GSMA Spectrum

# Effective Spectrum Pricing: Supporting better quality and more affordable mobile services

**Full Report**
February 2017

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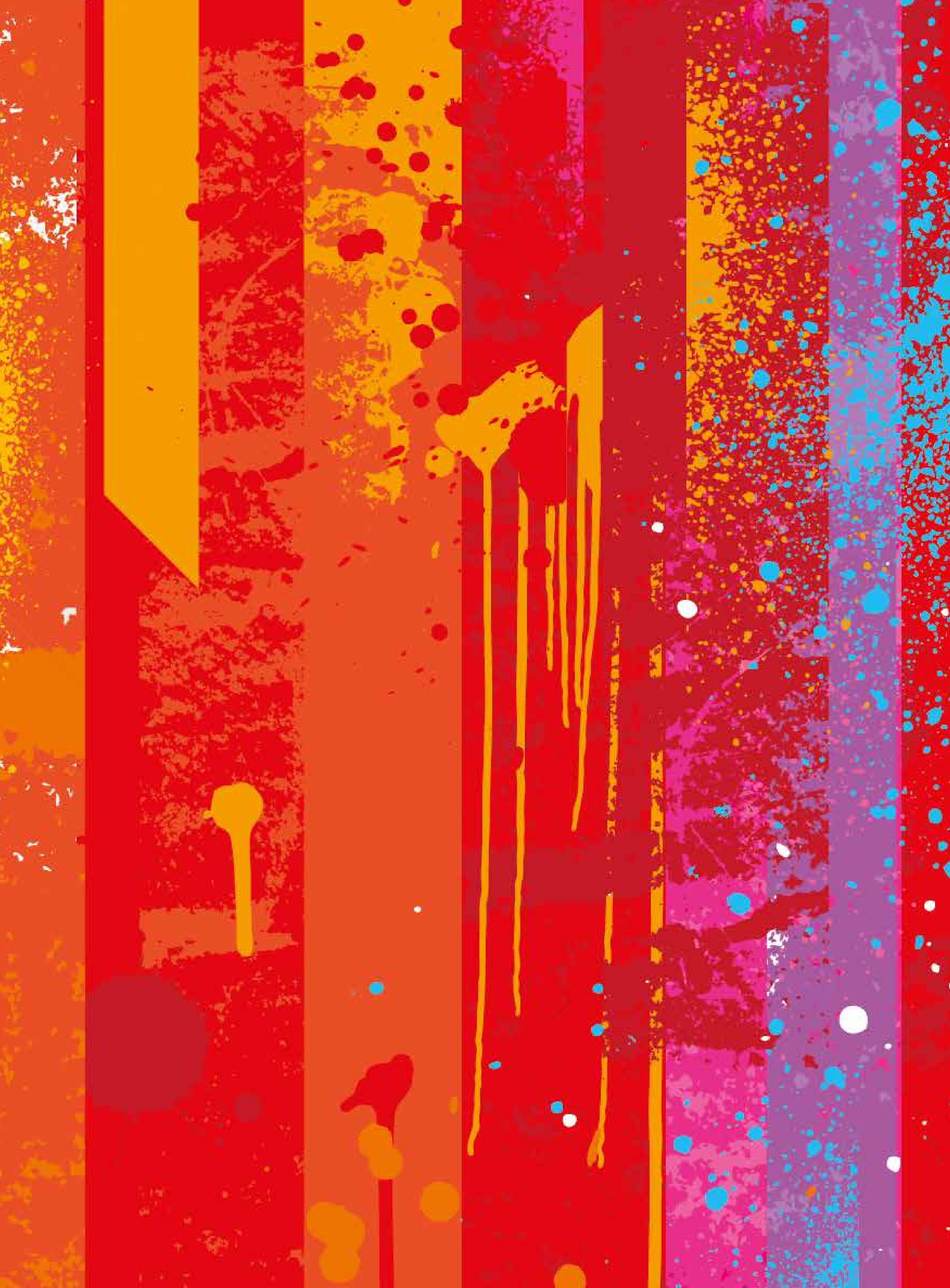


# Executive Summary

Radio spectrum is the key input underpinning the mobile industry. In this report, NERA Economic Consulting explores the relationship between the pricing of radio spectrum and the success of countries worldwide in developing markets for next-generation mobile data services. In the past, some observers of the industry have suggested that the amount of money that operators spend on spectrum should have no impact on the development of mobile services, as spectrum costs are sunk. This report firmly rejects that viewpoint by demonstrating that high spectrum prices negatively impact consumers and efforts to maximise revenues from spectrum auctions can damage the wider economy.

The report presents new empirical evidence, consistent with related academic literature, that links high spectrum spend with:

1. **Lower quality networks and reduced take-up of mobile data services owing to reduced incentives for investment;**
2. **Higher consumer prices for mobile broadband data; and**
3. **Lost consumer welfare with a purchasing power of US$250bn across a group of countries where spectrum was priced above the global median.**

### The right price for spectrum

The main rationale for charging a price for spectrum, whether through upfront fees or annual charges (or both), is to promote its efficient use. Price is an objective tool for regulators to distinguish between the business cases of potential users. Of course, pricing also generates revenues for the State and – in some countries – raising revenue is identified as an additional objective in spectrum awards. However, even governments that place a high importance on revenues should prioritise efficiency in allocation, so as to minimise the risk of award failure and maximise benefits to society. A regulator engaged in best practice should set auction reserve prices that are below a conservative estimate of true market value to enable price discovery and facilitate efficient allocations.

Both theoretical and empirical work from academia inform us that, in industries with natural limits on the number of viable operators, high input costs depress incentives for investment and price competition. Although upfront fees paid for spectrum are sunk, they continue to weigh on the business decisions made by operators and their owners throughout the licence term, and affect their approach to future spectrum awards. This observation reinforces the point that policymakers should never seek to price above the fair market level, as the revenue upside (if any) is more than offset by the risk of award failure and the long-term downsides for consumers.

### How spectrum prices impact mobile services, the economy and consumers

To explore the link between spectrum prices and investment and competition in mobile services, we conducted our own empirical research, using data from NERA's database of spectrum awards, covering 325 spectrum band releases across 60 countries from 2000-2016. We observe that, over the last eight years, both reserve prices and price outcomes have trended upwards.[1] While price outcomes for many awards remain moderate, the upward trend appears to be driven by a growth in the number of high price auctions, including many where reserve prices were set well above the global mean.

1 A three-year moving average of spectrum prices from 2008 to 2016 shows the average final price paid for spectrum sold at auction increased 3.5 fold, while average reserve prices increased over 5-fold.

Consistent with the academic literature, we also find statistical evidence linking higher spectrum prices to low investment in 4G and higher consumer prices for data. For countries holding spectrum awards from 2008-2016, we developed a 4G wireless score, which measures the quality and uptake of next-generation data services. We found that countries with lower spectrum costs have higher wireless scores than those with higher costs, after allowing for differences in economic development. We also found that countries with lower spectrum costs have lower consumer prices for data. By incorporating these findings into an econometric model of demand for data services, we demonstrate that high prices for spectrum are destroying billions of dollars in consumer welfare. If all countries in our dataset that have high spectrum prices had instead sold spectrum at the median price level, this could have generated incremental value for society with a purchasing power of US$250bn.

In other words, where governments adopt policies that extract excessive financial value from the mobile sector in the form of high fees for spectrum, a significant share of this burden is passed onto customers through higher prices for mobile and lower quality data services.

### Mistakes in spectrum pricing

Mistakes by policymakers when pricing spectrum can be grouped into three broad categories:

1. **Reserve prices and annual fees set above true market value. We highlight multiple examples linking high prices to award failure, including recent 4G processes in Mozambique, Ghana, and Senegal.**
2. **Artificial scarcity or uncertainty over future spectrum availability. We highlight the case of India, where a combination of over-pricing and delays in releasing spectrum has led to inflated valuations and also caused valuable spectrum to go unsold.**
3. **Inappropriate award rules. We identify award rules that create risk for bidders or options to foreclose competition. For example, we highlight distorted price outcomes in Austria, where the auction design put enterprise value for incumbent operators at risk, and the damaging effects of onerous coverage obligations in Argentina.**

These blighted spectrum awards are contrasted with more positive examples, notably Sweden, where the regulator has a track record of setting fair reserve prices, bringing spectrum to market in a timely manner and managing risk for bidders, for example in relation to rural roll-out. We do not think it is a coincidence that Sweden has amongst the highest wireless scores and lowest consumer prices for mobile data in our dataset.

### Observations from other industries

Mobile communications is one of a wide range of industries dependent on essential inputs provided by public authorities. We surveyed a number of industries and compared their approaches to pricing and allocation to policies used in the mobile sector. We also sought to understand how these practices varied across industries depending on the characteristics of that industry, namely: the level of competition in downstream markets; the risk profile of the investment; and whether the resource is renewable (like spectrum) or depletes (e.g. minerals).
In those industries with similar attributes to mobile, regulators engaged in best practice:

- **rely on the market to set prices;**
- **encourage full utilisation of the resource;**
- **take measures to mitigate risk for operators; and**
- **adopt a long-term perspective to social value creation.**

For example, best practice regulation of the airline industry prevents airports from exploiting monopoly power when pricing airport landing slots, and encourages full utilisation of capacity. In Europe, such policies have supported huge growth in air travel, including the low-cost carrier revolution. By analogy, pricing spectrum above market level or holding back spectrum from the market is equivalent to encouraging airports to cut the number of flights and raise landing fees, in the hope of raising more revenues from airlines, at the expense of paying travellers.

## Recommendations

With the increase in spectrum bandwidth needed to support high data traffic in a 4G and 5G world, fair pricing techniques will become ever more important to support efficient spectrum allocation, promote healthy investment in networks and encourage sustainable competition to support affordable services. Countries that persist with excessive pricing, constrain available spectrum, or enact conditions, rules or policies that place undue risk and cost burdens on operators, risk experiencing a widening gap in quality and pricing of the mobile services available at home versus abroad. Actions that depress growth and competition in mobile services have obvious negative implications for the broader economy, with the result that long-term losses in consumer welfare and tax revenues will outweigh any short-term gains from unduly high upfront or annual spectrum fees.

We have four recommendations for best practice in spectrum pricing:

1. **Set modest reserve prices.** Minimum prices for spectrum – taking into account both upfront reserve prices and annual fees – should be set below a conservative estimate of market value, so there is scope for competition and price discovery in auctions.
2. **Prioritise spectrum allocation.** Regulators should aim to bring spectrum fully to market as soon as it is needed, and provide clear signposting for future releases (e.g. through a spectrum roadmap). Because spectrum is a renewable resource, when it is left unallocated for any prolonged period, welfare benefits that would have accrued to consumers are lost forever.
3. **Help operators manage risk.** Prices paid for spectrum can be distorted if bidders in spectrum awards face undue risks. Regulators can mitigate such effects, for example by avoiding award rules that put enterprise value at risk, and off-setting onerous overage obligations with comensurate price concessions.
4. **Adopt a long-term perspective.** When policymakers plan spectrum awards, they should ideally prioritise long-term welfare benefits over short-term revenues. Measures that de-politicise spectrum pricing, such as devolving decisions to independent regulators or undertaking cost-benefit analysis are advised and are becoming more common.

# 1. What is the right price for spectrum?

Radio spectrum for deploying mobile networks is in limited supply. Only frequency bands that are integrated into mobile handsets and network infrastructure can be used to provide services. To provide a quality mobile broadband service (without undue interference), operators require exclusive access to adequate spectrum bandwidth, across multiple frequency bands. This, in turn, tends to limit the number of mobile network operators that can be accommodated in any given geographic area, and provides a rationale for governments to manage access to spectrum and charge for spectrum licences.

How regulators decide to price mobile spectrum bands has a big impact on the evolution of mobile services. If prices are set too high or are otherwise distorted by poor policy choices, this will negatively affect investment decisions, which may be manifested in slower data speeds, reduced network capacity, or reduced scope for price competition in mobile services. In contrast, if prices are set at fair levels, they can help ensure that spectrum use generates maximum benefits for society, while also raising revenues for the state, directly through spectrum fees and, more importantly, indirectly through accelerated GDP growth and tax revenues. The value of the mobile economy – which relies on spectrum – is sizable. According to the GSMA, in 2015, the mobile economy (directly and as an enabler of adjacent sectors and services) contributed US$3.1tn to global GDP (i.e. 4.2%) – and paid US$430bn in taxes (excluding spectrum payments). It also directly provided 17 million jobs and supported a further 15 million indirectly.[2]

We begin this chapter by setting out the core components of spectrum price. Our key point here is that a spectrum price includes not just the upfront fee but also any annual charges associated with spectrum holdings. We then discuss the rationale for spectrum pricing, as a tool to promote efficient use of spectrum. We make the point that even governments that place a high importance on revenues should prioritise efficiency in allocation, so as to minimise risk of allocation failure and maximise benefits to society. Next, we explore the notion of effective pricing for spectrum and how this may be achieved in practice. We make the case that a regulator engaged in best practice should set prices below a conservative estimate of true market value to allow for price discovery in an auction. This argument is reinforced by theoretical and empirical evidence that mobile operators do not, in practice, treat spectrum prices as sunk costs, and that high prices depress incentives for investment and retail price competition.

2 The Mobile Economy Report 2015, GSMA.

## 1.1. The components of spectrum price

Regulators impose a variety of upfront fees and annual charges on mobile network operators for licences to access mobile spectrum. These fees and charges together form the price that mobile operators must pay for the spectrum necessary to deploy their networks.

The price for spectrum sold has up to three components, as illustrated here (if the spectrum is awarded directly without an auction, then the competitive premium, which arises from bidding activity, is not relevant):

**UPFRONT RESERVE PRICE** + **COMPETITIVE PREMIUM** (IN AUCTION, IF ANY) + **ANNUAL FEES** (DISCOUNTED COST OVER LICENCE TERM)

Approaches to setting fees vary widely: some regulators put more weight on upfront fees, others on annual fees; some set low reserve prices and rely on the market to determine an adequate competitive premium; others opt for fixed fees or higher reserve prices that limit the range of possible price outcomes. There are advantages and disadvantages to each approach. When looking at award outcomes, commentators often focus only on the upfront price (reserve price plus competitive premium) and neglect the annual fees. This is misleading, as the cumulative cost of fees over the licence term may be substantial. In general, the relative weight placed on different components of spectrum prices is less important than the aggregate level.

Auctions are now the most widely used mechanism for allocating mobile spectrum, especially amongst countries with larger populations. They are particular widely used for awards of new mobile bands, and also are used where a regulator decides not to renew expiring spectrum licences but to re-award them.

For example, in the EU, 24 out of 28 countries used auctions to allocate 800 MHz spectrum, and 12 out of 28 countries used auctions to re-allocate 900 MHz spectrum. Regulators invariably set a reserve price for radio spectrum. Sometimes, as in Sweden or Germany, reserve prices are set at a modest but non-trivial level sufficient to deter frivolous entry, and to ensure winners pay at least the “opportunity cost” of denying the next-best use case (e.g. broadcasting). In other cases, as in France, the reserve price may be set closer to the perceived market value of the spectrum, in an effort to guarantee substantial returns for the treasury.

Even in countries where administrative processes are used for some or all awards of mobile spectrum, fixed prices are often set with reference to auction outcomes, either at home or abroad. For example, in the UK, licences for 900 MHz and 1800 MHz spectrum were renewed rather than re-auctioned, but the annual fees were set with reference to the outcome of the UK 4G auction and other comparable awards in Europe.

In addition to upfront fees, most regulators impose annual fees on operators, which are at least sufficient to recover the administrative costs of managing spectrum. Such fees are usually set proportional to the amount of spectrum, and may vary by band. Often, regulators (e.g. Denmark) set higher administrative fees for bands designated for use by higher value services, such as mobile, and for bands with particularly attractive propagation characteristics, such as sub-1 GHz spectrum. Typically, even with such variation, these fees are modest relative to the value of the licence. However, some regulators (e.g. Mexico) impose higher annual fees, which go well beyond the levels required for administrative cost recovery. In this case, these fees become an important component of the reserve price, and expectations for potential auction prices should be moderated accordingly.

The price of spectrum should not be confused with its value to operators, which depends on a combination of estimated incremental revenues and avoided costs from deploying the spectrum, less any incremental costs associated with licence conditions. In a properly functioning market, companies bid to acquire spectrum when their estimated value (adjusted for commercial risk) exceeds the price. When regulators attach licence conditions – such as rural coverage obligations or quality of service commitments – to spectrum licences, they may reduce the value that operators place on spectrum. This in turn reduces the willingness to pay of operators for additional spectrum, and thus reduces the market price of spectrum.

## 1.2. Spectrum pricing – a tool for promoting efficient use and maximising benefits to society

### Efficiency and revenues

The academic literature on pricing of scarce resources attaches primary importance to allocating those resources efficiently so that the benefits for society from its use are maximised. For example, in relation to spectrum, Martin Cave and William Webb say that:

*"The radio spectrum is a resource of great significance to all modern economies. The importance of services supported by radio spectrum has grown markedly in recent years, especially as more and more mobile communications applications take hold among the world's population. It is thus critical that this increasingly important resource is allocated efficiently, in a way that* ***maximises the benefits which people gain from their individual use of services*** *such as mobile telephony ..."* [3]

Leading regulatory bodies, such as the European Commission and FCC (United States) also identify efficiency as the primary objective in spectrum allocation. Efficiency is a universal concept that should apply to every government body concerned with regulating spectrum, whatever the size or wealth of the country concerned. An efficient spectrum allocation is one in which spectrum is distributed amongst operators in a way that allows them to collectively generate the greatest welfare for society, including both consumers and firms. When an efficient allocation is achieved, other goals, such as maximising the economic benefits for individual users of services and promoting a competitive mobile market should also be achieved.

Spectrum pricing also generates revenues. For many regulators, notably those in Germany and Sweden, revenue is not a priority – their focus is on the longer-term benefits to consumers and the broader economy through promoting mobile services and a digital society. However, for others, revenue generation may be an important policy consideration, for fiscal reasons and to demonstrate a "fair return" for taxpayers. For example, the United States and Indian governments have both opted to set revenue targets for major mobile auctions, albeit with mixed outcomes. Inevitably, the importance attached to revenues will affect decisions on spectrum pricing, in particular regarding a regulator's perspective on the minimum acceptable price outcome. Nevertheless, it is important to recognise that regulatory goals for spectrum awards are not all equal.

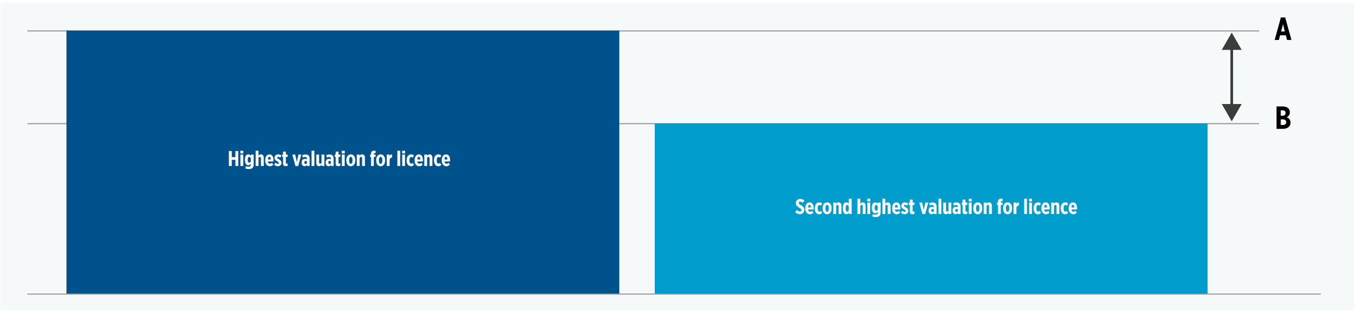
3 Martin Cave and William Webb, Spectrum Management - Using the Airwaves for Maximum Social and Economic Benefit, Cambridge University Press, 2015, p.42. Emphasis added.

Maximising benefits to society by promoting efficient use should always be the primary objective. Revenues should always be a secondary objective. Spectrum pricing is a tool that can help regulators achieve an efficient allocation, which also offers the added benefit that it generates revenues. As we will demonstrate in this paper, with appropriate safeguards against low revenue outcomes, award rules that prioritise efficiency are the best approach to minimise risk of allocation failure and maximise benefits for society (including tax revenues) over the medium-to-long term.

### The role of price mechanisms in promoting efficient use of spectrum

Price mechanisms, implemented through primary awards or secondary trading, encourage spectrum to flow to the operators that can generate the highest value. To understand this point, it is helpful to consider the simplest case of one licence and two bidders, as illustrated in Figure 1: the strongest bidder (with bid amount A) should win the licence, and the price (B) is set by the bid amount of the second highest bidder. B also represents the "true market value", as it is the price that should emerge in a properly functioning market in which all participants reveal their true willingness to pay.

FIGURE 1: TRUE MARKET VALUE (B) FOR A SINGLE LICENCE AUCTION




An efficient allocation is not possible at a price above A, as no rational bidder would buy the spectrum licence. Failing to sell a licence because it is over-priced imposes an opportunity cost on society.[4] This includes not only producer surplus[5] that would have flowed to the operator but also, more importantly, lost consumer welfare from the service enhancements and lower mobile data prices that would have flowed from the deployment of the spectrum. Although the spectrum may still be allocated later, the lost welfare benefits during the delay can never be recouped. Such costs can be very high. For example, Hausman (1997) calculated the loss in consumer welfare associated with the 7-10 year regulatory delay in approving the widespread availability of mobile telephones in the United States at up to $24.3bn a year in 1983 dollars.[6]

In contrast, an efficient allocation is possible at any price below A, as the strong bidder will always have a business case to buy the licence. In principle, this is true even if the licence were given away at zero price to another bidder, as any inefficiency can be resolved through trading. However, in practice, as Coase (1960) and Myerson and Satterthwaite (1983) observed, the secondary market is not necessarily a panacea, as there may be barriers to trade, such as transaction costs[7] and informational asymmetries.[8]

Therefore, it is prudent for governments to aim for an efficient primary outcome if possible, and rely on the secondary market to resolve future changes in the efficient allocation.

Spectrum auctions typically involve multiple licences or units of spectrum that can be aggregated to form licences. In a multi-unit auction, point A in Figure 1 is equivalent to the valuation of the weakest winning bidder, and point B is the valuation of the strongest loser (which could be another bidder or a winner that would have been willing to buy more spectrum). In all cases, the general principle that spectrum should be always priced lower than the value of the weakest winner (A) holds.

Although an efficient outcome is possible at any price between zero and A, this does not mean that an efficient outcome is equally likely at any price level in this range. Auction theory – backed by observations from actual spectrum auctions – tells us that efficient outcomes are less likely at either very high or very low prices. More specifically, award failures are most likely when regulators try to price above or close to true market value (B). Good practice would recommend setting the price below B (the strongest loser value) to allow his participation.

4 The opportunity cost to society is the loss of potential gain from using the spectrum in the period when it instead goes unsold.

5 Producer surplus is an economic measure of the difference between the amount a producer of a good (or service) receives (price) and the minimum amount the producer is willing to accept for the good (cost). The difference, or surplus amount, is the benefit the producer receives for selling the good in the market.

6 Hausman, J (1997), "Valuing the effect of regulation on new services in telecommunications", Brookings Papers on Economic Activity, Microeconomics.

7 Ronald H Coase (1960), "The Problem of Social Cost", Journal of Law and Economics. 3 (1): 1–44.

8 Roger Myerson and Mark A. Satterthwaite, "Efficient mechanisms for bilateral trading", Journal of Economic Theory 28 (1983): 265-281.

The following considerations are particularly relevant for setting reserve prices for mobile spectrum:

1. **Valuation uncertainty.** Spectrum valuations are based on long-term business cases, involving assumptions about network deployment, and technical and commercial trends. Many of these assumptions are uncertain and subject to a variety of external risks, so valuations are typically subject to a wide margin of error. Of course, if it is difficult for a bidder to value a spectrum licence, it is even more difficult for a regulator to do so. A reasonable regulator may try to estimate both "A" and "B", but should assume a wide error band. If a regulator is prioritising efficiency, then this implies a need for caution when setting reserve prices, so as to avoid the risk of inadvertently pricing too high and not selling spectrum.
2. **Price discovery.** As mobile operators usually deploy spectrum in similar ways, there is typically a high degree of common value in their business cases for spectrum. Also, bidders are often uncertain about the same factors, such as the timing of availability of handsets incorporating new bands or future growth in data demand. Accordingly, bidders may benefit greatly from price discovery during an auction. Auction theory tells us that price discovery can ease common-value uncertainty, and encourage bidders to bid a higher proportion of value (equivalent to raising B in Figure 1). This is especially relevant in auctions with many spectrum lots, where bidders can vary their demand. Of course, price discovery is only possible in a multi-round auction setting when bidding starts at prices below the true market level.
3. **Cost recovery.** Governments incur costs when managing radio spectrum. In the case that spectrum is allocated for exclusive use, it is reasonable for governments to expect the licensees to cover those costs, including making a contribution to common costs. Cost recovery, which is often covered through annual fees, may be seen as a lower bound for the price of mobile spectrum.
4. **Demand reduction.** In certain market situations, if the minimum price for spectrum is set at a very low level relative to the true market value (B), then bidders may have a financial incentive to reduce their demand at prices below valuation. In principle, this could be achieved by merging bidder groups, unilaterally dropping demand for spectrum lots, or taking advantage of auction rules to tacitly coordinate demand reduction across operators. Demand reduction may result in lower auction revenues, and may or may not be a concern from an efficiency perspective. This is a rationale for not pricing bands known to be valuable at very low levels. However, it is not a strong rationale for pricing above a conservative estimate of market value, not least as there are other tools (such as auction design) that can be used to reduce incentives for demand reduction, if this is a concern.
5. **Bidder asymmetry.** Within each market, there are often predictable asymmetries between bidders, for example between entrant and incumbents, or between incumbents in terms of market share or financial backing. In some cases, such asymmetries may deter participation by entrants or act as a focal point for demand reduction. If regulators are concerned that competition in the award process will not materialise, they may be inclined to set higher reserve prices. However, this comes with significant risks as if operators perceive that reserve prices are set too high, for example above B, they may refuse to acquire licences, as they anticipate that there are no other buyers at these prices. Such impasses are bad for everyone: the government does not get its revenues, operators do not get their spectrum, and welfare benefits to consumers and society at large are delayed. Overall, concerns about competition linked to bidder asymmetries provide a rationale pricing relative to market value, but still being conservative so as to ensure the price is below B.

