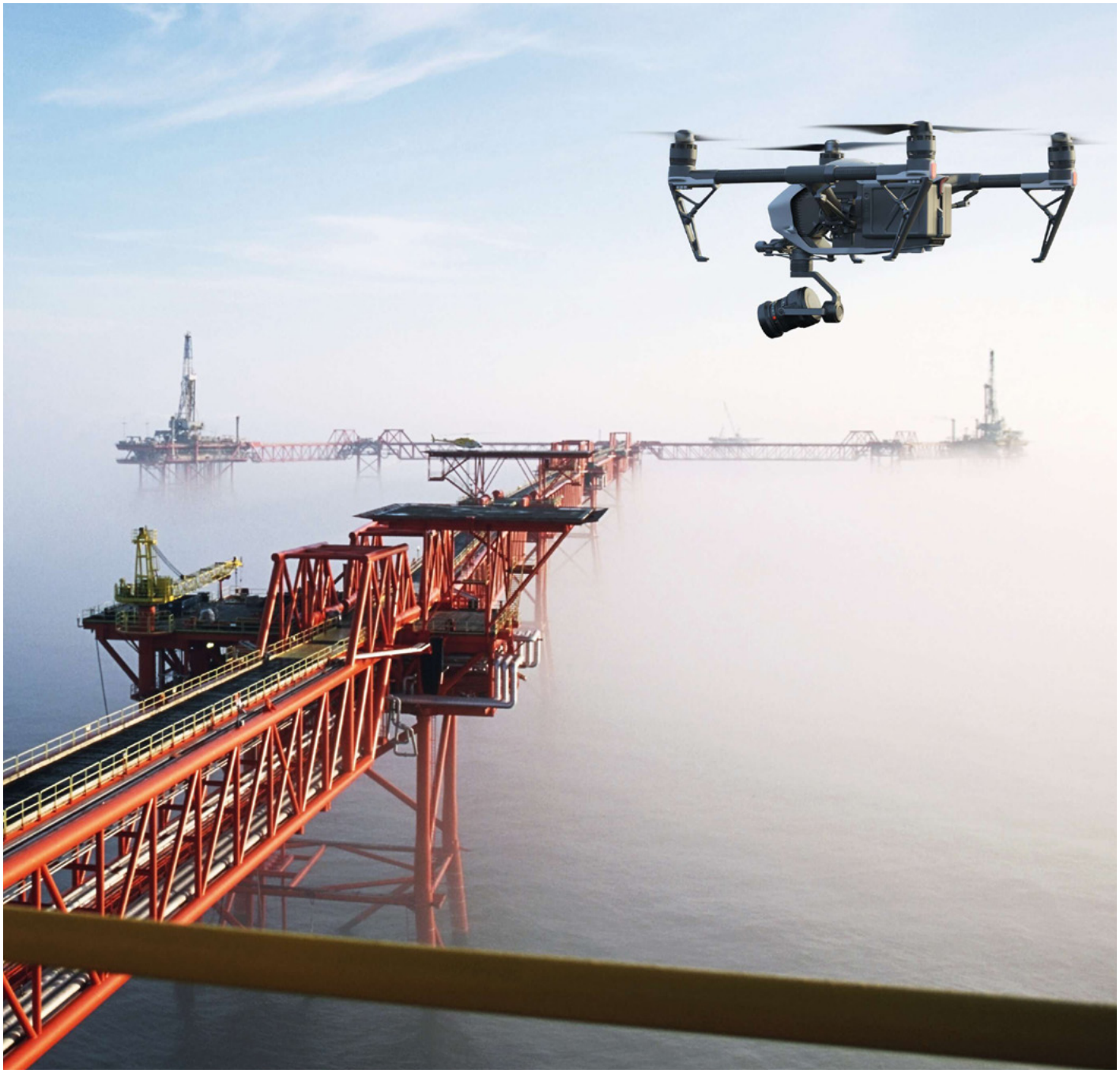
[11] www.ft.com/content/f8ad7698-b397-11e9-8cb2-799a3a8cf37b
[12] docs.fcc.gov/public/attachments/DOC-359335A1.pdf
[13] See: Article 54 of the European Electronic Communications Code
[14] www.euractiv.com/section/competition/opinion/europes-opportunity-to-lead-on-5g-deployment-is-dwindling/
[15] api.ctia.org/wp-content/uploads/2018/04/Recon-Analytics_How-Americas-4G-Leadership-Propelled-US-Economy_2018.pdf

One country that should increase the score for the efficient side is France. Following a windfall gain from the 700 MHz auction in 2015, the Macron government found that the coverage was not sufficient and subsequently reversed its spectrum policy objective from revenue maximisation to extending and deepening connectivity. The approach includes granular obligations (more of this below), an assumption that financing is exclusively from the private sector and carries a commitment to remove costly and lengthy deployment barriers.

Indeed, French Secretary of State Agnès Pannier-Runnacher said in June 2019 "We will not make the choice to maximize the immediate profit, it would delay the ability of operators to deploy." And the amount of the reserve price would be weighted "by the commitments made by telecom operators on the" deployment speed, coverage goal, nature of commitments.[16]

In Latin America, Brazil is looking to substantially increase the spectrum supply early next year and to do so using a licensing and taxation framework that will accelerate the adoption of 5G services rather than maximise revenues. A recent law has created a secondary market for spectrum and enables the regulator Anatel to extend spectrum licences an indefinite number of times with the option for operators to partially or totally convert renewal fees into binding investment and deployment targets.

Columbia is also adopting a new approach having recently enacted a law that permits spectrum to be granted with the purpose of not only raising revenues but ensuring deployment though more obligations, and purposefully calling out local governments to remove deployment barriers in return for prioritised coverage. It also allows for secondary trading and doubles the period of the license term.



[16] www.newsy-today.com/5g-government-says-it-wants-to-avoid-crazy-auctions/

The effects of spectrum prices on service prices

We now compare two states of the world. In one competition among bidders yields a competitive outcome. In the other, spectrum prices are lower by a given amount. What happens to the extra profits put into the sector? The context is assumed to be the commonly-encountered one in which spectrum fees for the whole licence period are paid at the start. In other words, they are a sunk cost.

Normal economic reasoning suggests that firms price on the basis of what they expect their forward-looking costs to be, on their interpretation of competitive interactions with their rivals, and the strength of demand. Thus their pricing decisions are not affected by any reduction in spectrum fees. Consumer prices stay the same, so any reduction goes to investors as profit.

What does the evidence say on this matter? A recent academic article bears explicitly on this question, examining the link between auction prices and outcomes in downstream service markets.[17]

The estimation procedure it employs must cope with the issue of causation (or 'endogeneity') noted above: that is, it must establish whether high spectrum prices cause high service prices or whether high service prices cause high spectrum prices. Based on data for 24 countries over the period 2005-2014, the authors' conclusion is that