## 1.3. Effective pricing of spectrum

In an auction, an efficient allocation of spectrum will materialise provided that bids reflect the true relative values of operators. Government can facilitate this by engaging in effective pricing practices.

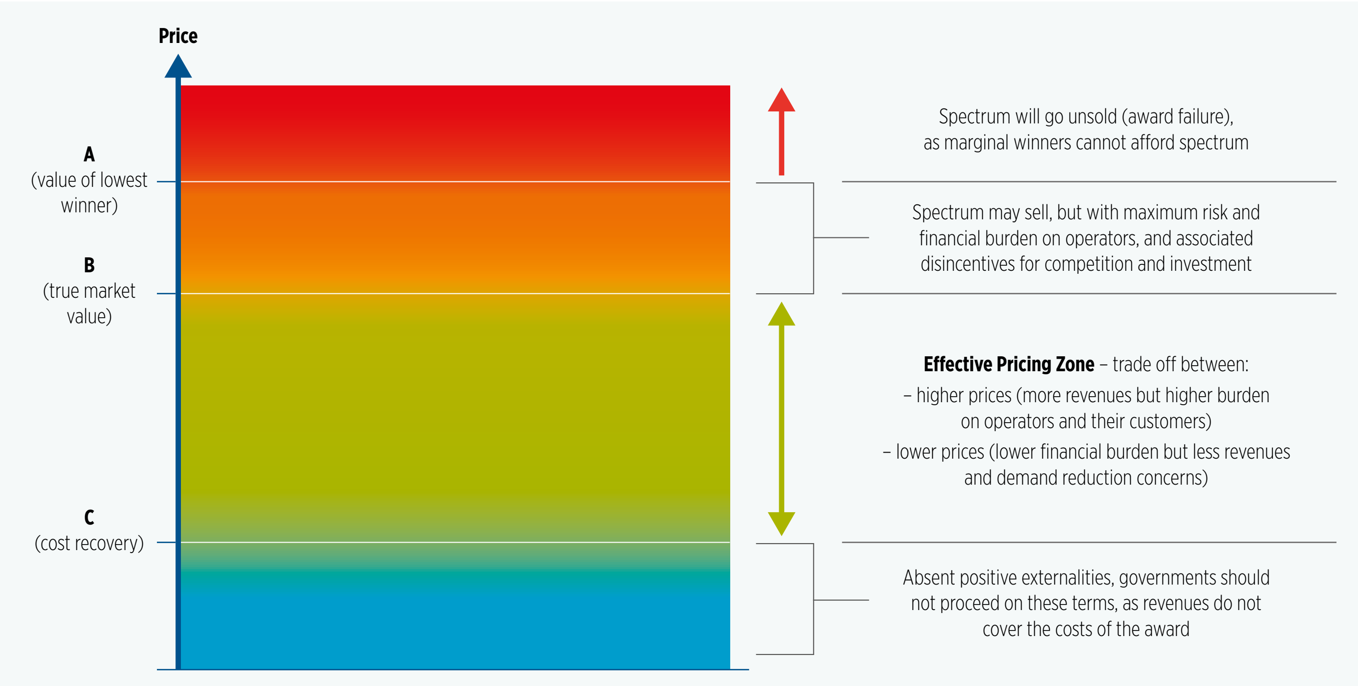
In the context of a primary award, this requires that initial prices be set:

- **below a conservative estimate of market value, so there is scope for competition and price discovery in auctions; and**
- **no lower than the costs of managing the spectrum.**

By true market value, we mean the price that would emerge from a well-functioning market in which bidders submit bids based on the intrinsic value of the spectrum to them. In turn, intrinsic value should reflect the costs that operators expect to avoid from deploying the spectrum and any increased profits from being able to offer a more compelling service proposition to customers. Such values will, in turn be affected by the conditions attached to the spectrum licence.

The range for effective pricing is illustrated in Figure 2.

FIGURE 2: EFFECTIVE PRICING OF SPECTRUM



When deciding where to set the minimum price within the effective price zone, policymakers must confront the risk asymmetry between setting prices too high or too low. If the price were inadvertently set above true market value, there is a material risk of award failure, with valuable spectrum going unused and consumer welfare gains delayed. Obliging any operator still willing to acquire the spectrum to pay more than market value may also be perceived as unfair, as it involves expropriation of the reasonable returns a company can expect in a competitive market. In contrast, in an auction setting, if minimum prices are set at a low level, the market will usually still identify the efficient outcome. Even if there is demand reduction, this may have no impact on efficiency and, while the state may lose some revenues, there is no equivalent to the welfare losses owing to unallocated spectrum in the high-price case, and indeed, in a competitive market, lower spectrum costs could be expected to be passed through to the market in the form of lower pricing.

The reality is that it is extremely difficult for any party to estimate market value. Even if a regulator would like to set prices at market value, it is most unlikely that it would pick the right level. This, of course, is a key rationale for auctioning spectrum. The assumption in an auction is that bidders themselves should be best at valuing spectrum, and that well-designed rules should provide incentives for them to validate and reveal relevant information about their valuations.

Regulators who are not focused on revenues find it easy to manage this risk asymmetry. They set prices at modest levels that they believe to be safely below true market value (i.e. in the low-to-mid area of the effective pricing zone in Figure 2), and rely on competition between bidders to determine the efficient outcome and final price. Of course, this approach creates some possibility that prices are lower than they could have been, in case the auction is not fully competitive. Many regulators, such as those in Germany and Sweden, accept this: they are much more concerned about realising welfare gains for consumers than they are about whether they could have extracted more money from the industry in selling the spectrum.

For regulators for whom revenue is important, setting prices is more challenging. If they wish to set prices closer to the true market value, they necessarily will need to expend time and effort trying to estimate that value. There are two approaches: modelling the business case of potential bidders; and benchmarking prices from other awards. Both approaches, can provide insights into the potential value of the spectrum. However, the estimates they produce should be treated with caution as they depend on many assumptions and are inherently uncertain. We explore the risks associated with such approaches further in Chapter 3, where we highlight examples of regulators that have over-estimated the value of licences, often because they have attributed too much reliability on benchmarks or failed to consider local market conditions or the costs of onerous licence terms when setting prices. This usually results in valuable spectrum going unsold, as with the 2016 auction of 700 MHz in India.

### 1.4. Investment incentives and consumer prices – two further reasons for caution when pricing spectrum

It is sometimes argued that, provided that the allocation is efficient, higher revenues should always be preferable to lower ones. This is based on two lines of thought. Firstly, standard economic theory predicts that sunk costs are irrelevant to investment and pricing decisions. Several commentators, such as Kwerel (2000)[9] and Wolfstetter (2001)[10], have argued that upfront spectrum fees are sunk costs, as they are inescapable, and do not vary with output or even if a firm fails. Secondly, it has been suggested that an efficient sale of radio spectrum is an example of "a distortion-free tax", which may be preferable to other revenue mechanisms, such as income tax. These arguments tend to suggest that a regulator that fails to extract the true market value (or even any price up to A in Figure 2) was leaving money on the table.

9 Evan Kwerel, Federal Communications Commission, 2000, Spectrum Auctions Do Not Raise the Price of Wireless Services: Theory and Evidence, available at: http://wireless.fcc.gov/auctions/data/papersAndStudies/SpectrumAuctionsDoNotRaisePrices.pdf

10 Elmar Wofstetter, 2001, The Swiss UMITS Spectrum Auction Flop: Bad Luck or Bad Design?, https://www2.wiwi.hu-berlin.de/institute/wt1/research/2001/swiss_umts_flop.pdf

Such arguments are, however, flawed for two reasons. Firstly, higher prices are inherently risky, as they are more likely to be associated with award failure. Therefore, as both Kwerel and Wolfstetter accept, the sunk cost argument does not provide a justification for setting prices at a level that risks spectrum going unsold. Secondly, more sophisticated theory backed by empirical observation contradicts the notion that firms ignore sunk costs when making decisions on investment and pricing. Far from being a distortion-free tax, the literature suggests that high upfront input costs can depress investment and reduce price competition, especially in settings when there are only a small number of operators. Given the scale of the mobile sector and its role in facilitating broader economic activity, this implies that high spectrum prices are bad for economic growth.

There are three distinct and complementary explanations why firms do not behave as if upfront spectrum costs are fully sunk. These come from the fields of traditional economic theory, financial theory and behavioural economics. We describe each one here and summarise them in Figure 3. They provide a clear theoretical and empirical basis for the argument that high spectrum prices are harmful to society. As we will show in Chapters 2 and 3, this argument is also supported by quantitative and case study analysis of 4G investment and pricing. Taken together, this evidence reinforces the case that policymakers should never set reserve prices above a conservative estimate of true market value.

### The hold-up problem

Although standard economic theory predicts that sunk costs are irrelevant to investment and pricing decisions, this is predicated on the notion that such decisions do not influence future choices. The classic example is a factory that invests in a machine that cannot be sold again. The upfront cost of the machine is sunk and as it cannot be recovered should not influence future decisions on the price of the products created using the machine.[11] Kwerel (2000), Wolfstetter (2001) and others have argued that spectrum auctions are one-off transactions and that spectrum licence prices are thus sunk costs.

However, this simplistic interpretation of licence fees as sunk costs does not consider the dynamic effects that high spectrum prices have over the long term. The sunk cost argument ignores the repeated nature of auctions and investments into the mobile sector. When spectrum is priced above true market value, it reduces the firm's profits which, to a large extent, are the returns on the investments that it has already made (for example in its network) and which are now sunk. In the short run, operators that need more spectrum may decide that they have little choice but to accept such terms. However, in the long term, they will respond by lowering their expectation of returns on future investments. This will reduce overall investment and may even lead to market exit or consolidation if operators cannot earn sufficient returns on their investments. In the economic literature, this phenomenon is referred to as the "hold-up problem".[12]

11 Walter Nicholson, 1978, Microeconomic Theory, Hinsdale, Illinois: The Dryden Press, p.223.

12 Hold-up arises when the return on one parties' sunk investments can ex post be expropriated by another party. In the case of spectrum licences, the government can expropriate the returns on other sunk investments (such as in network infrastructure) made by a mobile operator by overcharging for access to spectrum. The hold-up problem has played an important role as a foundation of modern contract and organisation theory. The associated inefficiencies have justified many prominent organisational and contractual practices. See for example William P. Rogerson, 1992, Contractual Solutions to the Hold-Up Problem, Review of Economic Studies, Vol 59, pp. 777-794.

## FIGURE 3: WHY FIRMS DO NOT TREAT UPFRONT SPECTRUM FEES AS SUNK COSTS

| | |
|---|---|
| **1. Hold-up problem**<br>(Economic theory) | ■ Spectrum awards are recurring transactions, not one off events<br>■ If firms perceive that their expected returns will be extracted in successive auctions, they will moderate their investment behaviour accordingly (and may even exit) |
| **2. Internal financing constraints**<br>(Financial theory) | ■ High auction prices may exhaust access to scarce lower cost internal funds, displacing other investment activity<br>■ Access to capital from multinational parents or external sources may be rationed in response to low profitability |
| **3. Observed pricing decisions**<br>(Behavioural economics) | ■ Empirical evidence suggests that in sectors with naturally constrained competition, firms with high sunk costs are more reluctant to engage in price competition<br>■ High upfront licence fees may act as a signal for market participants to set higher prices |

### Constraints on internal financing

The pricing structure for spectrum is fairly unique. Spectrum sold in auctions usually requires a large upfront payment followed by smaller annual fees. The upfront payment is usually financed internally. High upfront payments therefore reduce internal funds available for other projects. According to the "pecking order model", the cost of financing increases with asymmetric information. Internal funding is cheaper than external funding, as external providers of finance have much less information about these investments than the mobile operator and thus require a higher risk premium. Using external sources to fund these other projects may mean that they are no longer profitable as returns may be insufficient to cover the higher risk premium.

Globally, the mobile market is characterised by a number of multinational companies that operate in a large number of countries. Headquarters have a finite budget available that they can allocate to different regional markets. With this structure in place, it is quite natural that funds are diverted from less attractive markets to markets with higher expected profitability.[13] As we have already discussed, profitability of sunk investments is directly linked to spectrum prices. Artificially high spectrum prices in a country can therefore lead headquarters to allocate less to a high spectrum-price market in the future. In the literature, this phenomenon is referred to as "de-escalation" or "reverse sunk-cost effect" owing to financial constraints.[14]

13 Stein, Jeremy C, 1997, Internal Capital Markets and the Competition for Corporate Resources, The Journal of Finance, Vol. 52, pp. 111-114.

14 McAfee, Mialon, and Mialon, 2010, Do Sunk Costs Matter?, Economic Inquiry, Vol. 48, No.2 pp. 323-336.

### Observed pricing decisions

In classic microeconomic theory, firms maximise profits by setting prices such that marginal revenue equals marginal cost.[15] Sunk costs, such as upfront spectrum fees, do not feature in this version of the price-setting process. Some early studies on the relationship between spectrum fees and consumers prices appeared to confirm this assessment.[16] However, more recent research in the field of behavioural economics suggests that this classical view is a poor reflection of how firms actually make decisions. In particular, in sectors with imperfect competition in which firms have some degree of flexibility over the prices they set, researchers have observed a tendency for prices to inflate over the theoretically efficient price if sunk costs are increased.

In one simulated experiment, **researchers found that upfront fees for entry licences produced high short term prices for consumers in markets with a small number of participants.** In addition, the average price for consumers remained high long after the upfront entry fee was paid. Researchers then examined if the increase in prices were specific to the allocation mechanism (either a fixed fee or an auction). The results showed that the method of allocation did not affect price levels, but the simple presence of an entry fee in a market with limited competition increased prices paid by consumers. The experiment's result directly contradicts the classic economic argument that prices only reflect marginal cost.[17]

In another experimental study, researchers showed that varying sunk costs produce different outcomes for consumer prices. Specifically, the experiment was set up in a way that the market could either produce a stable high-price outcome or a stable low-price outcome. In situations of high sunk costs, firms tended to select the high-price equilibrium whereas in situations of medium-to-low sunk costs, firms tended to select the low-price equilibrium. Overall welfare, therefore, could be described as following a "reverse U" pattern, where moderate sunk costs produced the optimal level of welfare.[18]

15 Put differently, an operator will increase its profit by expanding production provided that the revenue from producing an extra unit of a good or service exceeds the cost of producing that extra unit.

16 Evan Kwerel, 2000, Spectrum Auctions Do Not Raise the Price of Wireless Services: Theory and Evidence, FCC

17 Offerman and Potters, 2006, Does Auctioning of Entry Licences Induce Collusion? An Experimental Study. Review of Economic Studies (2006), Vol. 73, pp. 769-791.

18 Buchheit and Feltovich, 2001, Experimental Evidence of a Sunk-Cost Paradox: A study of Pricing Behaivor in Bertrand—Edgeworth Duopoly. International Economic Review, Vol. 52, pp. 317-347.

# 2. How spectrum prices impact mobile services, the economy and consumers

In the previous chapter, we addressed best practice in setting spectrum prices, and highlighted theoretical and empirical evidence that high prices can depress incentives for investment and price competition. In this chapter, we present the results of our own quantitative analysis of spectrum prices and their impact on competition and investment in 4G services. We observe that, over the last eight years, both reserve prices and price outcomes have trended upwards. While price outcomes for many awards remain modest, the upward trend appears to be driven by a growth in the number of high price auctions, including many where reserve prices were set well above the global mean. Consistent with the academic literature, we also find statistical evidence linking higher spectrum prices to low investment in 4G and higher consumer prices for data.

As an illustration of the negative impact of high spectrum prices on consumers, we apply an econometric model to our data set in order to estimate the relationship between mobile prices and data consumption. We then assess the sensitivity of spectrum costs on consumer welfare and auction revenues. Our model implies that if all countries in our dataset that have spectrum prices above the median had instead sold spectrum at the median price level, this could have generated incremental value for society with a purchasing power of US$250bn. This value reflects gains in consumer surplus[18] owing to greater price competition in the downstream market, which more than offset losses in auction revenues. Note that this approach only captures a fraction of the consumer benefits of lower spectrum prices, as it does neither consider the negative impact on quality owing to lower investment nor the knock on effects on other industries, given the role of mobile data as an enabler of economic activity.

Looking ahead, the mobile industry will begin the transition to 5G in around 2020. This next generation of service will require roll-out of new infrastructure and a greatly expanded spectrum base to support a huge increase in network capacity and data speeds. In a world where spectrum scarcity is reduced and total spend on communications services is plateauing, this should mean that prices paid for spectrum will fall sharply. Countries that try to resist this trend, either by restricting spectrum availability or overpricing newly released spectrum, are likely to find themselves falling even further behind in availability and take-up of next generation data and associated connectivity services.

### 2.1. The growth in high price spectrum awards

There have been four major waves of spectrum awards for mobile, each linked to a new generation of technology. We focus here on the two most recent waves:

- **The 3G era, which began in 1999. A larger number of awards of spectrum designated for 3G took place from 2001-2002, with a small number of further awards occurring over the following years. This era primarily involved the award of 2100 MHz and AWS spectrum bands.**
- **The 4G era, which began in around 2008. There has been a significant increase in the number of spectrum awards, covering a range of bands, including 700 MHz, 800 MHz, AWS-3 and 2600 MHz, as well as liberalised spectrum in existing mobile bands, such as 900 MHz, 1800 MHz and 2100 MHz.**

19 The difference between the total amount that consumers are willing and able to pay for a good or service and the total amount that they actually pay (i.e. the market price).

Figure 4 charts the history of major awards for mobile spectrum since 2000. From 2000-01, there was a large number of awards of spectrum suitable for 3G (2100 MHz and PCS). This was followed by a quiet period of five years, with relatively few spectrum awards, which coincided with the slow launch of 3G services. Since late 2007 (when Norway awarded the 2600 MHz band), there has been a significant increase in the number of awards each year, driven by the need to find new bands and repurpose old ones for 4G mobile broadband. This period coincides with a take-off in consumer demand for mobile data services.

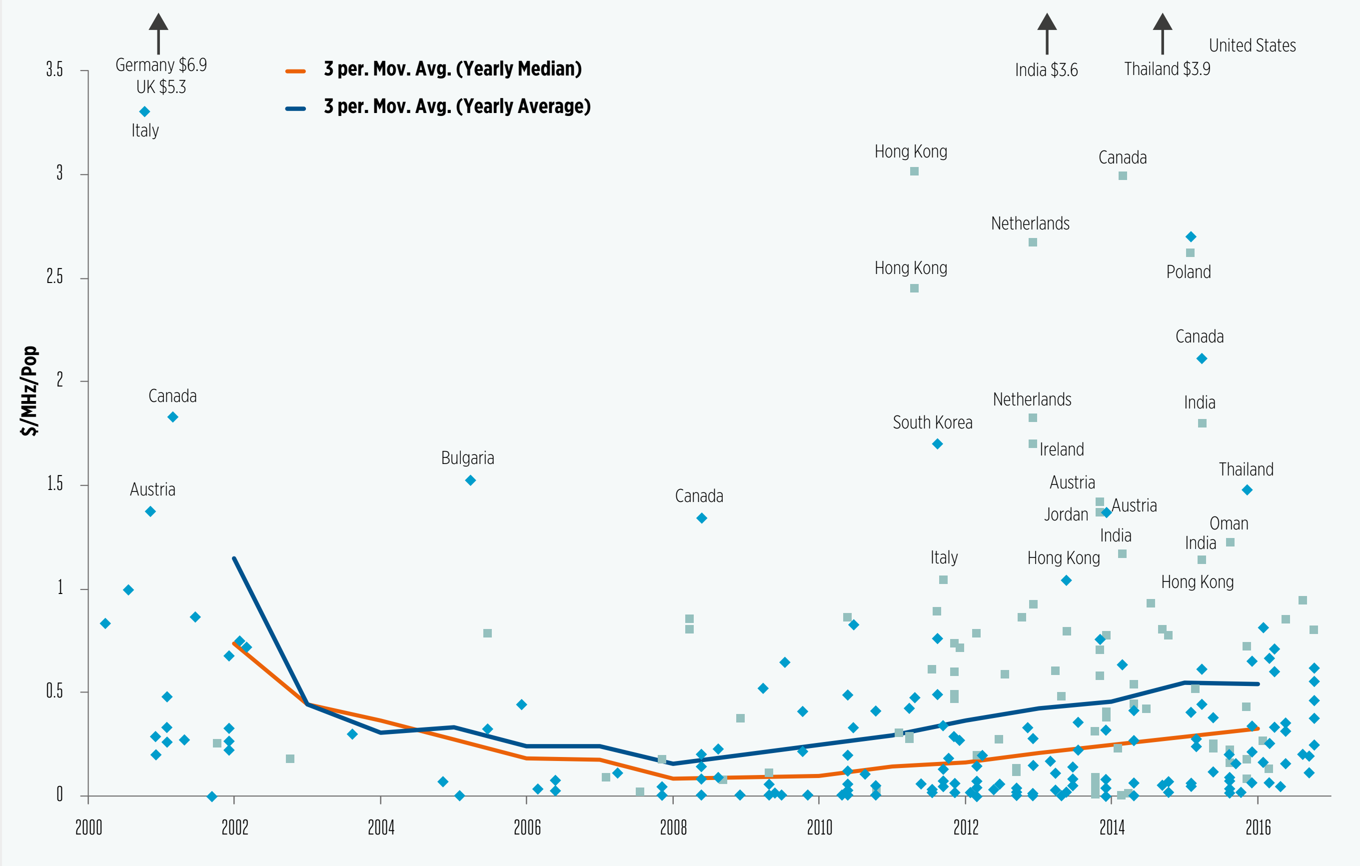
This growth in the number of awards is a worldwide phenomenon. Historically, medium and lower income countries have lagged behind higher income countries in bringing new mobile bands to market. However, in recent years, the gap in release times has tended to fall, as countries worldwide spot the opportunity to grasp immediate benefits from ubiquitous mobile data and 4G deployment. For example, Morocco (2015) and Kenya (2016) have already awarded spectrum at 800 MHz, just 3-4 years behind the typical European release date.

With the release of new spectrum in bands such as 700 MHz, 800 MHz, AWS-3 and 2600 MHz, many countries have seen an increase in mobile spectrum in the order of 70% or more since 2008. In countries where TDD bands at 1500 MHz and 2300 MHz have been released, this figure rises to over 100%. Much larger bands at higher frequencies, such as 3400-3800 MHz, have also been earmarked for release.

In Figure 4, we also plot a moving average of prices for mobile spectrum over the 2000-2016 period. This follows a U-shaped path. The beginning of the 3G era coincided with the so-called “tech bubble”, which generated huge enthusiasm regarding the potential of 3G data services. This was reflected in the very high prices achieved in some early awards, most notably the UK and German 3G auctions in 2000, which raised an exceptional $5.30 and $6.90 per MHz/pop respectively. Subsequently, there was a sharp drop in prices for 3G spectrum, and most awards for the remainder of the 2000s generated modest prices. Since 2008, however, there has been an upward trend in prices, coinciding with the take-off of 4G services.

In market economies, the price of spectrum should reflect the balance between supply and demand. Given the growth in spectrum availability, rising spectrum prices imply that growth in demand must be outpacing supply. It is true that companies need a lot more spectrum capacity to service a huge expansion of data traffic. However, in mature mobile markets, this increase in traffic has not been matched by any growth in revenues; in fact, average revenue per user (ARPU) has declined in many markets. In this context, it seems odd that average prices should be rising (notwithstanding the scope for growth in countries with less developed mobile sectors). Certainly, this implies that many mobile operators must be spending a much larger proportion of revenues on spectrum than ever before.

FIGURE 4: GLOBAL TRENDS IN SPECTRUM PRICES, BY BAND AND AUCTION, 2000-2016

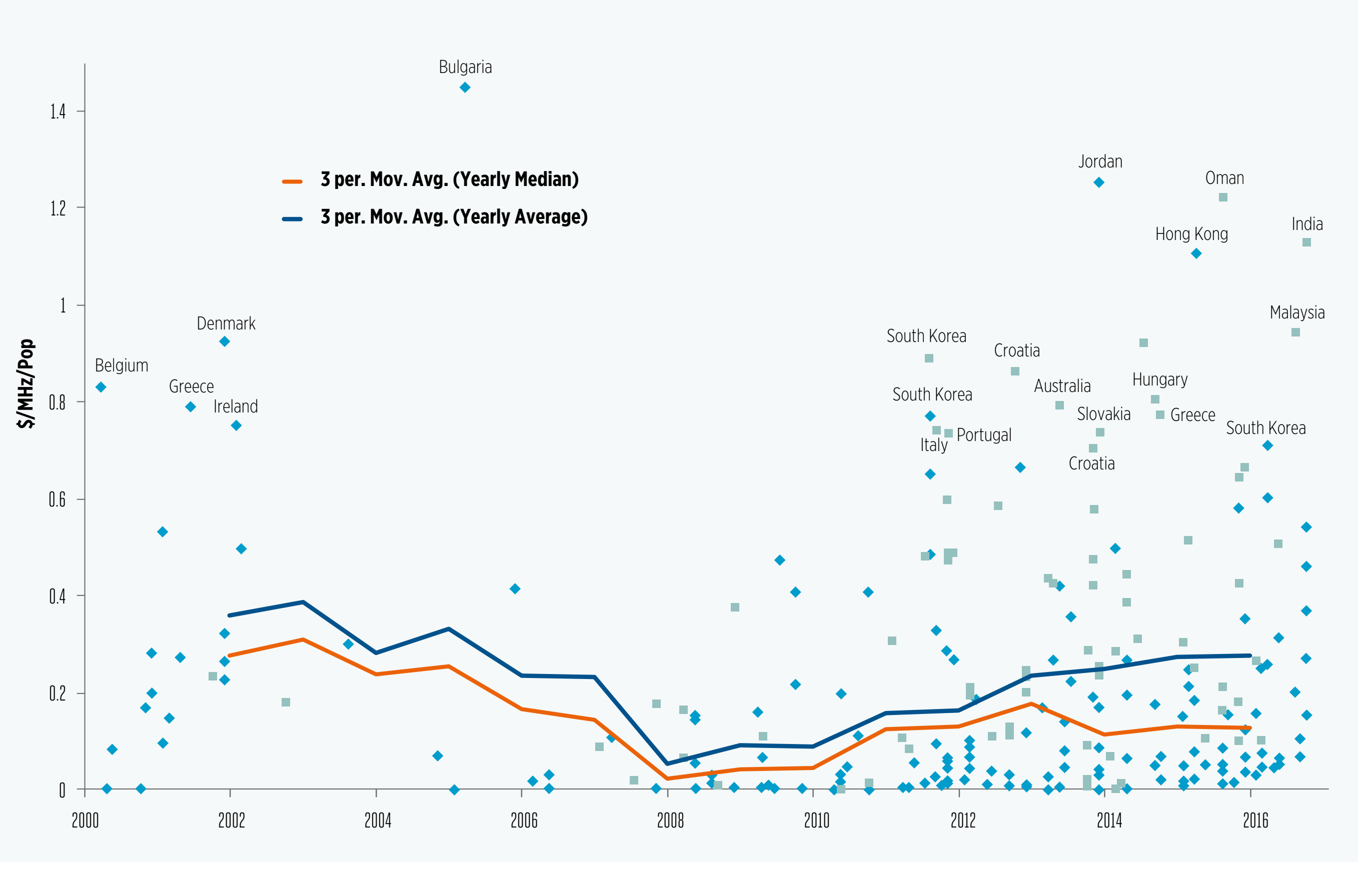



Notes: Green = Prices for coverage bands below 1 GHz) (700 MHz, 800 MHz, 850 MHz and 900 MHz); Blue = Prices for capacity bands above 1 GHz (PCS, AWS, 1800 MHz, 2.1 GHz and 2.6 GHz).

Prices per MHz pop are adjusted for inflation and were converted to USD using IMF purchasing power parity (PPP) rates. Prices are also adjusted for licence duration, based on a standard 15 years, using a 5% discount rate.

Source: NERA Economic Consulting Global Spectrum Auction Database.

FIGURE 5: GLOBAL TRENDS IN SPECTRUM RESERVE PRICES, BY BAND AND AUCTION, 2000-2016




Notes: Green = Reserve prices for coverage bands below 1 GHz (700 MHz, 800 MHz, 850 MHz and 900 MHz); Blue = Reserve prices for capacity bands above 1 GHz (PCS, AWS, 1800 MHz, 2.1 GHz and 2.6 GHz).

Reserve prices include both upfront payment and discounted value of any substantive annual fees associated with the spectrum, discounted at 5% per annum. Reserve prices per MHz pop are adjusted for inflation and were converted to USD using IMF purchasing power parity (PPP) rates. Reserve prices are also adjusted for licence duration, based on a standard 15 years, using a 5% discount rate.

Source: NERA Economic Consulting Global Spectrum Auction Database.

Why are spectrum prices rising in an era when spectrum supply is expanding but revenues are flat? The data highlights two possible explanations:

1. **An increase in the incidence of high price awards; and**
2. **An upward trend in reserve prices (as illustrated in Figure 5).**

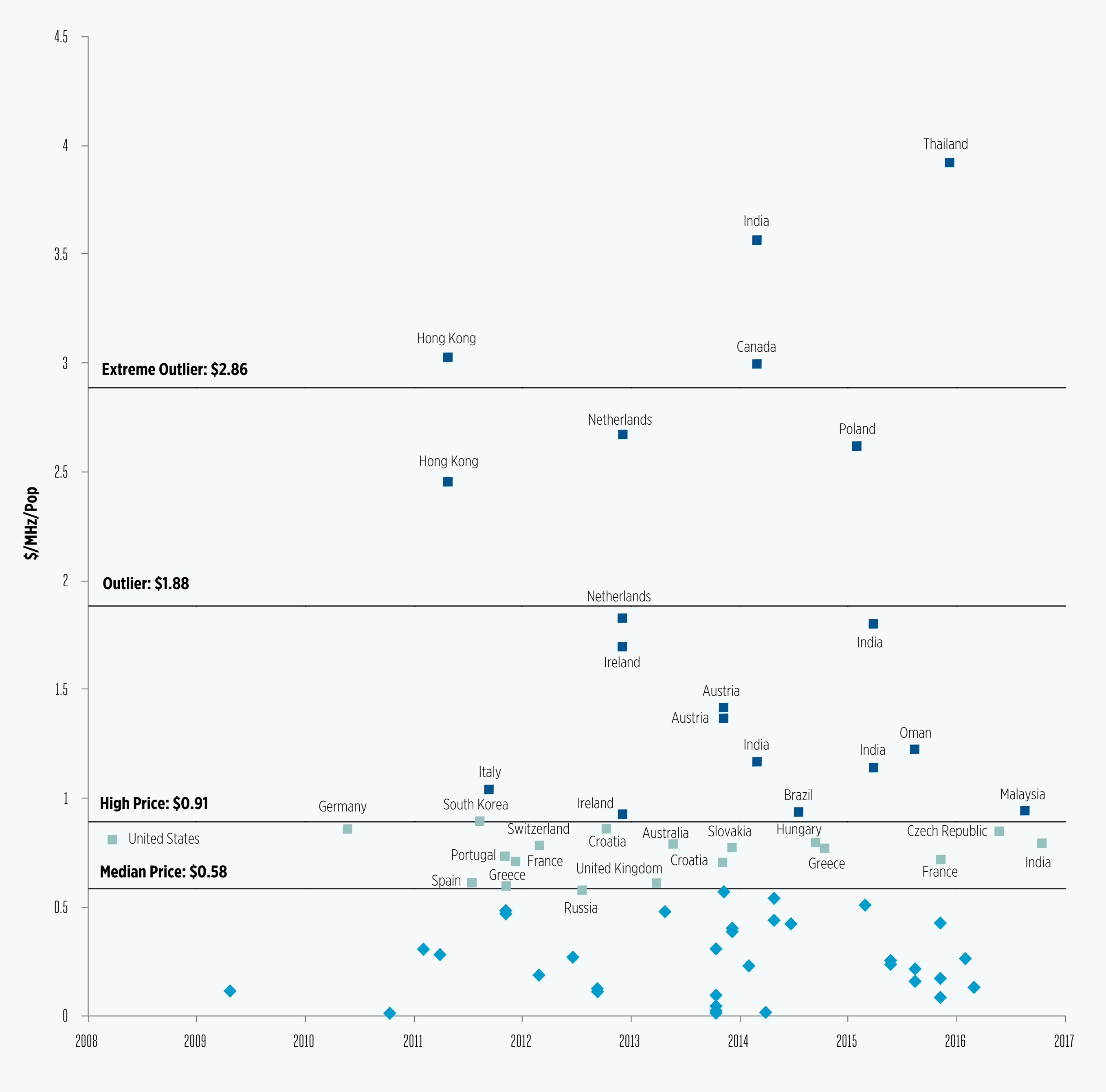
Starting in 2012, there has been a marked increase in the number of awards that ended with high prices, including a number that are statistical outliers to the sample. This is illustrated in Figure 6 and Figure 7. Between 2013 and 2016, there were 27 high price and outlier observations in the coverage and capacity bands, compared to only 19 between 2008 and 2012. This is based on analysis using standard statistical techniques to separate price outcomes in the 4G era (2008-16) for coverage bands (sub-1 GHz) and capacity bands (above 1 GHz) into five groups: below median prices; above median prices; high prices; outliers; and extreme outliers.

For illustrative purposes, we label countries with prices above the 75% percentile as high prices. This approach understates the problem of overpricing, as it compares prices across countries with very different income levels. While prices have been adjusted using purchasing power parity exchange rates[20], no further adjustment has been made to reflect huge differences in the spending power of consumers, nor the impact of coverage and other obligations that may lower the value of licences in some countries. In practice, the appropriate definition of a high price will vary by country, depending on local factors, and could be much lower for some countries, especially low income markets with uncertain growth prospects (for example, see the case studies in Chapter 3.1 on Mozambique, Ghana and Senegal), or those that attach costly conditions to licences (for example, see the case study on Argentina in Chapter 3.3). The price outcomes that we identify as outliers are ones where prices are so high that they would not be treated as plausible observations for comparative purposes in a statistical exercise.[21]

20 Differences between real and adjusted revenues can be large. For example, in 2012, the Romanian award of 900 MHz raised $0.25 per MHz/pop unadjusted, which more than doubles to $0.57 per MHz/pop after adjusting for purchasing power and licence duration. However, purchasing power is only a rough proxy for differences in costs of access to communications services. In particular, such adjustments may be insufficient to address issues in some markets with large population groups that lack the income needed to afford basic communication services.

21 In order to identify outliers we used a standard statistical technique. The IQR is defined as the observations between the 1st and 3rd quartile. Outliers are classified as being above an "inner fence," and extreme outliers are classified as being above the "outer fence." Inner fence = 3rd quartile + 1.5*IQR. Outer fence = 3rd quartile + 3*IQR.

FIGURE 6: COVERAGE SPECTRUM PRICES BY CATEGORY (2008-2016)




Notes: Coverage spectrum bands include 700, 800, 850 and 900 MHz bands; prices are adjusted for PPP exchange rates, inflation and licence duration, and include annual fees.

Light Blue = observations ≤ median price; Green = observations > median price ≤ 75th percentile; Dark Blue = observations > 75th percentile, including statistical outliers.

Source: NERA Economic Consulting Global Spectrum Auction Database.

FIGURE 7: CAPACITY SPECTRUM PRICES BY CATEGORY (2008-2016)


Notes: Capacity bands include AWS, PCS, 1800 MHz, 2100 MHz and 2600 MHz; prices are adjusted for PPP exchange rates, inflation and licence duration, and include annual fees. Colour key same as Figure 6.

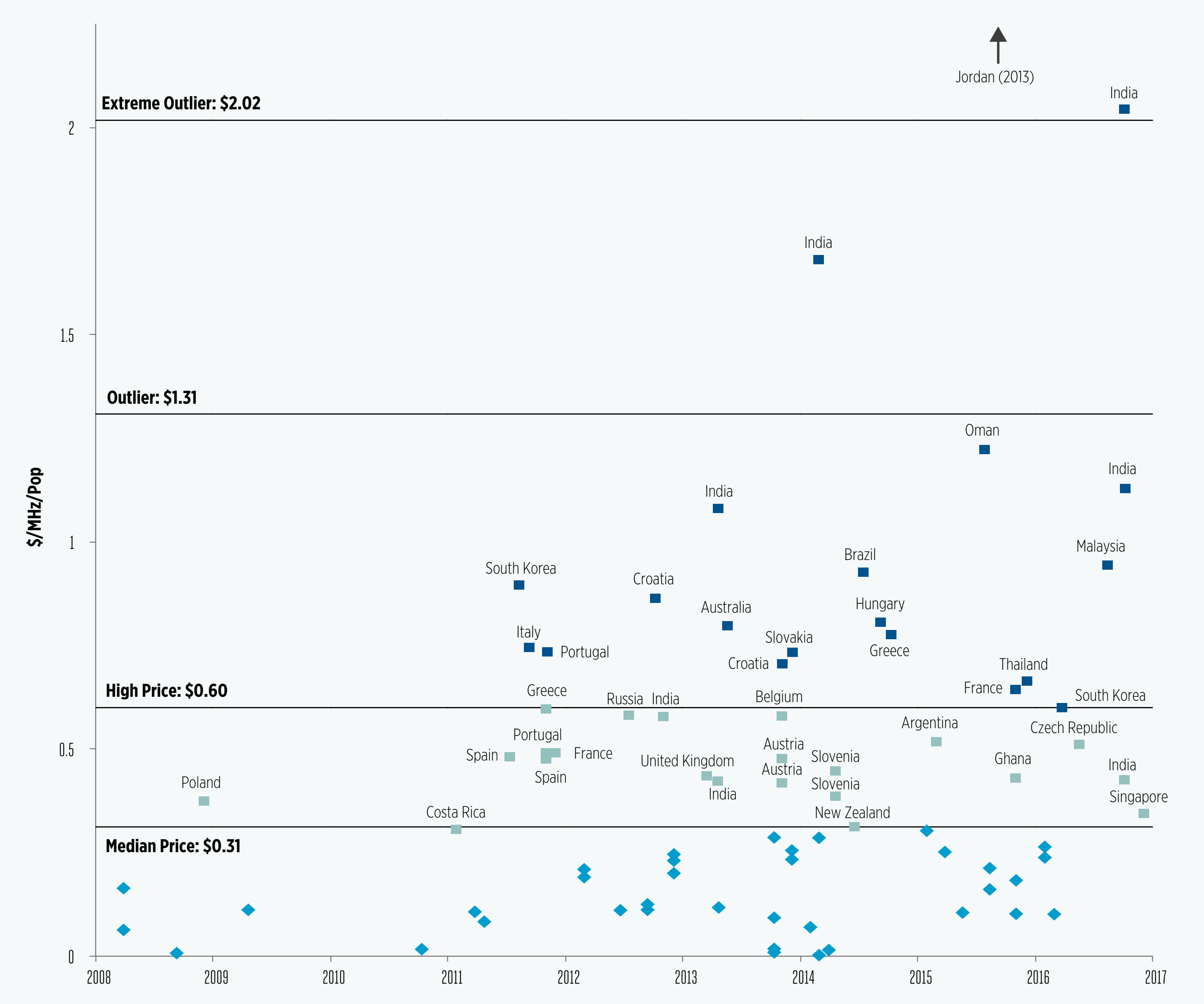
Source: NERA Economic Consulting Global Spectrum Auction Database.

The increase in high spectrum price outcomes can in part be linked to an increase in reserve prices. The upwards trend in reserve prices since 2008 is illustrated in Figure 5. Observe also the widening gap between average reserve prices and median reserve prices. This implies that the average is being dragged up by a minority of awards with exceptionally high reserve prices.

In Figure 8 and Figure 9, we provide a more detailed look at reserve prices for coverage and capacity bands in the 4G era, again using statistical techniques to differentiate awards by price level on a band-by-band basis. As with price outcomes, we also observe a growing incidence of awards in which reserve prices have been set at statistically high or extreme levels. Between 2013 and 2016, there were 38 high price and outlier observations in the coverage and capacity bands, compared to only 18 between 2008 and 2012.

This increase may be attributable to some countries using benchmarks from selected high price 4G award outcomes as justification for setting their own prices at high levels. Our case study research also highlights many recent examples of awards where core mobile spectrum is going unsold and/or is selling at reserve, which typically occurs when reserve prices are set above true market value.

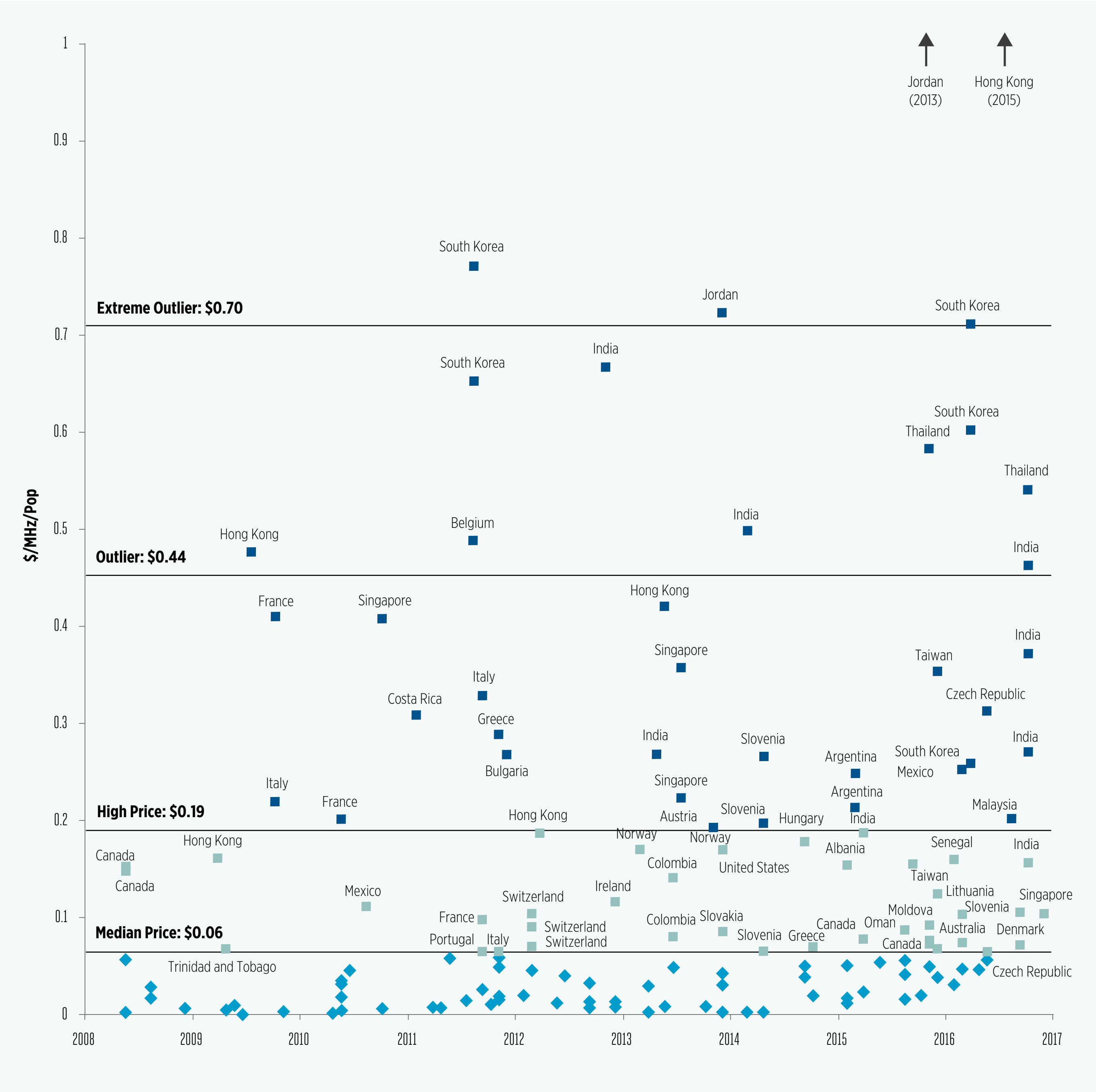
FIGURE 8: COVERAGE SPECTRUM RESERVE PRICES BY CATEGORY (2008-2016)




Notes: Coverage spectrum bands include 700, 800, 850 and 900 MHz bands; prices are adjusted for PPP exchange rates, inflation and licence duration, and include annual fees. Colour key same as Figure 6.

Source: NERA Economic Consulting Global Spectrum Auction Database.

FIGURE 9: CAPACITY SPECTRUM RESERVE PRICES BY CATEGORY (2008-2016)




Notes: Capacity bands include AWS, PCS, 1800 MHz, 2100 MHz and 2600 MHz; prices are adjusted for PPP exchange rates, inflation and licence duration, and include annual fees. Colour key same as Figure 6.

Source: NERA Economic Consulting Global Spectrum Auction Database.

In summary, while it is apparent that many countries are running awards which produce modest spectrum prices, there is a growing incidence of high price outcomes. Were this simply the result of strong competition between bidders with robust business cases, this would not be a concern. However, as our work in Chapter 3 shows, many of these high price outcomes are attributable to government policies that set excessive reserve prices, or distort valuations and bidding behaviour. Given the linkage between high spectrum prices and consumer welfare losses, owing to unallocated spectrum and disincentives for investment and price competition, the escalating frequency of high and extreme pricing events may be a sign of significant problems ahead.

## 2.2. Evidence linking lower spectrum prices to greater investment in mobile networks

In Chapter 1.4, we presented evidence from the academic literature linking high prices for scarce inputs to lower rates of investment. To test whether this relationship holds true for mobile spectrum, we undertook our own cross-country analysis of spectrum prices and investment in 4G services. Here, we set out our methodology and source data, and present our findings. For both higher and middle income countries, we observe a significant statistical link between higher spectrum prices and inferior 4G experiences for customers, which is likely attributable to lower rates of investment in next generation networks.

### Methodology and source data

Theory suggests that operators experiencing high spectrum licence costs will have less incentive to invest in their networks. To test this relationship, we require proxies for the total financial burden on operators and their investments in next generation networks. We focus on the 4G era, using data from 2008-2016.

In order to make comparisons of spectrum costs across countries, prices are typically expressed as a price per MHz/pop (i.e. price divided by MHz and total population), and measured in a common currency, adjusted using either real or purchasing power parity exchange rates. This approach is appropriate when comparing prices for similar frequency bands. However, this approach may not capture the financial burden and the strain on internal financing, as it does not consider the volume of spectrum sold and the aggregate spend. Since 2008, many countries have sold spectrum in multiple bands, which have together imposed a large aggregate financial burden on operators. For example, in the Netherlands in 2012, winning bidders spent almost $4.7bn or $280 per pop on spectrum across five bands. To capture this, we consider total spectrum costs across all bands on a per pop basis.

NERA maintains its own database of prices for mobile spectrum awards for countries around the world. This includes data on both upfront fees from auctions or direct awards, and, where relevant, incorporates annual fees for awarded spectrum. We used these prices to construct an index of the total financial burden on mobile operators from spectrum purchases in each country where we had comprehensive award data for the 2008-2016 period. We consider total industry expenditure rather than individual operator expenditure, owing to the difficulties of compiling comparable investment data for individual operators.

Many national mobile operators are subsidiaries of larger operators and not required to publish disaggregated data on their annual capex and opex. Therefore, we cannot directly observe expenditure on 4G networks for operators or countries worldwide. Instead, it is necessary to identify a proxy for network investment. To do this, we developed a "wireless score" which measures the quality and uptake of next-generation data services in each country using actual user data.

Our wireless score has three components:

**3G/4G COVERAGE** (%)

*

**4G SUBSCRIBERS** (%)

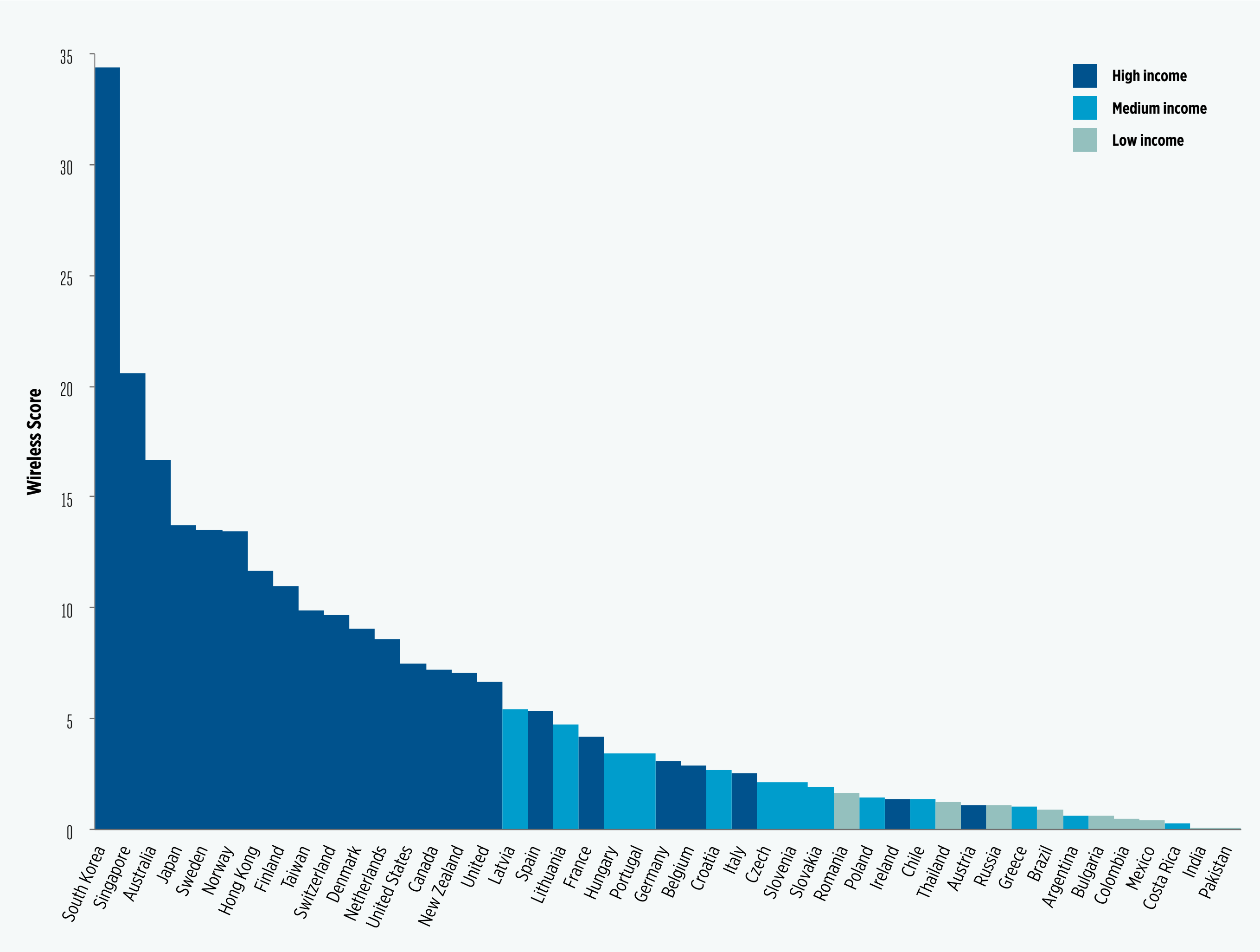
*

**AVERAGE SPEED** (Mbps)

We include both coverage and speed, because they are the main determinants of quality of service. For coverage, we use data for the percentage of time when users have access to a high-speed network, as this is a better proxy for comparing the actual ability of users to access mobile data than geographic coverage, given huge differences in population dispersal between countries.[22] We do not differentiate between 3G and 4G coverage, as – in many countries – 3G may provide a near-4G experience. We include 4G subscriber share as a % of total population in the score so as to ensure it reflects progress in 4G rollout, as opposed to just 3G.[23] Average speeds are measured in megabits per second based on observed user experience.[24] To arrive at a single score, we multiply the three numbers: in effect, our wireless score is a weighted measure of mobile data speed.