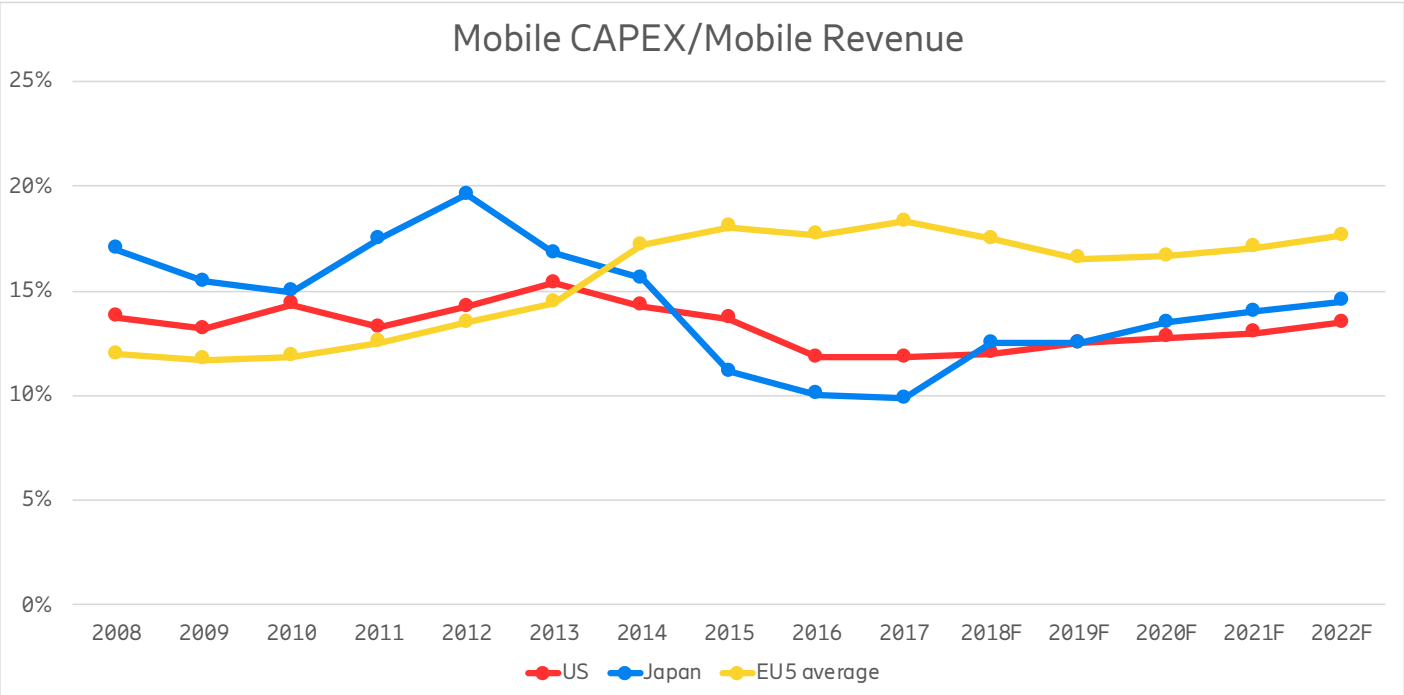
> "after controlling for the potential endogeneity, spectrum fees do not seem to be correlated with spectrum revenues.... The lack of significance of spectrum licences on revenue can thus be interpreted as a sort of "correct" forecast of future revenues by mobile operators in the licence paid: the cost of the licence already incorporates the future increase in revenues but it does not have any further incremental effect on them." (page 363)

The effects of spectrum prices on levels of investment

How would investment be affected? Many critics of standard auctions argue that the high spectrum prices leave no room for investment in the mobile networks. But on the face of it, we might expect each firm in the market place to take investment to the point where additional investment ceased to pay for itself in terms of the gap between incremental revenue and incremental costs (which, assuming the auction was efficient and not problematic, would exclude sunk spectrum costs). This would be the same limit irrespective of the sunk cost of spectrum.