Figure 10 shows the wireless score for each country included in our analysis.

FIGURE 10: WIRELESS SCORE BY COUNTRY




Source: NERA Economic Consulting, using data from OpenSignal.com and Telegeography GlobalComms database.

22 Coverage data is from OpenSignal.com.

23 Subscriber data is from the Telegeography GlobalComms database.

24 Speed data is from OpenSignal.com.

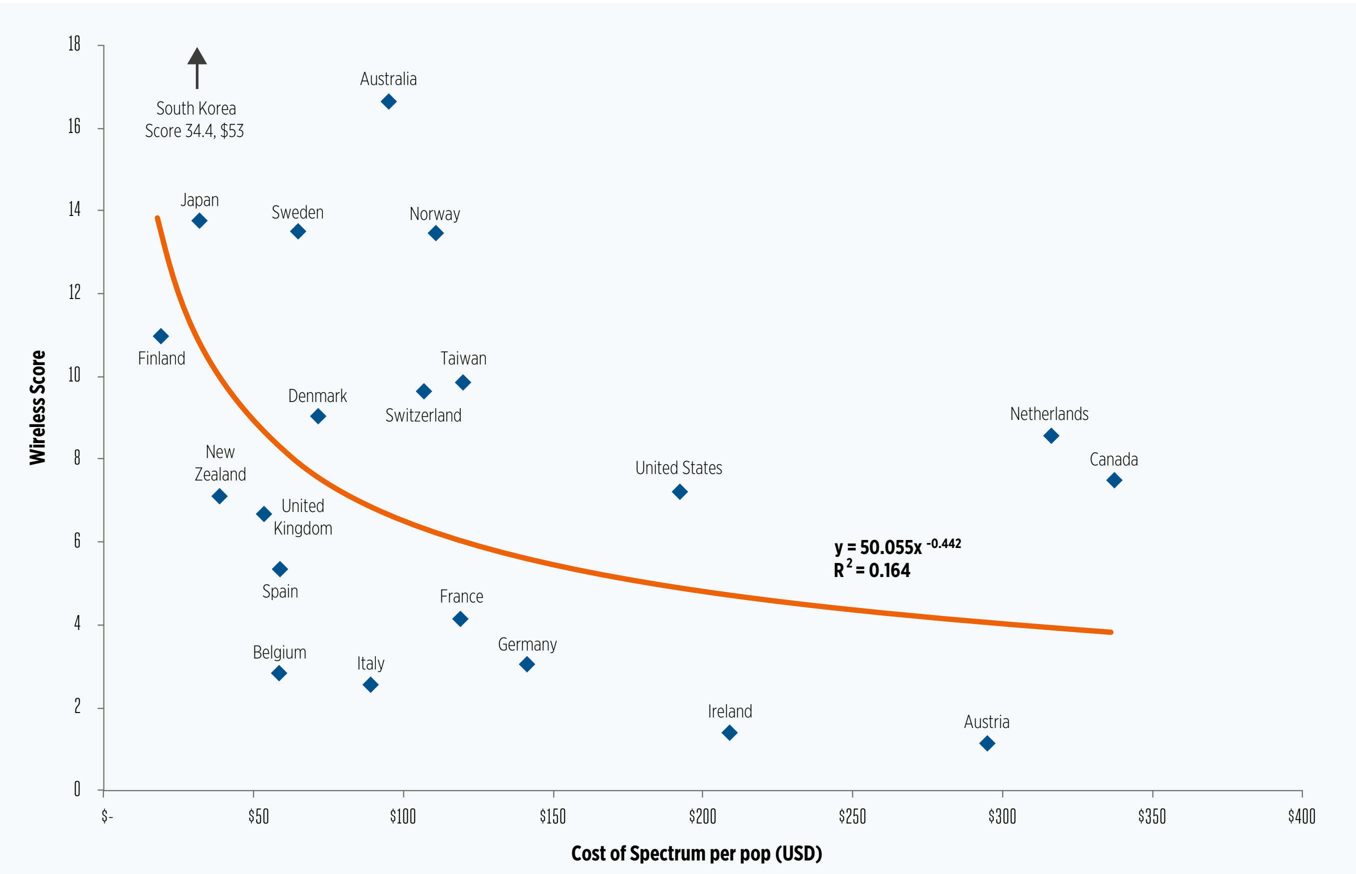
Countries differ widely in their uptake of 4G services and the coverage and speeds experienced by users. Countries with higher incomes typically have substantially higher wireless scores than countries with medium incomes, who in turn typically have substantially higher scores than lower income countries. This is hardly surprising, given that 4G technology was first launched in higher income countries, while many lower income countries in our sample have only recently launched services. Moreover, consumers in higher income countries have greater ability to pay for and more scope to use next generation mobile data services. We determined that the best way to account for these differences was to divide the sample into three groups of countries: higher income; medium income; and lower income, based on GDP per capita.[25]

## Findings

For all three country groups, we found a correlation between lower spectrum costs and higher wireless scores. These results support the hypothesis in the academic literature that high input costs suppress investments. They directly contradict the more simplistic hypothesis that licence costs do not affect investment because they are sunk costs. Although spectrum cost is one of a number of factors that causes differences between countries in network investment, the results indicate that they are an important factor.

The relationship between spectrum costs and wireless score for higher income countries is reported in Figure 11.

FIGURE 11: SPECTRUM COSTS AND WIRELESS SCORE IN HIGH INCOME COUNTRIES



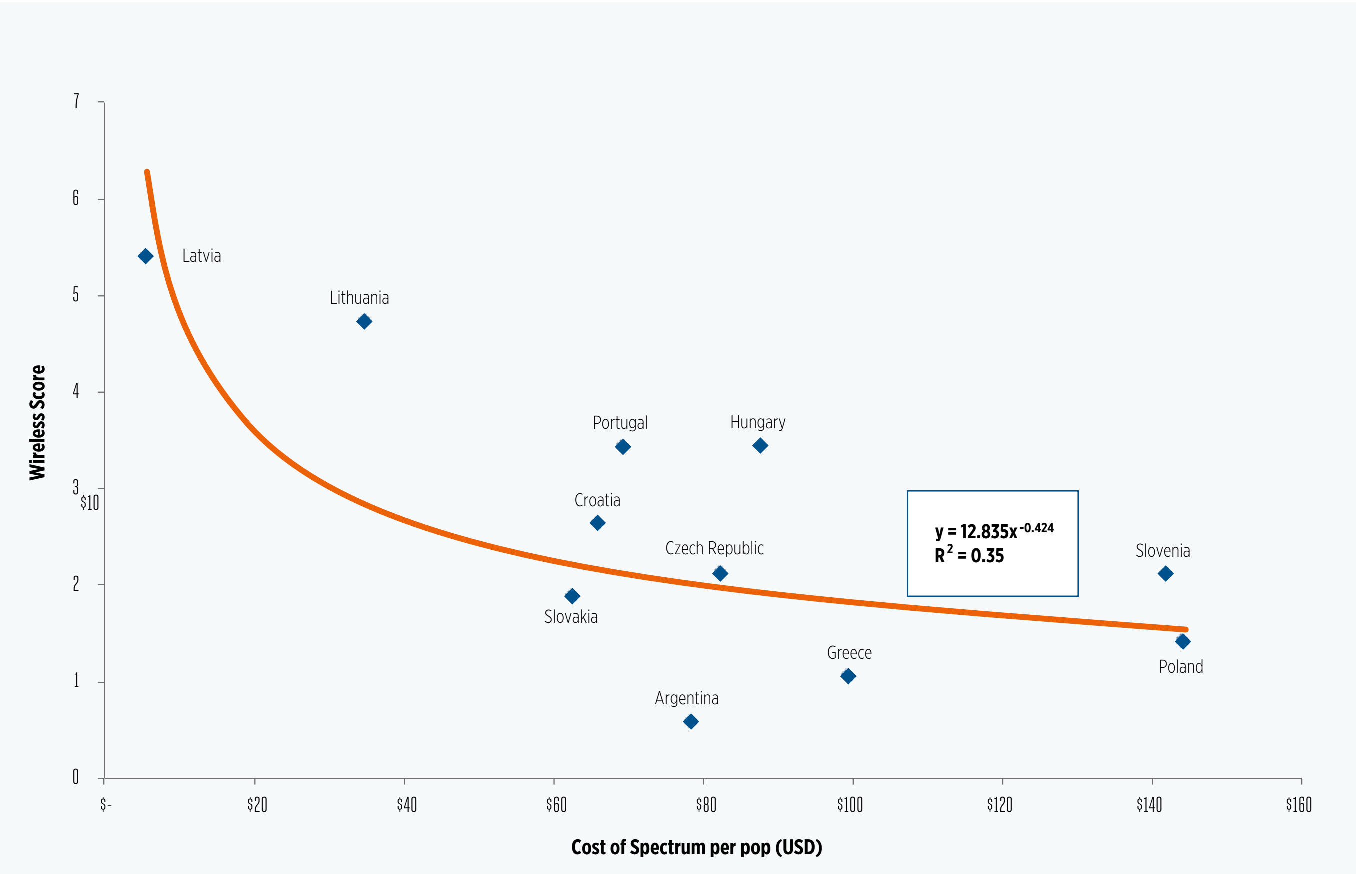

Notes: South Korea is located off the top left hand side of the graph; it has an exceptionally high wireless score (29.5) and modest cost of spectrum per pop ($53). We excluded Hong Kong and Singapore from our analysis, as they are city states and much easier to cover with 4G.

Source: NERA Economic Consulting using data from OpenSignal.com and Telegeography GlobalComms database.

25 We define high income as any country with GDP per capita above USD 25,000, medium income as between USD 11,000 and USD 25,000, and lower income as below USD 10,000. We use 2015 data from the International Monetary Fund (IMF) to determine income by country.

The relationship between spectrum costs and wireless score for middle income countries is reported in Figure 12. The relationship shown here is even stronger than for higher income countries, but the sample is smaller: only 12 countries, ten of which are in Europe.

FIGURE 12: RELATIONSHIP BETWEEN SPECTRUM COSTS AND WIRELESS SCORE IN MIDDLE INCOME COUNTRIES




Notes: Excludes Chile, which is an outlier owing to late adoption of 4G, which depresses its wireless score.

Source: NERA Economic Consulting with data from OpenSignal.com and Telegeography GlobalComms database.

We also explored the relationship between spectrum costs and wireless score for lower income countries. This sample of countries is small and much more heterogeneous than the other groupings, for example ranging from Pakistan, with a GDP per capita of $1,450, up to Mexico at $9,010.[26] Although the observed relationship is consistent with the hypothesis (and strongly significant if two extreme outliers from the sample of ten countries are dropped), all the countries have low wireless scores. Given that many of them only recently launched 4G services, we think it would be premature to place any great weight on observed differences between wireless scores. Nevertheless, it seems reasonable to anticipate that as 4G services mature in these countries, the same negative relationships as observed for the medium and higher income country groups will emerge.

## 2.3. Evidence linking lower spectrum prices to greater price competition

In Chapter 1.4, we also presented evidence from the academic literature linking high prices for scarce inputs to disincentives for price competition. To test whether this relationship holds true for mobile spectrum, we extended our cross-country analysis to consider the relationship between spectrum prices and downstream prices for mobile data. As above, we set out our methodology and source data, and then present our findings. For both higher and middle income countries, we observe a significant statistical link between higher spectrum prices and higher consumer prices for data.

### Methodology and source data

Theoretical and empirical research in the area of behavioural economics has highlighted a link between high sunk costs and higher prices for consumers. To test whether this relationship holds for spectrum costs, we compared spectrum costs (on a per MHz Pop basis) and observed prices in September 2016 for wireless data for each country in our sample. We again divided our sample into three groupings, based on GDP per capita, so as to avoid the results being distorted by the relationship between price levels and ability to pay in countries with very different income levels.

Wireless plans vary substantially across countries and across mobile operators. To make them comparable and to identify a representative price for 1 GB of data, we selected (or constructed with add on 'data packs') a 'representative plan' for every mobile network operator within a country.[27] The price of each MNO's plan was then divided by the number of gigabytes in the representative plan. Each country's representative price for 1 GB of data was then calculated using the weighted average (subscriber share) of all the representative plans available in the country.[28]

### Findings

For all three country groups, we found a correlation between lower spectrum costs and lower consumer prices for data services. These results support the hypothesis that high input costs suppress incentives for price competition. As with investment, they directly contradict the more simplistic hypothesis that licence costs do not affect competition because they are sunk.

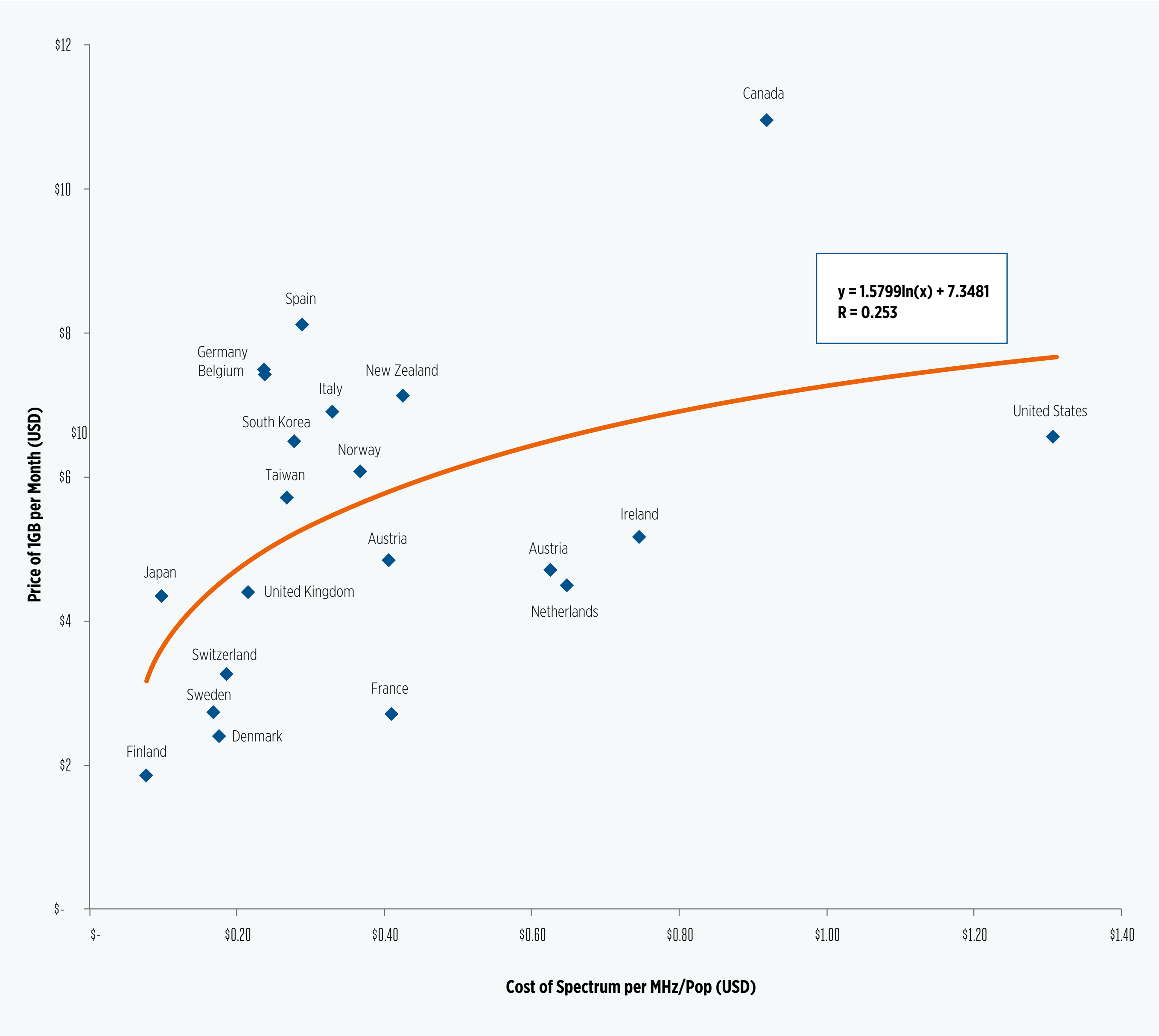
Figure 13 shows the negative relationship between the cost of spectrum and data prices in higher income countries. The relationship is again nonlinear, implying that proportionally greater gains for consumers through lower prices are possible as spectrum costs are reduced.

26 Using IMF 2015 data.

27 The representitive plans were constructed to have approximatly 10 GB of data per month as well as the highest SMS/voice minute combination. We add SMS and voice, as these are usually included in mobile plans in most countries. For example, in the United States, there are no limits on these services, whereas, in some other countries, SMS and voice attract premium fees (e.g. Singapore). We would not be comparing like for like if we ignored relatively expensive voice and SMS add on services in Singapore and only focused on data. We set a threshold of 15 GB per month for unlimited plans or for countries that price based on speed (Finland), given typical usage rarely exceeds this level.

28 Note that we intentionally chose not to use average revenue per user (ARPU) in this analysis. ARPU is not a good indicator for the prices that consumers face in different countries as it includes a decision by users on how much to consume. For example, consumers in a high-price country may decide to consume very little data whereas consumers in a low-price country may decide to consume a lot of data. Thus, the ARPU in two countries may be similar even though actual prices are very different.

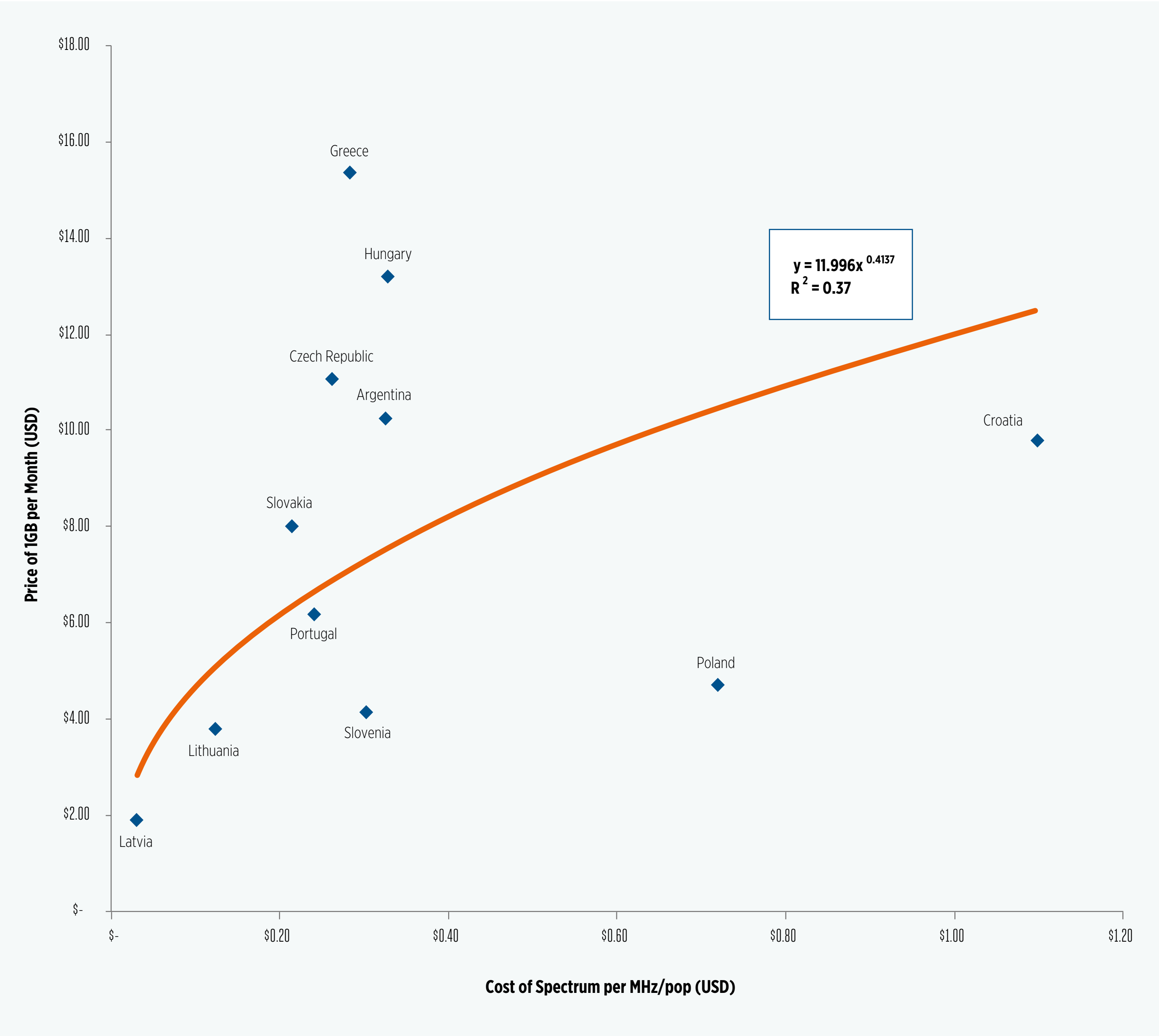
FIGURE 13: PRICE AND SPECTRUM COST RELATIONSHIP IN HIGH INCOME COUNTRIES




Source: NERA Economic Consulting.

The relationship is even stronger for middle income countries, as illustrated in Figure 14, albeit with a smaller sample size.

FIGURE 14: PRICE AND SPECTRUM COST RELATIONSHIP IN MIDDLE INCOME COUNTRIES



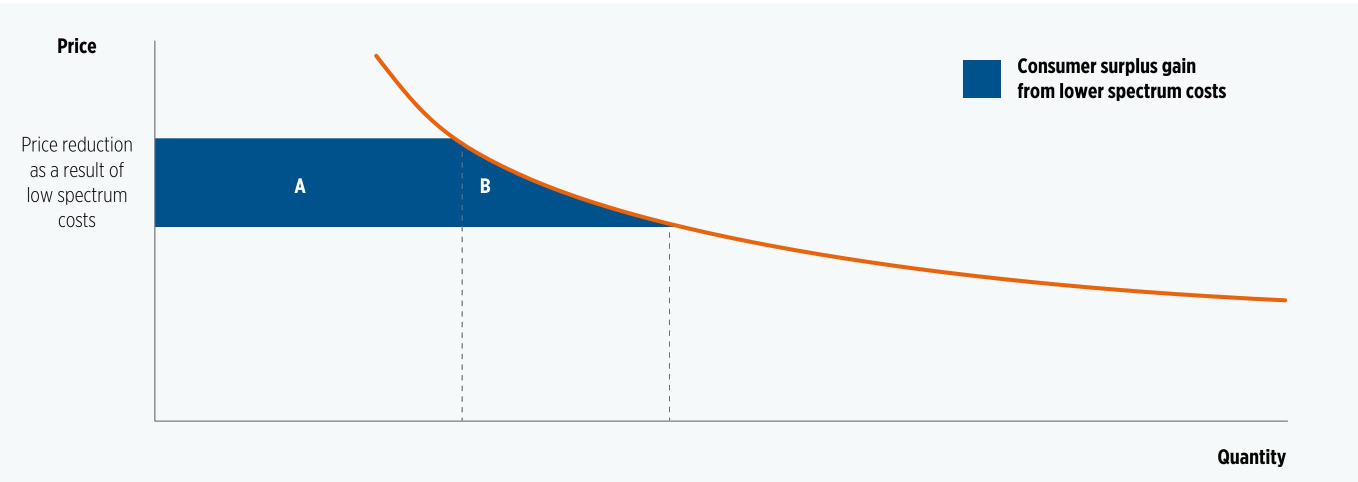

Source: NERA Economic Consulting.

For lower income countries, the relationship is in the same direction but not statistically significant. Again, as with our investment analysis, we think our sample of lower income countries is too small and heterogeneous and launched 4G too recently to place any great weight on observed differences between countries. Nevertheless, there is nothing to suggest that these countries will not follow the same path as the higher and middle income groups.

## 2.4. Evidence linking lower spectrum costs to gains in consumer welfare

We have shown that a reduction in spectrum costs can support a reduction in consumer prices for mobile data. This in turn should lead to an increase in the quantity of data services consumed. We illustrate this using a standard demand curve in Figure 15. The gain in surplus for consumers is equal to the blue shaded area. This consists of a transfer of surplus from producers to consumers (area A) owing to price competition, and previously unrealised surplus (B) generated by the increase in the quantity consumed. In effect, surplus that producers would have otherwise retained in order to fund spectrum costs (area A) is, in the counterfactual scenario of lower spectrum costs, competed away through lower prices. The resulting expansion in consumption also enables society to reclaim additional surplus (area B).

FIGURE 15: CONSUMER SURPLUS IMPACT OF PRICE REDUCTION




Building on our analysis of the relationship between spectrum prices and prices for mobile data, it is possible to construct an econometric model of demand for mobile data. We take the methodology developed by Hazlett and Muñoz (2004) to model demand for mobile voice in the early 2000s[29], and apply this to mobile data in 2016. The model takes into account the cost of spectrum, data prices and data consumption (quantity), as well as a number of explanatory variables for demand, including GDP per capita, urbanisation and mobile market concentration. A detailed explanation of the model is provided in Annex 1.

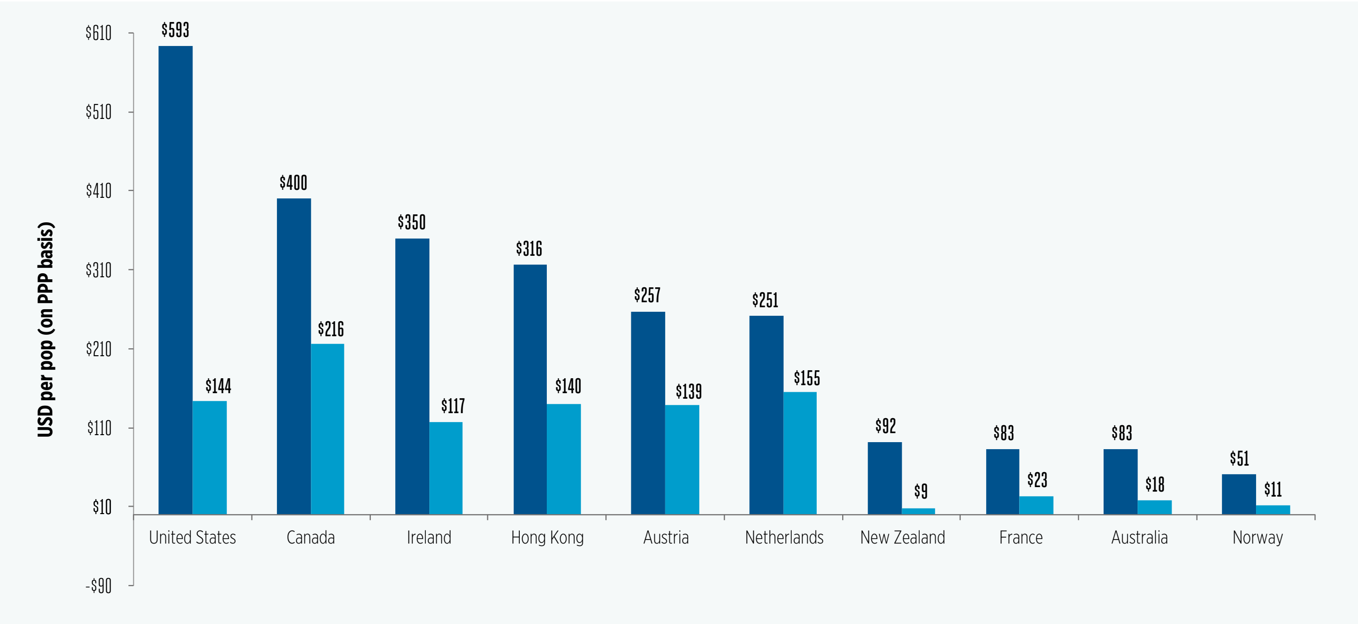
We use this model to calculate the potential welfare gains from lower spectrum costs (via lower data prices), as illustrated in Figure 15. Specifically, for each country which has a cost per MHz per pop above the median for its peer group, we ask what gains in consumer surplus are possible if the cost of spectrum was reduced to the median level. For peer groups, we use the same three categories – higher, medium and lower income – based on GDP per capita.

29 Hazlett and Muñoz, 2004 to today's era of high level data consumption. See Hazlett and Muñoz, 2004, A Welfare Analysis of Spectrum Allocation Polices. AEI-Brookings Joint Centre, pp. 4-18.

Across our sample of 32 countries, 15 had costs above the median level for their peer group. We estimate the aggregate gain in consumer surplus from reducing spectrum costs to the median level across these countries to be $445bn. This gain would come at the expense of reduced government revenues of $192bn. Thus, the net welfare gain for consumers in these countries from lower spectrum prices would be $253bn in total or $118 per person. All these figures are in purchasing power terms (with real exchange rates, our numbers would be lower).

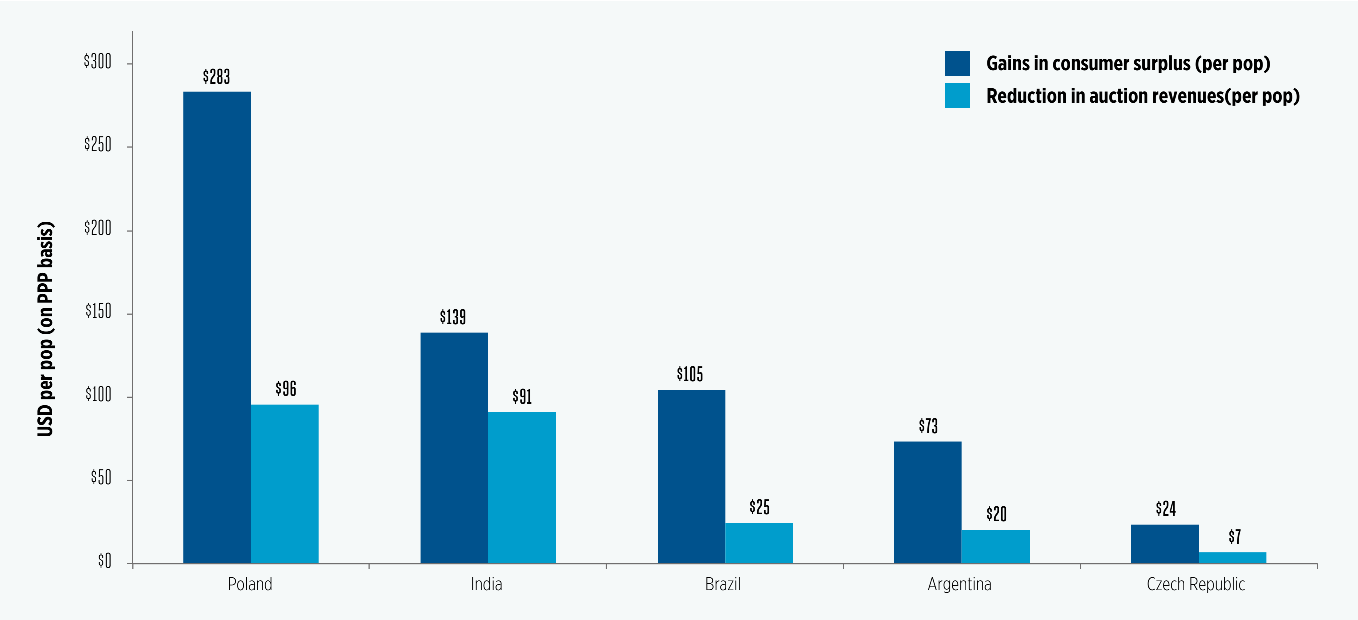
Figure 16 and Figure 17 provide a breakdown of the estimated welfare effects for countries in our sample with above median prices. Individual country calculations should be interpreted with caution, as our global model necessarily cannot account for local factors which may push the true market price up or down.

FIGURE 16: IMPLIED SCOPE FOR NET GAINS IN CONSUMER SURPLUS FROM LOWER SPECTRUM COSTS FOR SELECTED HIGH INCOME COUNTRIES




Source: NERA Economic Consulting, using data from various sources.

FIGURE 17: IMPLIED SCOPE FOR NET GAINS IN CONSUMER SURPLUS FROM LOWER SPECTRUM COSTS FOR SELECTED MIDDLE AND LOWER INCOME COUNTRIES




Source: NERA Economic Consulting, using data from various sources.

## 2.5. Spectrum pricing and the outlook for 5G

The price of mobile spectrum over time should reflect the evolving equilibrium between its supply and demand. Supply is driven by the release of new bands, and constrained by the availability of equipment to use those bands. Demand is driven by growth in consumer demand for mobile data, and constrained by the ability of mobile operators to monetise that value. Looking forward, it is apparent that supply of spectrum is set to increase rapidly, an appropriate regulatory response to forecasts of huge growth in mobile data demand. However, unless operators can find new sources of revenue, the price they can afford to pay for spectrum must decline.

The following are the key trends:

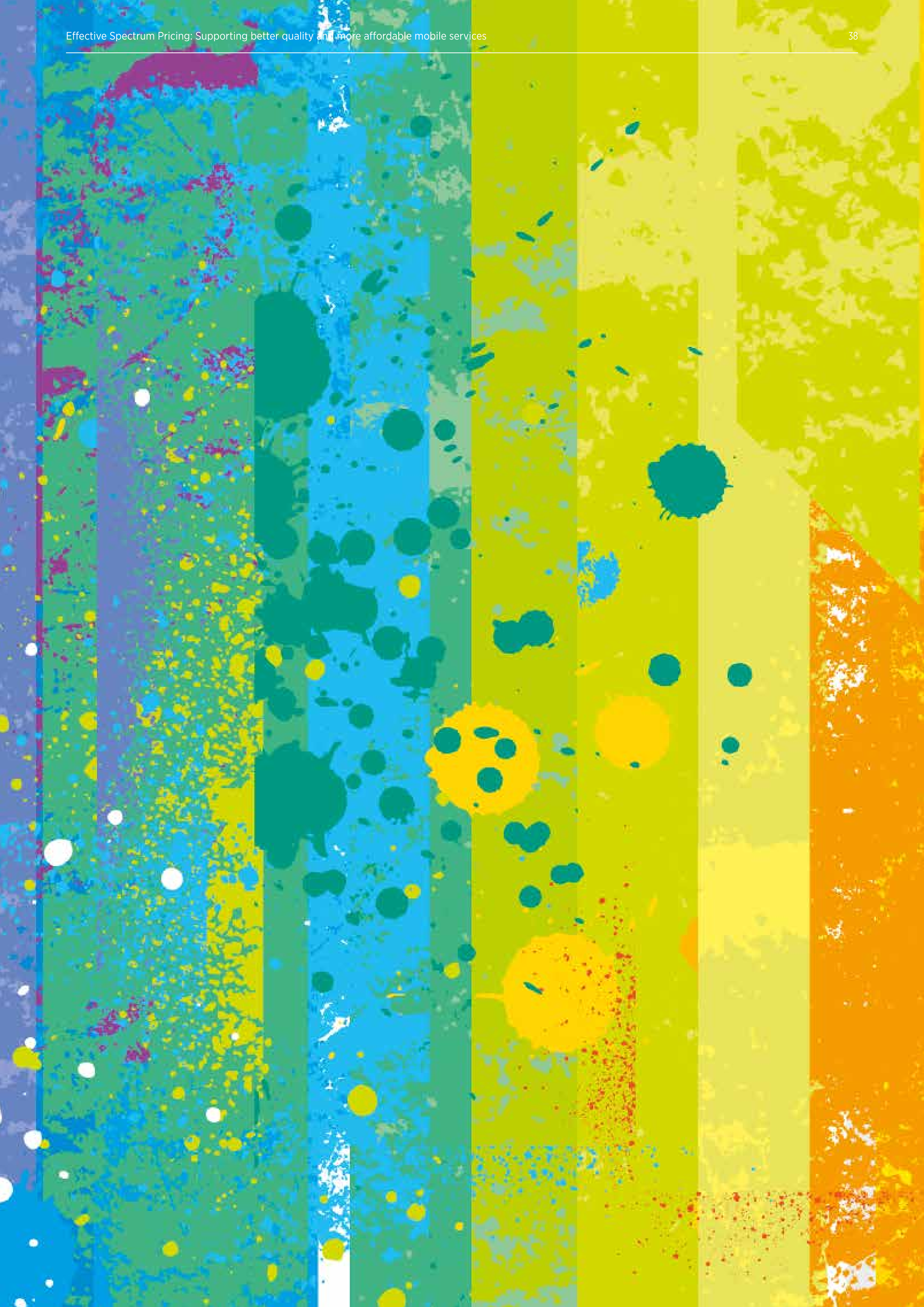
- **More spectrum.** The next five years will see an increase in spectrum availability, especially at higher frequencies. For example, in Europe, the release of spectrum at 700 MHz, 1500 MHz, 2300 MHz and 3400-3800 MHz has the potential to increase total spectrum for mobile from just 340 MHz in the 3G era to over 1,000 MHz by 2020. Looking further ahead, regulators are also exploring options for operators to access much larger swathes of frequency available in bands above 5 GHz.
- **More flexible technology.** This huge expansion in spectrum availability is supported by advances in antenna technology, which have made it possible for next-generation handsets to support all these frequency bands. Other technology advances are enabling operators to exploit ever larger blocks of spectrum, so as to expand capacity and headline speeds. For example, with 4G LTE, some operators are now aggregating up to three blocks of 20 MHz, and 5G may be deployed using much larger blocks of spectrum.
- **Rising demand for data.** MNOs are experiencing exceptional growth in mobile data traffic. This rise is driven by a growing number of users connected to faster networks doing ever more of their everyday tasks and enjoying more and more entertainment on their smartphones. While there is uncertainty over the level of future data demand, all industry experts predict massive growth.[30]
- **Huge investment required.** The next generation of networks that will support this demand will require roll-out of expensive new infrastructure, including densification of macro cells and roll out of small cells, in particular to exploit higher frequency bands. This point is made notwithstanding the potential to deploy spectrum as an alternative to some investment in network capacity.
- **Limited revenue growth.** In many advanced countries, subscriber penetration is well above 100% and ARPUs are not increasing.[31] Against this background, the ability of operators to monetize the growth in demand for mobile data, for example through fixed-mobile convergence or new value-added services linked to the Internet of Things, is uncertain.).

In summary, the current outlook is for reduced spectrum scarcity but uncertain scope for operators to generate revenues from mobile networks. This implies that prices paid for spectrum should fall, especially as future releases are increasingly focused on higher frequency bands. Countries that try to resist this trend, either by restricting spectrum availability or overpricing newly released spectrum, are likely to see large amounts of spectrum go unallocated. Such outcomes would constrain the ability of operators in those countries to develop new services, and act as a disincentive for them to invest and compete in the provision of next-generation services. Given the evidence that a growing minority of countries have engaged in high spectrum price practices in recent years, this points to an escalating divide between countries in the development of their mobile ecosystem.

Taking a more positive perspective, a lesson from our analysis is that by embracing policies that avoid inflating spectrum prices, countries have the opportunity to realise more rapid availability and adoption of next generation network services than would otherwise be the case. This observation may be particularly important for lower income countries, where there is greatest potential to grow the market for mobile data. Prompt and extensive deployment of the latest mobile technologies can stimulate the development of the whole digital ecosystem. This, in turn can increase the competitiveness of national companies and bring services like education, healthcare or banking to areas or citizens that otherwise would have scant and expensive access to them, if at all.

30 See, for example, GSMA, 2015, 'Data demand explained', which compares forecasts across four industry observers, available at: http://www.gsma.com/spectrum/wp-content/uploads/2015/06/GSMA-Data-Demand-Explained-June-2015.pdf.

31 According to data from Telegeography Global Comms Database, 67 out of 83 mobile operators in OECD countries reported declining ARPUs between 2010 and 2015. This excludes 9 operators where 2015 data is not yet available.



# 3. Mistakes in spectrum pricing

A striking feature of spectrum auctions over the last two decades has been the huge variation in price per MHz paid for similar spectrum, after adjusting for population and local economic conditions. As we highlighted in Chapter 2, there are many examples of awards generating prices well above average levels, and the instances of such high price outliers has increased in recent years. The variations in price are simply too great to be explained by differences in local mobile market conditions, such as market penetration or revenues per user. Sometimes, high prices may simply be the result of strong competition between current and aspiring mobile operators. This should not generally be a concern for regulators. However, in recent years, more often than not, high prices can be linked to decisions by local policymakers, in particular with regards to reserve prices. This in turn implies that many countries are implementing pricing policies that discourage roll-out of next-generation mobile services and constrain consumer welfare.

Mistakes by policymakers when pricing spectrum can be grouped into three broad categories, as illustrated in Figure 18. Firstly, and most obviously, reserve prices and annual fees may be set above the true market value. This approach is often associated with award failure. Secondly, high prices may result from artificial scarcity or uncertainty over future spectrum availability, factors that inflate valuations. Thirdly, inappropriate award rules create risks for bidders or options to foreclose competition, which oblige or tempt operators to overpay.

FIGURE 18: COMMON MISTAKES IN SPECTRUM PRICING


Source: NERA Economic Consulting

Often, in cases of high price spectrum allocations or failed awards, more than one of these policy errors is present. For example, if spectrum availability is artificially constrained, this may support excessive reserve prices and create gaming options for operators to foreclose competition.

We discuss below each type of mistake, illustrated by examples from awards around the world. We specifically focus on awards where high prices or award failure can be linked to errors in policymaking, because these are the areas where regulators can and should do better. A suitably empowered regulator should have control over setting fees, managing spectrum releases and designing award formats. They can also set rules that discourage incentives for anti-competitive bidding or prevent clearly undesirable outcomes, such as one party acquiring too large a share of the available spectrum.

We are less interested in cases where high spectrum prices were driven primarily by competition between operators and aspiring entrants. It is not the job of regulators to protect mobile operators from fair competition and it is unrealistic to expect them to protect operators from market bubbles. For example, the eye-watering prices realised in the UK and German 3G auctions in 2000 were primarily the result of unduly optimistic views regarding the commercial potential of 3G, as opposed to policy error. More recently, the record prices achieved in the US AWS-3 were primarily driven by competition between operators and other bidders, rather than intervention by the FCC, and likely reflect local market factors not present in any other national market.

As an antidote to our list of blighted spectrum awards, we conclude this chapter by presenting the case of Sweden which has one of the highest wireless scores and amongst the lowest consumer prices for mobile data in our country sample. In a number of interviews with mobile operators, it was cited as an example of better practice in spectrum pricing. PTS was praised for setting fair reserve prices, bringing spectrum to market in a timely manner and clearly signposting future releases, and setting auction rules that supported its policy objectives, including rural roll-out, with minimum distortion to valuations and competition.

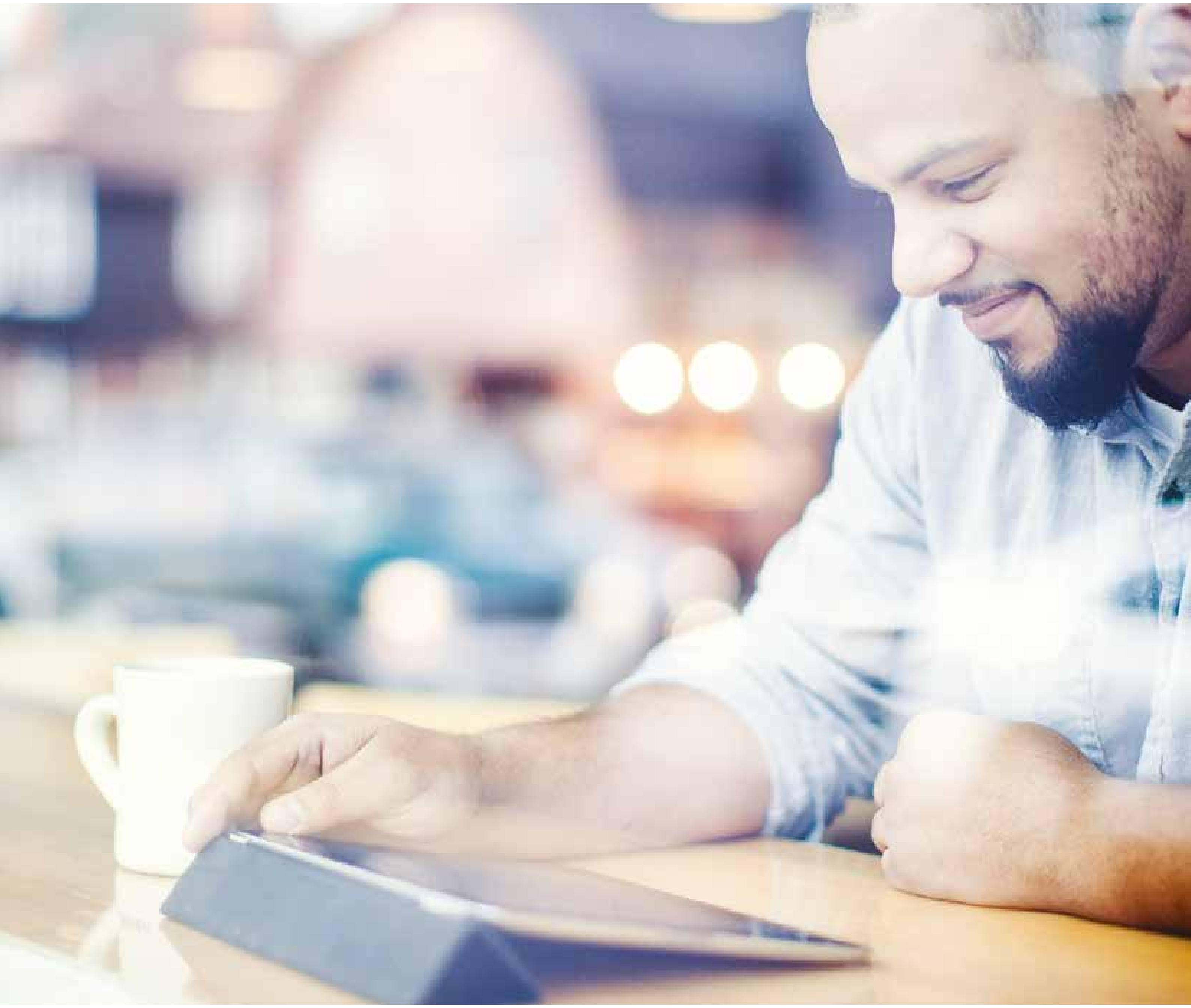
### 3.1. Excessive minimum prices

The most obvious mistake that some governments or regulators have made is to set minimum prices for spectrum that are too high, i.e. above the fair market value. If the regulator is fortunate, they may find a price point at which all or most of the spectrum sells. More typically, over-pricing results in substantial amounts of spectrum going unsold and also acrimonious disputes between the regulator and incumbent operators. Failure to sell spectrum in this case is clearly inefficient, preventing the use of a scarce resource to provide valuable services for consumers. Sometimes, it also means lower revenues for the government, as the regulator could have raised more money overall by selling the entire band at a lower price.

**Where no spectrum sells, the situation may eventually be resolved by the launch of a new award process at a lower reserve price.** Typically, this takes several years, as it may require time (or sometimes a change of government) before a regulator is ready or able to change its approach. A more complicated situation may occur where some but not all of the high priced spectrum sells. When this happens, it creates a divide between the interests of operators who have bought spectrum (typically larger incumbents) and those that refused (typically smaller incumbents or potential entrants). This may make it even harder for the regulator to adjust downwards the reserve price for future awards, especially if there is the possibility of legal challenge from operators that bought spectrum.

#### High upfront reserve prices

The classic example of spectrum being overpriced is the 2100 MHz band in France. We describe the saga of the French allocation of 3G licences in the box on page 42. In retrospect, it is obvious that the initial (fixed) reserve price was set too high, as it was based on the very high 3G prices realised in the UK and Germany. However, because some spectrum did sell to incumbents at the high fixed fee, it was subsequently difficult for the regulator to adapt the price and licence terms in the way needed to sell all four licences. As a result, operators were saddled with high spectrum costs, 2x15 MHz of prime spectrum went unsold for a decade, and consumers likely suffered as a result of enduring disincentives for operators to invest and compete to a maximum extent.



## France – The 3G licence saga

French regulator ARCEP launched its first award of 3G spectrum in August 2000, with applications due January 2001. Unlike the UK and Germany, which had run competitive auctions with modest reserve prices, France opted for a beauty contest with high fixed prices: four 2x15 MHz licences for $4.5bn each, $18bn in total. The enormous reserve price was influenced by the outcomes of the UK and German auctions, earlier in 2000. The decision backfired. Against a background of a worldwide collapse in market sentiment towards 3G, only two of the three incumbents – Orange and SFR – applied for licences, and no entrants participated.

After lengthy deliberations, ARCEP launched a new contest for the remaining two licences in September 2002. Despite slashing the licence price by over 80% to €619m ($565m) each plus 1% of 3G revenues, it was only successful in persuading the third incumbent, Bouygues, to buy a licence. ARCEP also gave the same price reduction to Orange and SFR.

ARCEP tried again to sell the 4th licence in 2007, with similar terms. This contest drew one application, from Free Mobile, but this was rejected as Free wanted to pay in instalments rather than upfront. After further consultations, in August 2009, ARCEP launched a new procedure for awarding a 2x5 MHz 3G licence. In December, it was announced that Free Mobile had acquired the licence for €240m ($350m). The remaining 2x10 MHz was sold in equal parts to SFR and Orange in February 2010.