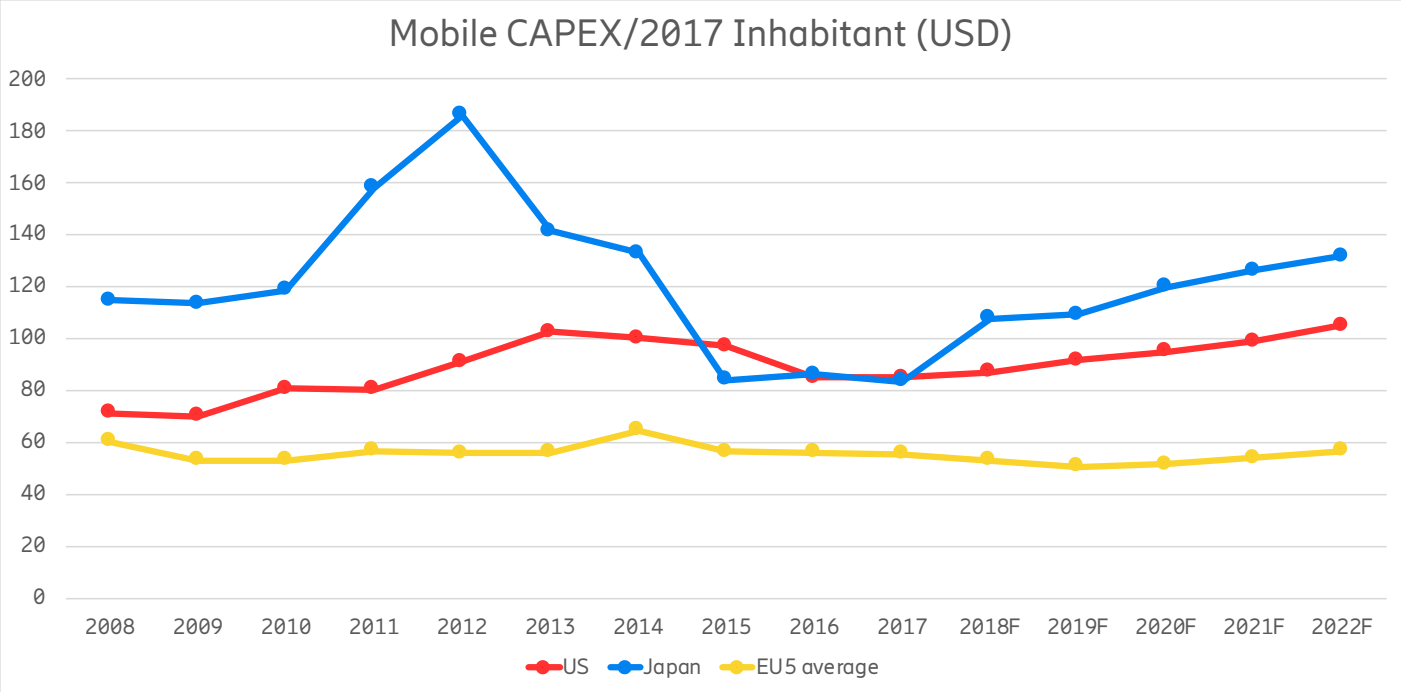
But there are some circumstances in which this would not apply. If an operator faced a constraint on what it could borrow in the capital markets, that constraint would be tighter with a higher spectrum price, and higher spectrum prices would reduce investment. Different operators would be differently placed with respect to capital constraints. This matter would have to be examined on a case-by-case basis. One might conjecture that capital constraints might be more severe for smaller, later-entering operators, which are the likely beneficiaries of spectrum caps.

There is evidence that such constraints are very much in play. On a regional comparison basis, European operators have greater capital constraints than their peers in, for example, Japan or the United States. As the graph below shows, CapEx to sales ratios of European operators are currently at historically high levels, well above the levels in the US and Japan.[18]



[17] C Cambini and N Garelli, 'Spectrum fees and market performance,' Telecommunications Policy, (41) 2017, 355-366.
[18] See: northstream.se/insights/white-papers/5g-outlook-in-europe/

And as we move into the 5G era, policy makers in Europe should be concerned of the ability of other regions to continuously invest more per capita. The graph below shows Japan and the US consistently investing more per inhabitant for more than a decade.[19] Not only does this put at risk consumer welfare, but also Europe's relative competitiveness with other regions that will adopt digital transformation at a quicker rate. Looking forward, over the five-year period between 2020 and 2025, when capex will predominantly support 5G network deployment, the accumulated investment gap could be more than $100 billion.[20]



That said, offering general encouragement to firms to invest beyond the point where incremental revenues equal incremental costs would not necessarily promote greater social welfare: investment is an input, not an output, and not desirable for its own sake. Where additional outputs are wanted – for example, deployments which extend the coverage of a service - they can be incorporated in the auction process through coverage obligations.