The entire process of allocating the spectrum took almost ten years, during which time valuable spectrum went unused. The incumbent operators were saddled with paying fees above the true market value, but these fees also acted as a barrier to new entry. At the time of the 2009 award, France had consumer mobile prices "among the highest in Europe."[32] Since 2010, the relative success of the new entrant Free (as compared to other recent entrants in European markets), which now has a 17.7% market share, may be evidence that the 3G process constrained incumbent incentives both to invest and compete over the preceding decade.

With the new wave of auctions for 4G spectrum since 2010, there have been a significant number of award failures which can be linked to high reserve prices. The incidence of such events seems to have picked up in recent years, consistent with the uptick in high spectrum price outliers we identified in Chapter 2.1. We suspect this is connected to two factors: (1) a surge in the number of spectrum awards in medium and lower income countries, where regulators may face stronger political pressure to consider revenue outcomes; and (2) an emerging trend for regulators to rely on (often inappropriate) benchmark price outcomes from prior awards when setting reserve prices.

32 ARCEP, Results and summary of the award procedure for the fourth 3G licence, 18 December 2009.

In the box below, we describe the recent award failures in Ghana, Mozambique and Senegal, all caused by prices being set at levels that local operators say are too high. A common theme across the three auctions is the use of international benchmarks to set reserve prices. While the regulators have not disclosed their methodologies, the suspicion is that they have placed substantial weight on prices from more developed mobile markets, and have made insufficient adjustment to account for differences in consumer spend on mobile services. Whereas Mozambique sold no spectrum, Ghana and Senegal are potentially in a worse position because they sold just one licence, in each case to the market leader. As in France in the 2000s, local regulators now face a difficult political choice between reducing prices (which might require them to refund the market leader) or hanging tough in the hope others will eventually buy. This may mean a long period of reduced competition in 4G services.

## Mozambique, Ghana and Senegal 4G – History repeated

Mozambique, Ghana, and Senegal all provide recent examples of countries that have overpriced 4G licences, leading to valuable spectrum going unsold. Each appears to be repeating a variant of France's 3G saga.

Mozambique was one of the first countries in Africa to offer 800 MHz, with an auction scheduled for June 2013. Instead of offering the usual six blocks of 2x5MHz, regulator INCM offered only five lots, an apparent attempt to use artificial scarcity to drive competition between the three incumbent operators, in case no new entrants participated. However, the auction failed to attract any applicants, as all parties baulked at the reserve price of USD 30 million per block ($0.12 per MHz per pop). Our understanding is that the reserve price was calculated using worldwide benchmarks for 800 MHz auctions (mainly from Europe), but insufficient adjustment had been made for the small size of the local telecommunications market. As of September 2016, the spectrum remains unallocated, limiting options for mobile operators to expand 4G coverage and capacity. However, with no spectrum sold, Mozambique at least has the option to start the entire process again with reduced prices.

In Ghana, the current situation draws even closer parallels with France. In December 2015, the regulator, NCA, proposed to auction two 2x10 MHz lots of 800 MHz spectrum, with the objectives to: provide valuable spectrum to the mobile industry; generate revenues for the government; and foster growth in the existing mobile internet. However, its decision to set a reserve price of USD 67.5 million per lot ($0.13 per MHz per pop) has put all these objectives at risk. Three of the four incumbent mobile operators declined to participate. Only the market leader, MTN Ghana – which has a 47% subscriber market share, acquired a licence. Ghana now faces the possibility of sector monopolisation as the market migrates from 3G to 4G.

A similar saga has begun in Senegal. In November 2015, regulator ARTP launched a tender to award 4G mobile licences with a reserve price of about USD 50 million. One month later, ARTP received a letter signed by all three incumbent mobile operations calling for a price reduction. ARTP refused, arguing that the prices were based on benchmarks from awards at 700 MHz, 800 MHz and 1800 MHz in over 20 other countries and appropriate given local market potential. It is unclear which benchmark countries were used, but given the bands mentioned, it seems likely that many were from much more developed markets. All three mobile operators subsequently boycotted the 4G auction. However, ARTP reported in June that market leader Sonatel will acquire a 4G licence as part of a USD 220 million package that will also renew all its existing mobile and fixed line licences. Again, this risks creating a competitive asymmetry in the market.

Examples of other countries that have failed to sell 4G spectrum owing to high reserve prices include:

- **Australia (2013), where the government intervened to price 700 MHz at A$311m per 2x5 MHz block (US$1.36 MHz/pop), with the specific objective of raising revenues. It missed its revenue targets, as only six of the nine 2x5 MHz blocks from this core 4G band sold. Notably, #3 operator VHA declined to bid, while #2 operator Optus bought only two blocks. As of 2016, ACMA, the Australian regulator, is consulting on selling the residual spectrum.**
- **India (2012-16), where a large amount of spectrum, especially in sub-1 GHz bands, has gone unsold owing to exceptionally high reserve prices (see case study under spectrum scarcity below);**
- **Jordan (2013), where the regulator offered large packages of spectrum across the 800, 1800, 2100, 2300 and 2600 MHz bands. It set very high upfront fees for each band, ranging from $0.37 up to $1.36 per MHz/pop unadjusted (or $0.72 up to $2.68 after adjusting for purchasing power). It also demanded a 10% revenue share. All operators refused this offer. However, in 2014, market leader Zain subsequently had an offer to buy 2x20 MHz at 1800 MHz for $200m accepted, and the regulator raised the 1800 MHz reserve to reflect this. Subsequently, Orange bought 2x10 MHz at 1800 MHz for $100m. The other spectrum remains unallocated.**
- **Romania (2012), where the regulator failed to sell 2x5 MHz at 800 MHz and 2x40 MHz at 2.6 GHz, in a multi-band auction with four competing bidders. The two large operators, Orange and Vodafone, each bought 2x10 MHz at 800 MHz. However, the reserve price at 800 MHz of US$0.22 per MHz/pop ($0.50 on a PPP basis) was too steep for the country's two smaller operators, Cosmote (which bought one 2x5 MHz block) and RCS & RDS (which did not buy any).**

The failure of these countries to sell valuable spectrum may be contrasted with the relative success of Morocco's 4G auction in January 2015. Morocco allocated a total of 240 MHz of spectrum (60 MHz each at 800 MHz and 1800 MHz, and 120 MHz at 2500 MHz), split equally across three packages, which were won by the three incumbent bidders. In a sealed bid, all spectrum sold at a price close to the reserve price per licence of DH 500 million plus a contribution of DH 239m to cover band clearing costs (US$77m per bidder). The price per MHz pop was $0.06, well below, for example, the $0.13 sought in Ghana, even though Morocco's GDP per capita is more than 40% higher. Overall, the government still realised a substantial windfall for taxpayers, but at a level which should not impede investment and competition in 4G services.

### High annual fees

High annual fees can also create difficulties for regulators trying to set reserve prices for new spectrum awards. In many countries, annual fees for frequency bands are set separately from awards, sometimes by legal statute. If set at a substantial level, then minimum upfront fees in auctions must be reduced accordingly to prevent award failure. In the worst case, regulators may be left with no flexibility to price spectrum appropriately.

On page 43, we discuss the example of Mexico, where annual fees as a proportion of total spectrum cost are unusually high. This has become a source of contention, with some mobile operators complaining that fee levels are unsustainable, given their requirements for more spectrum to meet the demand for new data. This was an issue in the Mexico AWS auction, where prior government decisions and precedents on prices left the regulator IFT with little flexibility on setting reserve prices for AWS spectrum.[33]

This challenging situation may be contrasted with Denmark, where annual fees are set at a low level, sufficient to recover spectrum management cost. For example, the 2016 fee for 1800 MHz spectrum was only Kr 56,000 ($10,000) per MHz, compared to MXN 40m ($2.9m) per MHz for AWS spectrum in Mexico. At the Danish level, annual fees place no constraint on reserve prices, leaving the regulator with great flexibility to vary upfront fees between bands and auctions based on local demand conditions.

33 NERA Economic Consulting advised the IFT on design and implementation of this auction.

### Mexico AWS – High annual fees limit independent regulator's options

In Mexico, spectrum fees for legacy mobile bands were set by law (Ley Federal de Derechos) and subject to annual increases. When the fees were established, they were supposed to capture 70% of estimated market value; however, this was at a time when relatively little spectrum had been released. As operators have secured more PCS and AWS spectrum, the aggregate fee burden has increased substantially. Such costs fall particularly heavily on the country's second and third largest operators –Telefónica and AT&T – owing to their modest market shares of 24% and 9% respectively, compared to 67% for market leader Telcel.

For the 2016 AWS auction, the annual fees for AWS spectrum was set at MXN 400m ($29m) per annum index linked, per 2x5 MHz block. This is equivalent to $0.17 per MHz/pop.

This exceptionally high annual fee created significant challenges for the regulator IFT in designing the award process. While it could be reasonably certain that it would sell all available AWS-1 spectrum, which was usable immediately, the outlook was less certain for AWS-3, where equipment was not yet available. IFT decided to set a much lower upfront fee per 2x5 MHz block for AWS-3 than for AWS-1:

- **AWS 3: Upfront payment of MXN 65m ($0.0025 per MHz/pop).**
- **AWS 1: Upfront payment of MXN 937m ($0.04 per MHz/pop).**

Despite IFT's decision to set a minimal upfront fee for AWS-3 spectrum, one 2x5 MHz block went unsold. The smaller operators have both argued that it was the high annual fees that deterred their participation in the auction. While the largest operator (Telcel) bought the maximum permissible amount of spectrum (and might have bought more if permitted), AT&T acquired only 2x10 MHz of AWS-1 spectrum, and Telefónica did not participate.

## 3.2. Artificial scarcity of spectrum

High spectrum prices can often be linked to artificial scarcity of spectrum. It is obvious that if the supply of a scarce resource is constrained, its price will increase. Although spectrum allocation for mobile is coordinated at an international level, countries follow very different approaches to the release of frequency bands. While some of these differences reflect legitimate factors, such as challenges in clearing legacy users or differences in the development of local markets, it is also the case that some countries appear to have deliberately held spectrum back. Other causes of high prices include artificially constraining supply for incumbents, through entrant reservations, or uncertainty over the roadmap for future spectrum releases.

### Holding back spectrum from the market

Developing countries have generally been slow to bring new mobile spectrum bands to market. Often, this reflects domestic regulatory challenges and issues with clearance or liberalisation of legacy bands. Certain countries have also deliberately held back spectrum from the market in order to increase award revenues.

While holding back spectrum from the market may mean you get higher revenues for the spectrum you do sell, the downside is significant:

- **It involves warehousing a valuable resource, thus constraining development of new services and scope for competition;**
- **Any premium that winning bidders pay may be reflected in an expectation of greater profits owing to a less competitive market, i.e. at the expense of consumer surplus;**
- **Lost consumer welfare owing to lower quality, higher priced services in the years that spectrum availability is constrained can never be recovered;**
- **High prices achieved in such auctions may generate unrealistic expectations that they can be repeated in subsequent awards, setting in train a path to future award failures owing to excessive reserve pricing.**

The evolution of spectrum awards in India since 2010 provides a case study of how government-induced artificial spectrum scarcity has supported high spectrum prices, which generates unrealistic expectations for further revenues from future awards, leading to excessive reserve prices and large swathes of spectrum going unallocated. We explore the Indian case in the box on page 47. Egypt is another example where operators have been in dispute with the government over timely release of spectrum for 4G services at fair prices.

Artificial scarcity of spectrum is most common in lower and medium income countries, where regulatory mandates to promote efficient allocation may be less embedded. Such practices are typically precluded in countries that have strong independent regulators and/or well defined rules for spectrum management. For example, EU law requires that countries make available new spectrum bands in a timely manner, and the European Commission actively monitors the progress of member states in this regard.[34] While EU member states do vary in the speed in which they have brought 4G bands to market, very long delays are rare and countries typically release frequency bands in their entirety.

34 See, for example: European Commission Press Release, Europeans suffering because most Member States are too slow delivering 4G mobile broadband spectrum, Brussels, 23 July 2013, available at: http://europa.eu/rapid/press-release_IP-13-726_en.htm

## India – spectrum scarcity inflates auction prices

Between 2010-16, India has held six auctions for mobile spectrum, more than any other country over this time period. Each auction has typically included only subsets of the total frequencies normally associated with IMT bands, with significant variance across regions. The process for determining which frequencies are made available when has also been fraught with uncertainty, meaning that operators lack a clear roadmap regarding their options to acquire spectrum in the future.

The 3G auction in 2010 was a key milestone in the development of the mobile industry in India. It supported the entry of a large number of new operators, many backed by established international operators. These companies collectively paid a steep price for the spectrum they won ($16bn). This likely reflected the perceived value of entering one of the world's largest markets by population rather than the intrinsic value of the spectrum.

Since the 3G auction, the government has in effect adopted a twin strategy of (a) drip feeding spectrum into the market; and (b) ratcheting up the reserve price for new spectrum, based on prices paid in previous auctions. This has had predictable results. Firstly, as spectrum remains artificially scarce, some frequencies are selling at ever-higher prices. Secondly, a large amount of spectrum has failed to sell because operators have been forced by the high reserve prices to ration their demand. Finally, the allocation of frequencies across bands has been distorted by the relative levels of reserve price. In particular, operators have perversely focused on capacity spectrum rather than sub-1 GHz spectrum, because the latter category has become so expensive.

The October 2016 auction featured a much greater quantity of spectrum, spread across seven bands, than previous awards. Had this entire spectrum sold, it would have contributed substantially to ending artificial spectrum scarcity in India. Instead, the auction flopped, with just 41% of the airwaves available sold and the auction raising only $9.8bn, against a reserve price of $84bn. Bidding was heavily focused on high band frequencies, whereas 700 MHz and 900 MHz received no bids.

The Indian market has great potential, but until operators have the chance to acquire substantive spectrum holdings at realistic prices, the deployment of next-generation data networks will remain stunted. Moreover, deployment will likely focus on urban areas at the expense of rural ones, as most operators cannot acquire the sub-1 GHz spectrum they need to cost effectively cover the rural population. This should be particularly alarming in a country with an exceptionally high rural population that has limited access to fixed line communications.

### Squeezing the supply of spectrum for incumbents

While regulators in OECD countries rarely act to hold back spectrum from the market, they have sometimes created artificial scarcity for incumbent operators through measures that reserve spectrum for entrant bidders. If this leaves too little spectrum available to meet the minimum demands of large incumbents, this may result in operators paying very high prices for the spectrum that they do win. Typically, in such cases, high prices for winning incumbents are offset by much lower prices for entrant bidders.

Three recent 4G auctions where actual or de facto reservations for recent entrants had a huge impact on spectrum prices were the Canadian 700 MHz and AWS-3 auctions and the Netherlands multi-band auction:

- **In Canada in February 2014, market leader Rogers paid C$3.3bn (US$3bn) for a near national 2x12 MHz lower 700 MHz band footprint, while rivals Bell and Telus (who operate a network and spectrum share) paid C$1.7bn (US$1.5bn) in aggregate for a clearly inferior footprint that straddled the lower and upper bands. In the subsequent AWS-3 auction in March 2015, Bell and Telus in aggregate paid C$2bn (US$1.6bn) for a national 2x15 MHz footprint, while Rogers won nothing. Each auction also featured entrants who secured (actual or de facto) reserved spectrum at steep discounts. The asymmetric auction outcomes were shaped by entrant caps and reservations that precluded auction outcomes in which all incumbents could secure satisfactory amounts of spectrum.**
- **In 2012, the Netherlands ran an auction for five bands, including the 800, 900, 1800 and 2100 MHz bands in their entirety, raising €3.8bn (US$5bn), well above pre-auction expectations. The auction was shaped by decisions to (1) reserve 2x10 MHz at 800 MHz for a new entrant; and (2) not impose any spectrum caps on bidders. This meant that at least one incumbent would fail to win 2x10 MHz in this core LTE band. Each incumbent also faced the risk of not winning back sufficient 900 MHz and 1800 MHz spectrum to maintain their legacy 2G businesses.**

In both these cases, incumbent operators were likely obliged to pay much more than the true market value, absent measures to promote entry. The authorities in Canada and the Netherlands obviously hoped that new entry will stimulate consumer benefits through greater competition, but it remains to be seen if this is the case, and whether such benefits can offset the disincentives for competition and investment that may result from the high prices paid by established operators.

### Failing to provide a roadmap for future spectrum releases

A related issue is the failure of some regulators to provide a roadmap for future releases of spectrum, including renewal and liberalisation of existing bands. This makes it difficult for companies to value new spectrum, as they cannot properly assess their future options. The uncertainty may distort relative valuations, resulting in inefficient outcomes with some companies buying too much and others too little.

Argentina has been cited as a country that has a poor record of signposting spectrum awards. There was a gap of nearly 15 years between the award of 3G and 4G spectrum, and – during this period – operators had to manage with 40-50 MHz each. In the 2014 auction for 700 MHz and AWS spectrum (see box on page 51), operators had to contend with high reserve prices, onerous coverage obligations and uncertainty over future spectrum availability, not least as the 2600 MHz band is currently allocated to fixed wireless access services. The situation in Argentina may be contrasted to the typical approach in Europe, where regulators flag bands for future release many years in advance. For example, in the UK in 2012, Ofcom began consulting on plans to release 700 MHz, even though an auction is not expected before 2018 and band clearance would not be complete until 2020.

Some regulators have been criticised for the opposite problem of bringing spectrum to the market too soon. For example, in 2010, Switzerland proposed to include 2100 MHz in its multi-band auction, even though existing licences did not expire until 2017. The regulator presumably believed that combining all bands in a single auction would make it easier for operators to manage substitution risks across bands. However, this approach meant that operators would have to pay upfront for something they could not use for seven years. This issue, amongst others, likely contributed to a delay in the multi-band award, until 2012.

Meanwhile, in 2014 in Brazil, operators were obliged to bid for 700 MHz licences and commit to covering the costs of re-tuning broadcast equipment so as to allow clearance of incumbent TV broadcasters. It could be five years or more before Brazilian operators are able to access this valuable spectrum nationwide. The latest timetable is for spectrum to be released one year after the analogue TV switch off, which will be staggered on a regional basis from October 2016 to December 2018. The timetable for several major cities has already been set back once, and further delays are possible.

## 3.3. Bad award rules

Prices in spectrum auctions will always reflect the conditions under which bidders are competing for the scarce resource. If those conditions are distorted, then the price may deviate from the fair market level.

Our final category covers a range of policies, award rules and licence conditions that create risk for bidders, and distort award outcomes, including:

- **Onerous or ambiguous licence obligations;**
- **Rules that promote insincere bidding;**
- **Rules that put enterprise value at risk; and**
- **Rule that incentivise anti-competitive bidding.**

### Onerous licence obligations

Governments often attach conditions to spectrum licences as a way of influencing the behaviour of operators in the downstream consumer or wholesale markets. Network rollout conditions covering population, geography or specific locations, are the most common form of obligation. Examples of other conditions include obligations to host MVNOs, provide roaming access to entrant operators, and paying costs to cover band clearance. Whenever an operator is obliged to take actions that go beyond its commercial self-interest, they impose a cost, and thus reduce the value of the spectrum licence.

With respect to their impact on spectrum pricing, regulators commonly make three types of mistake when imposing conditions on licences:

1. **The conditions are ambiguous or too onerous (sometimes not credible);**
2. **They are badly structured – in particular, obligations that could be fulfilled by one operator or shared across operators are instead applied to all operators; and**
3. **Reserve prices are not adjusted to reflect the financial burden of meeting the obligations.**

Onerous obligations have a similar effect to increasing the reserve price. They stifle scope for price competition in the auction, and decrease incentives for (other forms of) investment and competition in the downstream market. Many Latin American countries – including Argentina, Brazil, Colombia – have higher consumer prices and lower wireless scores than European countries with equivalent GDP. This may be attributable to the widespread application of onerous coverage obligations on all operators. For example, in the box on page 51, we highlight the case of Argentina, where a combination of high prices and onerous coverage obligations on 700 MHz likely contributed to the failure of new entrant Airlink.

Argentina would likely have had a better outcome if it had adopted an approach closer to that used in Denmark or Sweden. These two countries use different auction formats but there are three common themes in their approach to coverage. Firstly, rural coverage obligations are only attached to low band spectrum, such as 700MHz or 800 MHz, suitable for wide area coverage. This makes them feasible. Secondly, obligations are either tied to specific spectrum blocks available in the auction or the auction format is set up in a way that ensures that only one operator will ever be obliged to cover a specific uneconomic area. This avoids wasteful duplication of infrastructure and makes such investments more economic. Thirdly, both countries use modest reserve prices and have adopted pricing structures that allow those bidders that take up a coverage obligation a discount. This allows operators to express a value on taking the obligation and stimulates competition in the award.

## Argentina – Onerous obligations and high prices create uncertainty about future investment

In Argentina, there was a gap of nearly 15 years between the award of 3G and 4G spectrum. During this period, operators had to manage with 40-50 MHz each. Consequently, when 700 MHz and AWS spectrum was finally released in a combined award in 2014, incumbent operators had little choice but to participate.

They did so on very onerous terms:

- **High reserve prices – $0.23 per MHz per pop for 700 MHz and $0.22 for AWS spectrum.**
- **Harsh coverage obligations which went far beyond what an operator might build on commercial terms:**
  - Requirement to cover all cities with a population of over 500 (approximately 98% of the population) within 5 years; and
  - Requirement to cover 26,000 km of roads.
- **Upfront fees and any penalties for non-fulfilment of obligations to be payable in US dollars, not Argentinian pesos.**

They also bid with no certainty regarding future availability of spectrum, not least as the 2600 MHz band is currently allocated to fixed wireless access services. This meant that any operator that skipped the auction would face not being able to offer a competitive 4G service for an indefinite period.

All the spectrum sold, raising $2.23bn in total, modestly above the reserve price. However, one winning bidder – new entrant Airlink – subsequently defaulted on its first auction payment and had its licence withdrawn. It appears that external investors baulked at the prospect of investing in a start-up facing very high upfront spectrum costs and tough roll-out obligations. The spectrum it won remains unsold with no information provided about when it could be made available to incumbents.

Looking forward, the remaining incumbents face the challenge of roll-out obligations which many believe are unrealistic and will have to be renegotiated. As of October 2016, the 700 MHz band has not yet been released to operators: the deadline for clearance (July 2016) has already passed and broadcasters are in litigation with the regulator. In the meantime, high costs are likely to dampen incentives for 4G investment and price competition in the cities, which suggests that Argentina is likely to remain close to the bottom of our wireless score rankings (see Figure 10).

### Rules that promote insincere bidding

Auctions work best when bidders bid truthfully, submitting bids that reflect their true, undistorted valuations. A key requirement is that bids are committing. If bidders can renege on their bids at little or no cost, then auctions may be vulnerable to over-bidding, resulting in prices that are inflated well beyond true market value. In certain situations, bidders may also be able to place bids that they know they will not win, thus distorting prices for opponents but not themselves.

There have been a number of 4G auctions where the auction rules contained loopholes or lacked credibility, leading to perverse price outcomes:

- **In 2012, the Czech Republic took the extraordinary step of cancelling its multi-band 4G auction owing to "excessive prices", after bids topped $1 billion. Pavel Dvorák, chairman of the CTU warned that: *"Such excessive prices of the auctioned frequencies would have to negatively translate into excessive charges for fast mobile internet ... We therefore consider it necessary to step in and prevent future negative consequences for the customers."* [35] The auction lost credibility because the rules contained a loophole that could potentially enable a bidder to escape its commitment, so no one could be sure that other bidders were sincere. Later the same year, with the loophole closed, a re-run of the auction raised $423m, with some capacity spectrum going unsold.**
- **In 2013, the Finnish 800 MHz auction lasted for an incredible nine months, owing to a loophole in the rules that allowed prices to fall as well as rise. The spectrum eventually sold at prices close to reserve, with the three bidders sharing the spectrum equally. This is a rare example where it is clear that spectrum sold below true market value.**
- **In 2015, the Polish 4G auction also took nine months to conclude. As prices climbed to high levels, confidence in the auction was eroded owing to concerns that bidders might exploit a loophole enabling them to renege at no cost on their licences. The regulator stepped in, first to pause the auction and then announce a sealed bid finale. Ultimately, the entire spectrum sold for $2.3bn, but entrant winner NetNet declined to pay for the 800 MHz lot that it won. In this case, it seems likely that competition from an insincere bidder may have pushed prices beyond true market value.**

Even in auctions without such loopholes, price distortions are possible on a band-by-band or even a lot-by-lot basis if incumbents have predictable and inflexible demand. For example, in Canada's AWS auction in 2008, a large entrant set-aside ensured that the three incumbents could predictably be expected to buy the rest of the spectrum. Entrant bidders took advantage of this to repeatedly bid on more expensive spectrum outside the set-aside (knowing they would be overbid) as a way of delaying competition with rivals for the set-aside spectrum. The result was that the incumbents were obliged to pay substantially more than the entrants for spectrum that should have had identical value.

35 For a detailed analysis of the Austrian auction, see: Maarten Janssen and Vladimir Karamychev, Gaming in Combinatorial Clock Auctions, University of Vienna.

### Rules that put enterprise value on the line

A common feature linking many high price spectrum auctions is that bidders are competing not just for spectrum, but also their relative position in the downstream market. This is always true for potential entrant bidders but may also be true for incumbents, where access to incremental spectrum may be essential to their ability to compete for customers. As demand for data grows, an incumbent operator that fails to maintain a critical mass of 4G capacity spectrum could be permanently diminished as a competitive force or even being knocked out of the market.

In recent years, many countries have held large multi-band awards, many including 900 MHz and 1800 MHz spectrum, where existing licences were approaching expiry. Such large auctions offer both advantages and disadvantages. At their best, such events make it easier for bidders to manage substitutability and complementarity across bands, and thus identify the optimal spectrum portfolio for their needs. At their worst, they open up the possibility that an incumbent could suffer serious network disruption or even be knocked out of the market, especially where they face losing access to legacy spectrum. In such settings, a bidder's enterprise value may be on the line, meaning they could be induced to bid very aggressively. This creates the potential for grossly inefficient spectrum allocation, as bids may be based on bets about implications for downstream competition rather than the incremental value of the spectrum.

In the box on page 55, we explore the example of the 2013 Austrian multi-band auction, where three incumbents unexpectedly fought a fierce battle for 800, 900 and 1800 MHz spectrum. The high prices and a very asymmetric allocation can be linked directly to auction rules that encouraged competition for enterprise value. The Austrian auction may be contrasted to more modestly priced multi-band awards in countries such as Slovenia and Montenegro, where similar auction formats were run with greater transparency and spectrum caps that protected incumbents from the risk of losing spectrum essential to their business.

## Austria – enterprise value on the line

Austria's multi-band auction for 800, 900 & 1800 MHz took place in 2013. It was a very important auction, mixing legacy 2G spectrum and key 4G bands. However, it was not expected to be a high price event, as only the three incumbents had qualified to bid. The market had recently been reduced from four players, following the merger of the two smallest operators.

The regulator, RTR, however, adopted policies that appear to have been designed to stimulate competition between the three operators, who might otherwise have been willing to share out the spectrum at modest prices.[36] Firstly, they selected a combinatorial clock auction (CCA), a format that discourages unilateral demand reduction.[37] Secondly, they took the unusual step, for a CCA, of hiding information about aggregate demand, meaning that bidders were bidding blind. Finally, they adopted lax spectrum caps, which left open the possibility that one of the bidders could be shut out by the other two. This created risk for the incumbent operators, who each had minimum demands to maintain their legacy 2G networks and be competitive at 4G.

With each company's enterprise value on the line, bidding was fierce. Final prices, at €0.84 per MHz/pop were – by some distance – the highest in Europe for a 4G award. The final spectrum allocation was also highly asymmetric, with the largest operator, Telekom Austria, winning 50% of the spectrum, while its smaller rival Three was shut out of the 800 MHz band.

In the aftermath, it appears that all parties were embarrassed by the result. RTR put out a statement implying that the high prices were the result of bidders making inflated bids for large packages they knew they would not win as a way of increasing prices for rivals. Meanwhile, all three operators released statements criticising the auction format, with some warning that investment would suffer. For example: T-Mobile said that *"If one of the three operators was unable to afford spectrum, they would not be able to provide 4G services, and we came very close to that scenario. Therefore, the prices set are at the market value of the entire company, rather than the market value of the spectrum,"* [38] and Three described the auction as a *"as a disaster for the industry because the high pricing is likely to see rural rollouts abandoned"*.[39]

As illustrated in Figure 11, as of 2016, Austria has the lowest wireless score amongst our sample of 23 high income countries.

36 For a detailed analysis of the Austrian auction, see: Maarten Janssen and Vladimir Karamychev, Gaming in Combinatorial Clock Auctions, University of Vienna.

37 For further explanation, see: Richard Marsden and Soren Sorensen, Strategic Bidding in Combinatorial Clock Auctions, in Bichler, M and Goeree, J, Handbook of Spectrum Auction Design (forthcoming, Cambridge University Press).

38 http://telecoms.com/201711/t-mobile-austria-confirms-intent-to-appeal-auction-results/.

39 https://www.telegeography.com/products/commsupdate/articles/2013/10/22/a1-scoops-half-of-spectrum-spoils-h3g-brands-process-a-disaster-for-industry/.

### Incentives for anti-competitive bidding

In auctions where enterprise value is at stake, the valuations and bids of some parties may be inflated owing to expectations of anti-competitive benefits from blocking rivals from access to spectrum. In the worst case, governments may embrace rules that actively entice operators to pay high prices in return for the potential to eliminate competition. Perhaps the most notorious example (widely cited in the spectrum auction literature) is the Turkish 2G auction in 2000, which we describe in the box below, where the winner of the first 2G licence was de facto able to block bidders for the second licence.[40] As discussed above in relation to high reserve prices, any auction where reserve prices are inflated to a point where smaller operators are priced out of the market potentially has this feature.

### Turkey - unintended consequences

The 1800 MHz award in Turkey is widely cited in the academic literature as a good example of how not to run a spectrum auction. The authorities offered two identical 1800 MHz licences in sequential auctions. For reasons that are unclear but may reflect a misguided effort to increase revenues, the rules set the reserve price of the second licence at the final price of the first licence.

The winner of the first block (Is-TIM) strategically placed a very high bid on the first licence. This was effective in pricing out competition for the second licence, which went unsold. As a result, incumbents Telsim (now Vodafone) and Turkcell were each unable to win any 1800 MHz spectrum. A further licence was granted directly to state-owned Turk Telecom. Subsequently, Is-TIM and Turk Telecom merged in 2004 to form Avea.

This approach shows the obvious folly of trying to price new awards based on the outcome of previous ones. Not only did Turkey delay bringing valuable spectrum to the market and artificially constrain the number of operators able to launch 1800 MHz networks, but it also likely secured much less revenue than if it had sold all the spectrum.

## 3.4. How to avoid mistakes

The many mistakes in spectrum pricing that we described above can be avoided if regulators follow these three rules:

1. **Price spectrum to sell.** The key to selling spectrum is to set a reserve price below a conservative estimate of market value, ideally relying on competitive bidding to determine if a higher price is justified.
2. **Bring spectrum to the market as soon as it is needed.** Regulators who sit on valuable spectrum are destroying value for consumers that can never be recovered. Ideally: spectrum should be released as soon as there is a supporting ecosystem and operators are ready to plan deployments; bands should be cleared and released in their entirety; and future awards should be appropriately signposted.
3. **Manage risk for bidders.** Regulators should carefully consider the impact of licence terms, such as duration and roll-out obligations, on value, and reflect this in spectrum pricing decisions. In particular, coverage requirements should be realistic and the most onerous obligations, when considered necessary, should be shared rather than duplicated across operators, with reduced reserve prices to reflect the burden.

In the box on page 57 we highlight the case of Sweden, where the regulator PTS has followed each of these rules. Since the mid-2000s, when it first embraced a market-led approach to spectrum management, PTS has held a succession of successful spectrum awards. We do not think it is a coincidence that Sweden has one of the highest wireless scores and amongst the lowest price levels for data services in our country sample.

40 For example, see: Paul Klemperer, What Really Matters in Auction Design, Journal of Economic Perspectives, Volume 16, Number 1 – Winter 2002, p176.

## Sweden – better practice in spectrum pricing

PTS has a policy of using auctions for assignment of licences when there is competition for spectrum. Since 2003, it has held ten spectrum auctions, with a further two currently planned. Its priority is always an efficient allocation to the users who express the highest values. PTS has no explicit mandate to raise revenues, but is happy to do so as a by-product of securing an efficient outcome.
Sweden has a policy of setting modest reserve prices, such that it is confident the spectrum will sell if there is a use case. It often prices at a low but non trivial level, but does set higher prices when it is clear there will be demand at that price level (e.g. 800 MHz).

This approach has resulted in a series of competitive auctions for major mobile bands, in which prices have significantly exceeded the reserve level:

- **2.6 GHz (2008): Paired Reserve $0.005, Sold $0.14;**
- **1800 MHz (2011): Reserve $0.01, Sold $0.18; and**
- **800 MHz (2011): Reserve $0.11, Sold $0.28.**

All of Sweden's spectrum auctions have been single band awards. Our understanding is that this is a natural outcome of their efforts to bring spectrum to market as soon as practicable. Indeed, Sweden has always been amongst the first countries in Europe to clear and release new 4G spectrum bands. Where feasible, entire bands are always released at the same time.

A benefit of this approach is that each individual auction is a relatively low risk event for operators, as only a modest proportion of total spectrum is ever available at any one time. Indeed, this has allowed Sweden to embrace typically lax spectrum caps within auctions, as it has never faced a situation where there were serious concerns about an auction outcome creating risks to downstream competition.

Sweden also takes other steps to reduce risk for bidders. The mobile licence term is 25 years, amongst the longest in the world. It does not impose coverage obligations on frequency bands above 1 GHz. With respect to 800 MHz, PTS took the decision that a coverage obligation was required to ensure service in selected rural areas. It attached this obligation to only one 2x10 MHz licence, so as to avoid unnecessary infrastructure duplication. It further adopted an innovative approach of allowing operators that bid for this licence to commit to spending between SEK150m-300m ($22m-44m) on specified rural coverage, and count this amount towards their bid. This created an implicit discount for taking the coverage obligation which encouraged active competition between operators for the associated licence.

# 4. What do other industries do?

Mobile communications is one of a wide range of industries dependent on essential inputs provided by public authorities. The terms, conditions and selection criteria that authorities use to allocate those inputs may cast light on potential ways to improve spectrum management, and support effective pricing of spectrum.

We surveyed a number of industries and compared their approaches to pricing and allocation to policies used in the mobile sector. We also sought to understand how these practices varied across industries depending on the characteristics of that industry, such as the level of competition or risk profile of the investment. In this chapter, we describe the survey, and explain some lessons that can be taken from those industries' experiences. Our key observation is that best practice in pricing and allocation is always tailored to the characteristics of the industry.

In those industries with similar attributes to mobile, regulators engaged in best practice:

- **rely on the market to set prices;**
- **encourage full utilisation of the resource;**
- **take measures to mitigate risk for operators; and**
- **adopt a long-term perspective to social value creation.**

## 4.1. Survey of pricing and allocation practices across industries

We surveyed twelve other industries in a number of countries. The common theme across these industries is the presence of private suppliers dependent on an input supplied or regulated by the government.[41] The inputs themselves vary, including: essential resources for the production process (e.g. spectrum licences or mineral extraction rights); licences to operate in a regulated activity (e.g. taxi medallions or toll highway concessions); and customers from publicly supplied services (e.g. social security patients cared for at private hospitals).

These industries are very different. To identify patterns and isolate policies that may be applicable to spectrum pricing, we identified three key dimensions:

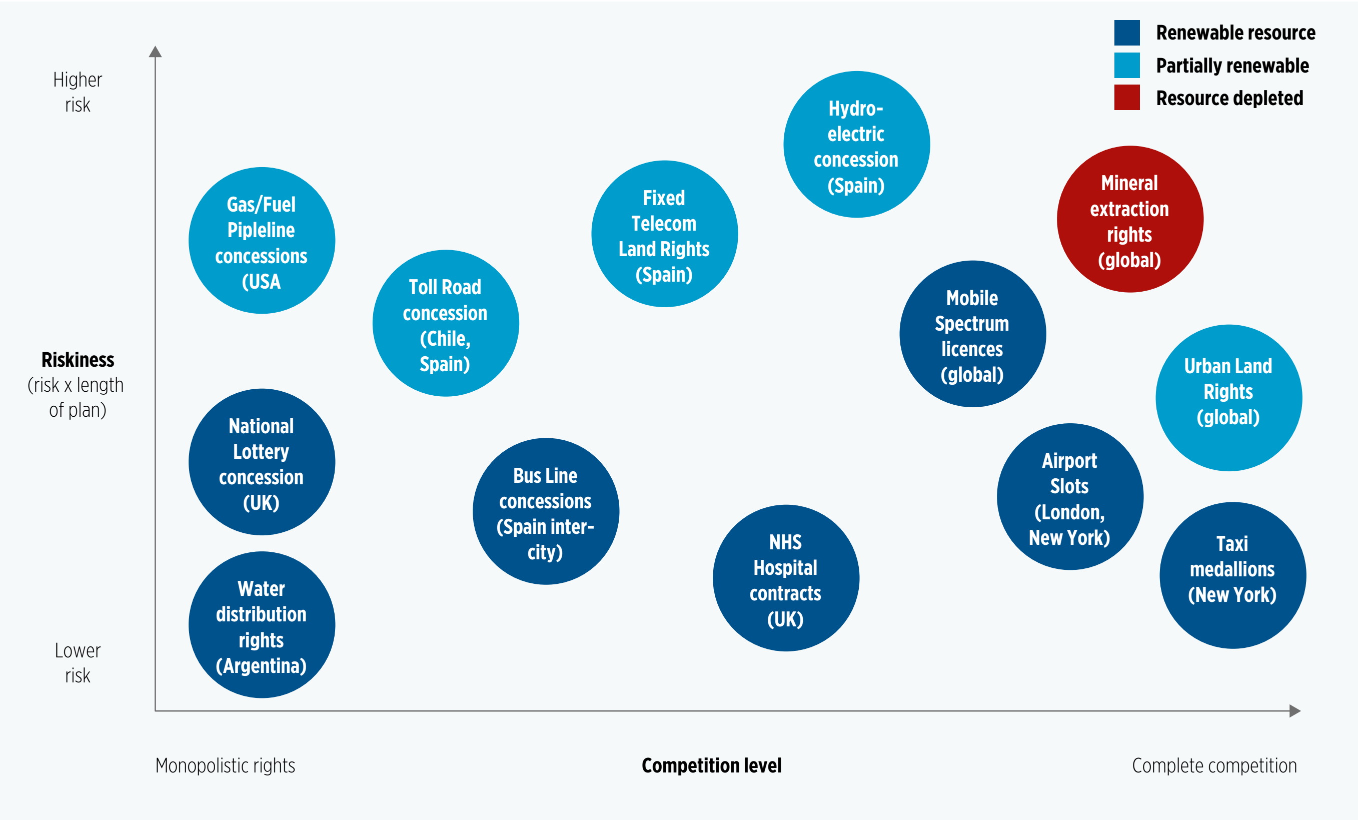
- **Competitiveness.** Mobile communications are competitive worldwide, with three or four mobile network operators in most countries. Industries in our survey that have competitive downstream markets include air travel, taxis, electricity generation and mineral trade. Other industries are only partially competitive: they have local monopolies but face intermodal competition from other activities (e.g. toll road operators or bus line concessionaires[42] face competition from free roads, private cars, railways and airlines). Finally, some industries operate under full monopoly, such as water distributors and gas pipelines.
- **Risk.** By risk, we mean the probability that the company will not achieve the profitability expected in its business plan during the term of its licence. Here, we consider two related dimensions: the intrinsic riskiness of the business; and the length of the business plan. Even the most stable industries are prone to changes in technology, demand, costs and regulation that are more likely to appear the longer the timeframe required to make a return on investment.
- **Renewability.** Another relevant dimension is what happens to the input resource once it is used by the private company. In some cases, like spectrum, water flows or airport slots, the resource is not altered by use: the availability of radio frequencies or airport slots in one period of time is the same irrespective of how intensely they have been used or not in the previous period. In some others, the resource remains in place but is altered by its use; this is the case with land, toll roads or dams. Finally, there are resources like minerals that are depleted when exploited.

41 In some cases the input is not supplied by the government itself, but by any other branch of the public administration (e.g. a sector regulator) or a state-owned organisation (e.g. Social Security or National Health Service), or by a private company (e.g. an airport) that is regulated.

42 Bus lines are operated under exclusive concessions in many countries, e.g. Spain. In other countries (e.g. France) there is free entry and exit to the industry.

A classification of industries along these dimensions is shown in Figure 19. The closer two industries are in the graph, the more likely that best practices in one industry may provide insights for the other.

FIGURE 19: COMPARISON OF SURVEYED INDUSTRIES BY RELEVANT ATTRIBUTES




Source: NERA Economic Consulting.

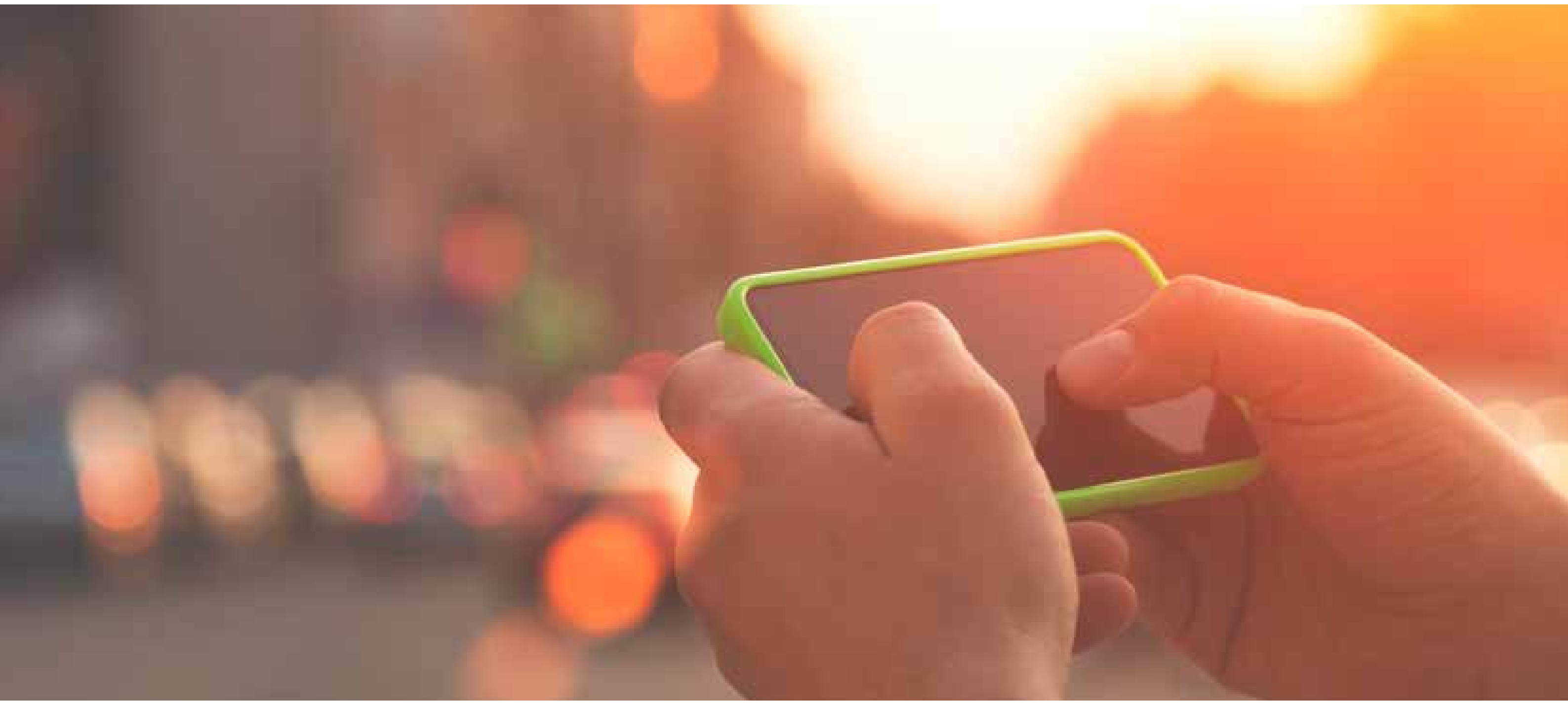
## 4.2. Lessons from other industries

We observed how policymakers responsible for other industries have managed access to state-supplied inputs to ensure that customers receive affordable and quality services. These range from actions designed to enable the growth of competitive industries to those that support a sustainable and affordable supply of monopoly services. In cases of best practice, the appropriate actions are tailored to the structure of the market, based on what can be achieved with and without intervention, and careful consideration of the impact of pricing and associated policy decisions on the behaviour of operators.

Our main observations are summarised in Figure 20 and set out in detail below:

FIGURE 20: LESSONS FOR SPECTRUM AWARDS FROM OTHER INDUSTRIES

| MARKET LED PRICING | FULL ALLOCATION | RISK SHARING | LONG-TERM APPROACH |
|---|---|---|---|
| **Spectrum is a competitive market input:**<br>– In competitive markets, policymakers use the market to promote efficient allocation and set market prices<br>– This contrasts with monopoly markets, where licence fees and consumer prices are linked and linked and tightly regulated | **Spectrum is a renewable resource:**<br>– When values cannot be stored, policymakers maximise welfare by allocating all available capacity<br>– Trade-off between price and time is only relevant when resource depletes | **Mobile network investments carry risk:**<br>– Policymakers can raise the value of licences through risk sharing<br>– Risk mitigation is particularly relevant when licence obligations are onerous | **Welfare maximisation requires a long-term perspective:**<br>– Consumer welfare generation throughout the life of the licence should be the priority of awards<br>– Decisions on allocation and price should be objective and evidence-based |



## 1. In competitive industries, let the market take the lead in pricing

It is standard practice for regulators to charge fees or provide subsidies when granting a licence or concession tied to an essential input controlled by the state. Fees are applied for ventures that are expected to be profitable and subsidies for operations that offer valuable benefits to society but are expected to be unprofitable.

Looking across other industries, a distinction can be drawn between how prices are determined, based on the competitiveness of the downstream industry:

- **Competitive industries.** When downstream industries are competitive, regulators often adopt simple pricing practices and allow the market a leading role in setting prices. For example, many countries use auctions to allocate exploration rights for minerals, and many cities and regions use auctions to allocate transport licences, such as bus routes and taxi medallions. As an alternative approach, some authorities award licences at fixed prices, but allow the secondary market to determine their value: this approach has been widely adopted at congested airports. In a primary award, inventory is usually priced to sell (i.e. reserve prices are set below expected market value), as the state's priority in most cases is to ensure full allocation.
- **Monopoly markets.** In monopoly markets, pricing structures are typically more complicated, owing to concerns about profitability, windfall gains and monopoly pricing power in the downstream market. For example, in the case of water distribution and toll roads, licence fees and consumer prices are linked and tightly regulated to ensure a fair balance over the licence term between the interests of the state, the operator and consumers. In these types of industries, it is more common for regulators to demand revenue shares and/or cap rates of return.

Mobile telephony is at the competitive end of the spectrum of industries relying on an essential input controlled by the state. This implies that spectrum allocation and pricing can be largely devolved to the market, and that windfall gains should not be a major concern, as they will be competed away, either through a spectrum auction or downstream competition. It is clear from our study that many countries are following this approach through use of auctions and/or fair reserve pricing. However, some governments appear to be treating spectrum as if the mobile industry was more akin to a regulated monopoly, where price regulation is necessary to promote the proper functioning of the industry and to prevent windfall gains. This is manifested through imposition of high reserve prices and revenue share requirements on operators.

In the box on page 63, we address the experience of the airline industry, where market reforms have facilitated a huge expansion in air travel, especially owing to low cost services. Regulatory measures that constrain the prices that airports can charge for airport slots and incentivise them to expand capacity have been a crucial part of this success story. By analogy, policies that promote access to spectrum and discourage excessive pricing of spectrum can be expected to maximise the scope for growth in availability and use of 4G and 5G services.

## Airlines – a thriving consumer industry built on affordable access to airport slots

Air travel has become common and affordable since its liberalisation in the early 1980s to 1990s. Competition and innovation have allowed what used to be a luxury service to become a mass market. For example, low cost tickets have made it possible for students and workers to commute between countries in Europe and for low-wage migrants to keep in touch with their families and culture. Mass tourism enabled by low cost air travel has been an important driver of economic growth in many countries.

The essential input for airlines is airport slots, including take-off and landing slots, and access to gates and terminal capacity. At the beginning of the liberalisation process, the main bottleneck for new carriers to enter the market was the incumbent's control of airport slots in major cities, such as London. Air authorities launched several initiatives to make slots more accessible to new entrants, without hampering the ability of incumbent carriers to meet their demand.

In the UK, for instance, these measures included:

- **Regulatory oversight of the prices that airports can charge for airport slots, based on the principle that prices should be non-discriminatory across airlines and reflect the cost of the services provided. Such regulations are designed to prevent airports from exploiting monopoly power, and encourage them to invest in new capacity and quality of service as a way of increasing revenues.**
- **Promoting competition between airports, for example through the 2009 Competition Commission decision requiring Heathrow owner BAA to sell its other London airports, Gatwick and Stansted. This reform reduced BAA's monopoly pricing power and created incentives for airports to compete.**
- **Legal decisions at UK and European level which upheld the right of airlines to buy and sell airport slots. These decisions created important flexibility at congested airports, such as Heathrow, where airlines are given indefinite (grandfathered) rights to slots subject to use-it-or-lose-it obligations.**

As a result, the overall utilisation of airports across the UK and especially around London has increased hugely. Most notably, secondary airports, with cheaper slots, have emerged as hubs of low-cost airlines. More efficient use of existing resources has also allowed total industry capacity at congested airports to outpace the investment in new runways and terminals.

## 2. With renewable resources, welfare is maximised when capacity is fully allocated

Spectrum cannot be stored and value is lost if frequencies are not used at a given time. In other industries where resources are similarly renewable – such as airport slots, hydroelectric generation and irrigation rights – regulators seek to promote full utilisation in each time period, so as to maximise consumer welfare. High market prices for renewable inputs are (correctly) interpreted as evidence that greater supply is needed, and are often a source of political concern, owing to the link between input prices and consumer prices.

**In industries that depend on renewable inputs, it is generally taken for granted that customers will end up paying for artificial scarcity of the input.** Reducing a scarce input has two obvious effects. Firstly, it implies a corresponding reduction in output in the downstream market, and therefore higher prices for consumers. Secondly, when a given amount of input is needed for a supplier to be viable, scarcity may reduce the number of suppliers in the industry, thus reducing competition.
Consider the case of airport slots. Absent environmental externalities, such as noise concerns, airport operators are incentivised to maximise capacity utilisation at congested airports. Any other approach would mean fewer destinations and/or lower frequencies on existing routes for consumers (see box on page 63). In many countries, both airports and airlines have been privatised, and airport slots change hands through secondary market transactions. This means that the state has no direct revenue interest in the prices of slots. It is noteworthy that, in this context, high slot prices at London Heathrow were a key evidence point underpinning the economic case to expand capacity through construction of a third runway. By analogy, countries with high spectrum prices should prioritise releasing more spectrum.