It is worth noting that a recent GSMA report concluded that while there is inconclusive evidence of spectrum prices being correlated with higher service prices, there is stronger causal evidence that higher spectrum prices have a negative impact on coverage as well as download and upload speeds.[21]

[19] Ibid
[20] Roles and Effects of Access Regulation in 5G Markets, 2018, Johannes M. Bauer and Erik Bohlin
[21] See: https://www.gsma.com/spectrum/wp-content/uploads/2019/09/Impact-of-spectrum-prices-on-consumers.pdf

Ever more granular coverage obligations

Auction design today will have a material impact on the version of 5G that is realised. For a limited version, in which 5G is a quicker and more efficient version of 4G, spectrum policy and license terms continue largely unchanged. But for an expansive version, where fast and low latency communications capacity is available everywhere and "digitizes" industry verticals not yet much penetrated by intelligent connectivity, spectrum policy needs to change course.

Historically, obligations on network deployment contained in auctioned licences have typically been measured as a percentage of the population covered. They have often applied to spectrum assigned for a new generation of technology where the initial condition is one of zero coverage. Subsequently, it has become apparent that, for a variety of circumstances – based on a combination of topography, demographics and other factors - some locations are either not covered at all ('not-spots') or left uncovered by one or more operators. Regulators have taken a number of **ex post** measures to fill in these gaps. An example relating to France is discussed below.

The combination of 5G and the imminent more widespread digital transformation within general social and economic arrangements creates an opportunity for a step change in the uses to which connectivity can be put, in a fashion which has the capacity to transform many sectors – i.e. have major positive external effects – if the connectivity is widely available. In order to profit from a more expansive version of 5G connectivity, which delivers the potential efficiencies and externalities associated with the wider application of the industrial internet, e-government and Smart Cities (to name but a few applications), obligations are becoming more granular.

Coverage goals may still include a population percentage but are being extended to geographic targets including roads, railways and inside buildings. Regulators are also considering obligations that include consistent levels of quality and experience, currently measured by minimum speeds but that may extend to throughput and latency.

There is thus a case for governments to stipulate more granular obligations in licenses subject to auction. In doing so, they would accept less revenue upfront, but they would attain a better and more equitable market outcome within a given timeframe.

Licence renewals

Renewal decisions are of ever-increasing weight in spectrum management, as more bands have been put to higher value use in past decades. In such cases a decision must be made whether to renew or to re-auction the relevant licences. Re-auctioning opens the door to possible new entry or to the rebalancing of existing operators' holdings if they are no longer proportionate to market shares, but it may cast a blight on investment at the end of the earlier licence. Moreover, if incumbent licensees have a major cost advantage in the following period, competition for the licence may be weak. Renewal on the other hand requires the regulator to bargain with incumbents or to make an 'as if auctioned' valuation. It is not surprising that spectrum regulators in different jurisdictions have come down on either side in making this decision.

A notable recent spectrum decision in France has linked licence renewal with the goal of 4G network deployment being brought forward. In summary, the regulator ARCEP, with the support of the French government, agreed to waive the fee for renewing the spectrum licences of operators in the 900, 1800 and 2100 MHz band frequency licences expiring between 2021 and 2024, on condition that those operators made immediate additional deployments to extend and improve 4G connectivity.[26] The precise nature of the additional deployments was agreed by bilateral bargaining between the regulator and each company individually.

This process is functionally equivalent to the government borrowing money from the companies to pursue its deployment objectives now and repaying the loan by the abatement of spectrum charges later. The implicit interest rate of the 'loan' is not known, but one might expect the firm to seek to recover at least its own cost of capital. Since the loan is given in kind (increased deployment) and repaid in cash (fees abated), the borrowing side must have accurate information on the costs of incremental deployment in order to secure a good deal. In a regime of bilateral bargaining with each operator, there is no mechanism for competition among operators to take effect.

Of course, this approach only works in the context of licence renewals. It is hard to imagine that many spectrum regulators would agree fully to waive operator charges on a newly released 5G band. On the other hand, as noted above, new 5G spectrum can be assigned subject to more granular coverage obligations, focussed on general benefits to a country, than happened with 3G and 4G spectrum. Some governments understand that there is a trade-off between maximising spectrum revenues and operator's ability to deploy networks and are choosing to trade up to expansive connectivity.

[22] www.cerre.eu/sites/cerre/files/170330_CERRE_5GReport_Final.pdf

[23] Two 5G variants can be identified: a limited version, in which 5G is a faster and more efficient version of 4G, specialising in enhanced mobile broadband, and an expansive version in which very fast and low latency communications capacity is going to be available everywhere, and employed in 'verticals' not yet much penetrated by connectivity, such as connected cars, advanced manufacturing and e-health. See W Lemstra, 'Towards the successful deployment of 5G in Europe: What are the necessary policy and regulatory conditions?' Telecommunications Policy 2018[24] Two 5G variants can be identified: a limited version, in which 5G is a faster and more efficient version of 4G, specialising in enhanced mobile broadband, and an expansive version in which very fast and low latency communications capacity is going to be available everywhere, and employed in 'verticals' not yet much penetrated by connectivity, such as connected cars, advanced manufacturing and e-health. See W Lemstra, 'Towards the successful deployment of 5G in Europe: What are the necessary policy and regulatory conditions?' Telecommunications Policy 2018

[24] Thus the obligations attached to the 700 MHz 5G assignment in Italy call for operators to cover 99.4% of the population (4.5 years after the spectrum is released) and to cover the principal national roads and railways (3.5 years after spectrum is released) through reciprocal roaming agreements. The planned German auction calls for 98% population coverage with 100 Mbps, the same speed along all federal highways and important roads with 10 millisecond latency by end 2022.

[25] The Austrian regulator is proposing a direct trade off where operators agreeing to cover poorly covered areas will receive rebate on spectrum bids placed by them.[26] Thus each operator will deploy 5,000 new 4G sites across the country (with some shared sites), using its own funds. There will also be 1,000 new sites for fixed 4G. 4G coverage will be ubiquitous by 2022.

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Conclusions

Over the past 25 years, spectrum auctions have become a standard means of assigning high value spectrum. They have offered a competitive means of allocating spectrum efficiently among operators, at a time of large increase in spectrum scarcity. It does not seem likely that the allocation system they replaced – 'beauty contests' – could have achieved this goal.

Auctions allow the government, not the operators, to capture the rents associated with that increased spectrum scarcity, and use them for various public policy objectives, including policy objectives pertaining to the mobile sector itself. Spectrum auctions have also had grafted on them, in the form of spectrum caps and coverage obligations, by means of which greater downstream competition and wider deployment of networks can be gained at the cost of some of the government revenues achieved. Obligations are an increasingly important trade off to consider in wake of the potential positive external benefits that could be associated with the expansive version of 5G.

This would be a more constructive approach than a poorly constructed 'command and control' approach. It retains the competitive advantages of spectrum auctions, which have brought considerable benefits to the countries which have employed them. At the same time, auctions can be adapted to the new circumstances, and the balance between government revenue and increasing deployment can be flexed. This is likely to be a better course of action than 'throwing the (auction) baby out with the bathwater.'

To promote the reach, availability and quality of connectivity some auction best practise approaches have emerged:

- Align spectrum pricing with policy goals, for example, by including coverage obligations in the pricing objective
- Package spectrum into small lots to enable rational and competitive bidding
- Avoid sealed bids, reduce complexity and ensure transparency
- Avoid set asides and artificial scarcity and maximise the spectrum available per band. C-band assignments in many countries keep aside spectrum that is being held by incumbent users that ultimately must be moved out of the band
- Maximise license duration to increase the asset life and investment horizon and set out renewal criteria to reduce uncertainty around investment
- Ensure predictability and allow for budget planning by providing a clear road map of spectrum assignment over the medium to long term
- Allow secondary trading of licences along with the ability to sub-lease amounts of spectrum to third parties

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