As with spectrum, industries dependent on scarce renewable resources are typically tied to specific locations. Provision of new capacity is often subject to long lead times but can have a big impact on the geographically-constrained downstream market. Best practice involves provision of roadmaps for future capacity. For example, Spanish hydroelectric concessions are managed through “Planes de cuenca” (River basin plans). These plans provide details of the new water flows that will be made available for hydroelectric generation and the year when concessions will be allocated. This way, bidders for today’s concessions have reasonable certainty over the future evolution of their competitive environment.

The situation of markets based on renewable inputs contrasts with extractable resources, such as oil or mineral rights, where there is a genuine trade-off between exploiting resources now or saving them for the future. Public authorities in countries with finite reserves of commodity natural resources often actively manage the release of extraction rights, and expand or contract allocations in response to market price signals, so as to manage revenue flows and safeguard value for future generations. In general, countries are price takers rather than price setters, and national roadmaps are somewhat less important because markets for raw materials are global.

When policymakers manipulate the price of spectrum by holding back frequencies from the market or fail to signpost future allocations, they are effectively treating spectrum as if it were a global commodity whose value can only be realised once. Yet, it is a national renewable resource, which will generate returns for society over and over again and, as we have shown in Chapter 1, the costs of holding it back can be huge.

## 3. Policymakers can increase the value of licences through risk sharing

Risk management is key to the viability of capital intensive industries such as mobile communications. The business model involves large upfront investments in supporting network infrastructure, which is paid for by uncertain revenues over a long time horizon. There are various ways in which governments can help mitigate the risks inherent in such investments.

Risk limitation not only benefits the concessionaire's shareholders, but also consumers. Cost of capital is one of the largest cost components in capital-intensive activities, and it is driven by the risk perceived by investors and lenders. High costs of capital can harm consumers in multiple ways: they may prompt the supplier to raise consumer prices or lower quality so as to improve profitability; or even prevent a project from going ahead. Government measures that decrease the perceived risk should lower the cost of capital of the operator, and thus improve customer welfare. Of course, these must be weighed against the cost of such support.

In many capital-intensive industries, where there are high upfront costs and long time horizons, compensation mechanisms are used to cover operators against risks beyond their control, such as regulatory changes, demand slumps, inflation spikes or foreign exchange movements. Often, these are offered in exchange for regulatory checks on the ability of the operator to set prices and define downstream services. For example, with toll roads, governments may guarantee minimum revenues, or extend the duration of the licence to allow the operator to recover all of its initially accepted costs, but only in return for tightly regulated toll fees. As discussed in the box on page 66 Chile has pioneered new methods aimed at mitigating external risk for private investment in toll roads.

When compared to other capital intensive industries in our sample, the mobile industry requires less support than most because it has a strong, consumer-based business model with potential to generate substantial revenues. As the market is competitive, regulatory constraints on pricing and quantity decisions are typically limited. Accordingly, mobile operators do not require the type of revenue guarantees developed, for example, for Chilean infrastructure projects. Nevertheless, the general principle embraced in Chile of building a regulatory and pricing framework that reduces risks for operators is still relevant. In particular, where policymakers adopt policies aimed at obliging spectrum licensees to make investments in networks that are not commercial viable, they should take into account the increased risk for operators when setting upfront spectrum prices and other licence terms..

## Chile – better practice in risk management

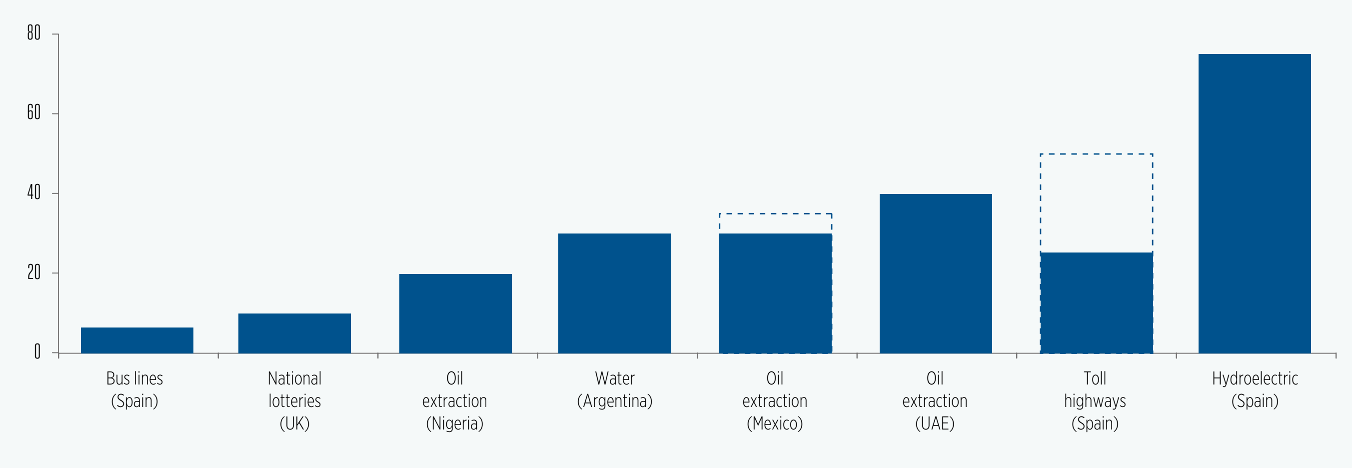
Chile has had particular success with the implementation of flexible-term concessions to mitigate demand risk in public infrastructures. The Chilean Public Works Concession Law defined the possibility of using the sum of total revenues – discounted or not – required by the concessionaire as the main economic variable for tendering concessions. The law led to the development of the "least present value of revenues" (LPVR) mechanism. Under this approach, the contract ends when a predetermined amount of accumulated revenues, as fixed by the terms of the contract, is ultimately reached.[43]

The first concession using LPVR in 1999 was the Santiago–Valparaíso highway (Route 68), which attracted four bidders. Since then, the least present value of the revenues (LPVR) has been used as the main criterion to award highway and airport concessions.

The LPVR approach was particularly effective in mitigating the effects of an economic recession on the profitability of the concession during the recession endured by Chile between 1998 and 2002. During this period, the government was obliged to vary the contract terms of many concessions in trouble by changing them from fixed-term to flexible-term contracts. The only concessions that were not renegotiated were the ones that had already been awarded under the LPVR approach.

One of the most effective solutions to providing investment certainty to mobile operators is to extend spectrum licence terms. As illustrated in Figure 21, licence durations vary widely across industries. Licence durations are generally longer in more capital intensive industries. For example lottery and bus concessions have licence duration of between 6 to 10 years whereas hydroelectric dams may have a licence term of up to 75 years.[44] Based on this comparison, the widespread use of 15-year licence terms for spectrum appears too short. Regulators worldwide could increase investment certainty for mobile operators by adopting the European Commission proposal for minimum 25-year licences, or the US approach of de facto indefinite rights.

FIGURE 21: DURATION OF CONCESSIONS OR LICENCES (YEARS) FOR SELECTED INDUSTRIES




Source: NERA Economic Consulting, using data from various sources.

43 For more details on the Chilean use of flexible term concessions, see e.g. José Manuel Vassallo, Flexible-Term Highway Concessions. How Can They Work Better?, Transportation Research Record: Journal of the Transportation Research Board, No. 2187, Transportation Research Board of the National Academies, Washington,D.C., 2010, pp. 22–28.

44 Some industries have even abandoned licence durations altogether. For example, oil extraction rights in the UK and Russia cover the time needed to extract the oil in the awarded field. Similarly, fixed telecommunication access to rights of way in European countries is typically indefinite as well.

## 4. Welfare maximisation requires a long term investment perspective

Investment in most infrastructures is perceived as an enabler of growth and competitiveness across an economy, and thus the level of investment is considered alongside the gains to society that are expected to materialise over time. This is the case, for example, with electricity, roads, harbours or airports, all of which enable companies and workers to be more productive and conduct business across the country and internationally more easily. This is also the case with dams and irrigation channels, which contribute to the improvement of land productivity and allow food production growth to outpace population growth. Similarly, a long-term perspective is needed for mobile networks which, in many areas, are now the main telecommunications infrastructure and often the only one potentially affordable to all citizens.

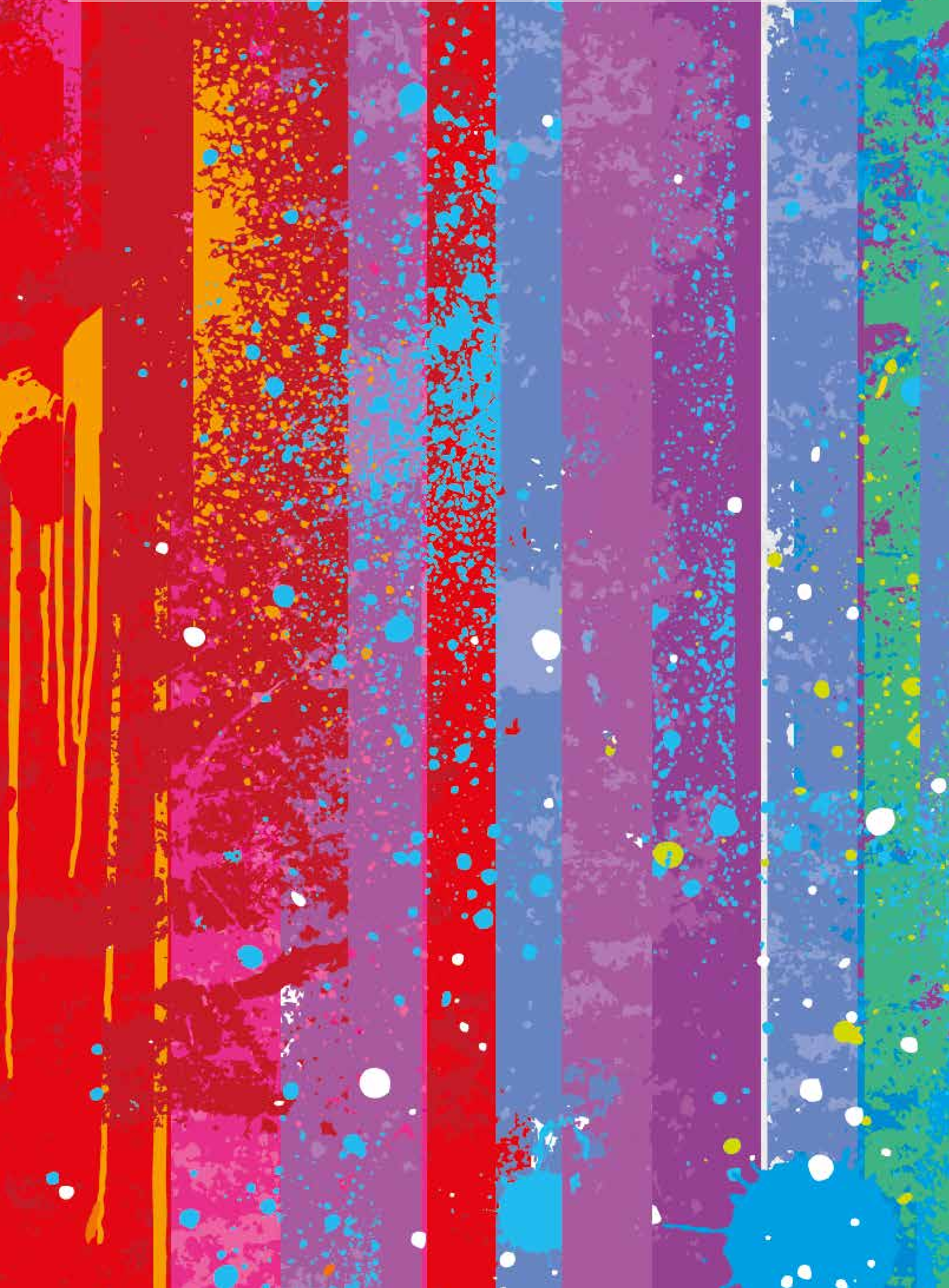
Many large infrastructure projects require state subsidies in order to proceed. In recent years, policymakers in many countries have come under intense pressure to embrace more transparent techniques to demonstrate the value of individual projects. In Europe, EU countries have responded by passing legislation which mandates the use of Cost-Benefit Analyses (CBAs) for projects over €50m initiated after 2014.[45] CBA is an analytical tool that directly assesses the welfare change attributable to the project, when compared to alternative interventions, and sets this against investment costs. When used effectively, it can help de-politicise spending decisions by providing an objective, evidence-based assessment of the case for government investment.

Consumer welfare is usually one of the main award criteria for infrastructure concessions. In monopoly situations, governments are often willing to forego cash payments from the concessionaire in exchange for lower prices for consumers and better outcomes for society. For example, this is the general case for public work concessions in Chile, for toll highways and bus lines in Spain, and for water distribution concessions in Argentina. Similarly, when tendering for the right to run the National Lottery, the UK National Lottery Commission focuses on the ability of the operator to generate returns for good causes over the licence period. In 2000, this led to the rejection of a bid offering the highest percentage contribution to good causes, as the Commission concluded that a rival bid would generate higher sales, and thus higher contributions overall.[46]

Mobile networks may appear different from other infrastructure because they are commercially viable without government support, and operate in competitive markets that require less regulation. In general, mobile operators pay to access the market, through acquisition of spectrum licences, and receive few if any subsidies for network provision. **Nevertheless, the principle that governments should aim to maximise welfare generation over the licence term still applies.** Happily, theory and practice has shown that this can largely be achieved through competitive awards which allocate spectrum based on willingness to pay. However, if governments enact policies that artificially inflate prices for spectrum, they risk constraining investment and competition, and reduce scope for welfare creation. This is analogous to picking an inferior infrastructure project because the upfront subsidy is lower or increasing fees for a monopoly concession but allowing the concessionaire to pass on those costs to customers through higher prices.

45 See European Commission, Guide to Cost-Benefit Analysis of Investment Projects, Economic appraisal tool, December 2014.

46 National Audit Office (May 2002), "Awarding the new licence to run the National Lottery", p.3.

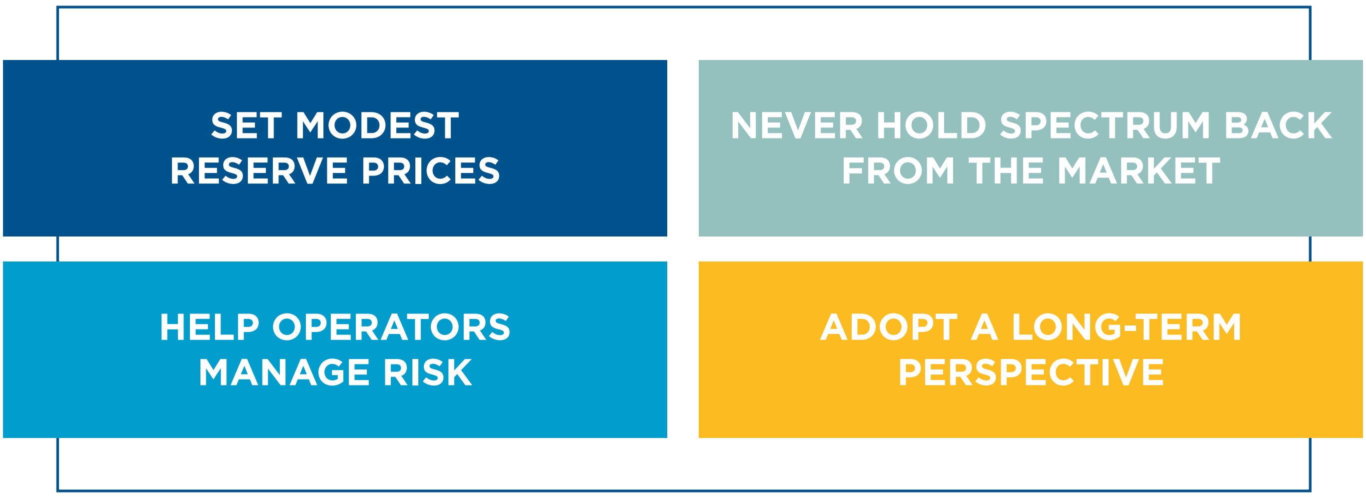


# 5. Best practice for setting spectrum prices

With the increase in frequencies needed to support high data traffic in a 4G and 5G world, effective pricing techniques will become ever more important to support an efficient spectrum allocation, promote investment in infrastructure and encourage sustainable competition. Countries that persist with excessive pricing, constrain available spectrum, or enact conditions, rules or policies that place undue risk on operators, will likely experience a widening gap in quality and pricing of the mobile services available at home versus abroad. Actions that depress growth and competition in mobile services have obvious negative implications for the broader economy, with the result that long-term losses in tax revenues will likely outweigh any short-term gains from unduly high upfront spectrum fees.

In this chapter, we set out our recommendations on measures that together should maximise the likelihood of effective spectrum pricing, thus supporting investment in high quality services and price competition to drive affordable services. Our four areas of recommendation are summarised in Figure 22.

FIGURE 22: RECOMMENDATIONS ON BEST PRACTICE IN SPECTRUM PRICING



#1

### 5.1. Recommendation #1:

## Set modest reserve prices

By reserve price, we mean the sum of any upfront payments and (discounted) annual fees. The primary objectives for any regulator when setting reserve prices should be to promote an efficient allocation of spectrum, one that will maximise long-term benefits for society. This is best achieved by allowing the market to identify the price. Such an outcome is only possible if reserve prices are set conservatively, below the expected market value. Otherwise, there is a risk that genuine demand is choked off. Annual fees should typically be set at modest levels, for example sufficient to recover spectrum-management costs. If a regulator decides or is required to impose higher annual fees, they become an important component of the reserve price, and expectations for potential auction prices should be moderated accordingly.

In this report, we have identified compelling empirical evidence, backed by economic theory, that high prices for spectrum depress operator incentives to invest and compete, resulting in lower quality and higher prices for consumers. This provides a further rationale for conservative reserve pricing. Of course, sometimes auctions may produce unusually high prices owing to competition between bidders; if this is what is required to identify the efficient users then so be it; but policymakers would be ill-advised to try to engineer such outcomes.

We recognise that governments may have legitimate concerns about valuable spectrum selling “too cheaply”. This is a rationale for pricing at a substantive level but not at a level that could plausibly be close to the market price. International price benchmarks can be helpful in identifying a value range in which a “fair price” for spectrum may sit, and thus provide a reference point for setting reserve prices. However, when benchmarking, it is crucial to pay close attention to differences in local conditions across countries and awards that may affect operators’ ability to pay. In particular, policymakers should be wary of placing too much weight on high price outliers, which usually have unique explanations, often rooted in policy error.

#2

### 5.2. Recommendation #2:

## Prioritise spectrum allocation

Spectrum is a renewable resource. When spectrum suitable for mobile is left fallow (or used to provide other, less valuable services), welfare benefits that would have accrued to consumers are lost forever. One of the most effective welfare-creating policies that a regulator can adopt is to release spectrum bands as soon as local operators have a business case to deploy them. Artificially constraining the supply of spectrum – a policy that has been used in a number of markets, most notably India – may boost prices paid for spectrum, but this comes at a huge cost for society in terms of lower competition and reduced quality of service in the downstream market.

Operators typically rely on a portfolio of spectrum, across frequency bands with different characteristics, to operate their networks. Valuing the impact of spectrum is challenging, especially in countries where many mobile bands have not yet been released. The best regulators provide roadmaps for future spectrum availability, so operators can understand their future options and can value spectrum with greater certainty. Good roadmaps reduce the risk that bids for spectrum are distorted, resulting in prices that are either too low or too high.

## 5.3. Recommendation #3:

# Help operators manage risk

The business model for running mobile networks is inherently risky as it involves substantial upfront investment in spectrum licences and network infrastructure, which are then recouped through revenues from consumers over many years. The viability of an operator also depends on maintaining access to a critical mass of spectrum, one sufficient to support growing demand for capacity for 4G data. Prices paid for spectrum can be distorted if bidders in spectrum awards face undue risks.

There are many ways that regulators can help reduce risk for operators, and thus reduce the potential for distorted allocation and pricing outcomes. These include:

- **Avoiding award rules that create options for bidders to foreclose the market or expose bidders to risk of outcomes where enterprise value could be lost;**
- **Applying realistic coverage and quality of service obligations (ideally ones that avoid needless duplication of networks in non-commercial areas), and setting reserve prices that take into account the cost burden on operators; and**
- **Adopting longer licence terms (e.g. 20-25 years or guaranteed renewal rights) that match the life of mobile network investments.**

## 5.4. Recommendation #4:

# Adopt a long-term perspective

Investment in mobile network infrastructure will be a key enabler of growth and competitiveness in national economies worldwide for the foreseeable future. When policymakers plan spectrum awards, they should be focused on maximising welfare benefits over the long term, by stimulating competition and investment, not on short-term revenue benefits. In recent years, many countries have launched ambitious national plans for ICT (information and communications technology) development. Timely award of mobile spectrum at prices that promote full allocation and efficient use should be a cornerstone of such plans.

Ideally, spectrum award rules should be divorced from government budgetary decisions. This is easy to say but hard to achieve in practice, especially where governments face fiscal deficits. One way to de-politicise decisions on spectrum pricing is to delegate them to an Independent Regulator with appropriate objectives to prioritise long-terms benefits for consumers through efficient use of spectrum and sustainable downstream competition. Another is for regulators to adopt the cost-benefit analysis frameworks that are widely used in other infrastructure-based industries as a tool to ensure that long-term benefits for society are not ignored when making input pricing and allocation decisions.

# Appendix A. Econometric model of welfare impact of high spectrum costs

In this appendix, we provide a description of the econometric model we used to estimate the welfare losses from high spectrum costs, as presented in Chapter 2.4. We follow the methodology used by Hazlett and Muñoz (2004) for mobile voice to estimate a demand curve for mobile data services in 2016.[47] Our model is based on data from 32 countries.

The consumer welfare produced through consumption of a good is a function of both the price paid for the good and the quantity consumed. Price and quantity are therefore the main variables in the model. These variables are endogenous, as they are jointly determined by the interplay of demand and supply in the market: the price that consumers pay affects the quantity consumed and the quantity consumed affects the price that consumers pay. In econometrics, this is referred to as a “reverse feedback affect” and ordinary regression techniques have been shown to provide poor results in these situations. We therefore use an Instrumental Variable (Two Stage Least Squares) model to estimate the demand for mobile data. In the first stage, we estimate price as a function of a number of variables that mainly impact the supply of mobile data (not demand).[48] In the second stage, we estimate the demand function or the quantity of mobile data consumed as a function of a number of variables affecting demand including the predicted price from the first stage. Using the predicted price rather than the observed price removes the feedback effect.

The inputs used in the model are summarised in Table 1. We also considered other inputs. Wi-Fi availability was tested as a substitute for mobile data usage, but was not statistically significant and was removed.[49] In the price equation, we considered labour costs as well as industrial electricity costs. Labour costs were highly correlated with GDP and thus dropped, while industrial electricity costs were not statistically significant in the price equation.

47 Hazlett and Muñoz, 2004 to today's era of high level data consumption. See Hazlett and Muñoz, 2004, A Welfare Analysis of Spectrum Allocation Polices. AEI-Brookings Joint Centre, pp. 4-18.

48 Note that in order to arrive at an unbiased estimate of the second function, we need to include all other variables included in the second function in the first function as well.

49 We used the average time that handsets are connected to wifi networks as a proxy. Data from OpenSignal.com.

TABLE 1: INPUTS INTO ECONOMETRIC MODEL

| Variables | Description and Data | Role in Model |
|---|---|---|
| **Quantity Consumed (GB per Month)** | The average amount of data per month consumed by wireless subscribers within a country. Data was collected from Tefficient reports and Cisco modelled data. | Second Stage Dependent Variable |
| **Price (USD per GB/ Month)** | The price paid by consumers in a country. In order to standardise across countries, we created a representative mobile plan for each country, based on information collected from local operator websites in September 2016. The prices are expressed in PPP-adjusted US dollars. This variable is the same as used in the price analysis presented in Chapter 2.3. | Second Stage Endogenous Variable and First Stage Dependent variable |
| **GDP Per Capita (USD/ pop)** | A higher GDP per capita implies higher disposable income for consumers and a higher demand for data; however, GDP per capital also implies more network maturity, which can depress consumer prices. We use data from the International Monetary Fund's 2015 database. | Independent variable in First and Second Stage Regressions |
| **Urbanisation (% urban pop)** | Urbanisation is included as a proxy for the difficulty of rolling out a wireless network in a country. In general, higher urbanisation means that greater capacity is required in small crowded areas. This requires higher densification of the network (more cells to cover a small area and can increase the cost of sites (higher rents, more stringent planning regulations.) On the other hand, lower urbanisation means that more cells are required to cover the same population. We use data from the World Bank Database. | Independent variable in First Stage Regression |
| **Herfindahl-Hirschman Index (HHI)** | HHI is a measure of market competition, and is a proxy for the pricing power of operators. Increasing competition in a market is associated with lower prices owing to the greater scope for consumers to move to an alternate provider. HHI is derived from total subscriber share by country using data from the Telegeography GlobalComms database. | Independent variable in First Stage Regression |
| **Cost of Spectrum (USD per MHz/pop)** | The purpose of the model is to understand the impact of spectrum cost on consumer welfare via the impact on consumer prices. We use the same spectrum cost data as used in our analysis in Chapter 2.3. | Independent variable in First Stage Regression |

We use the following specification for the price equation (first stage):

$$\ln(\textit{price}) = \beta_0 + \beta_1 \ln(\textit{gdppc}) + \beta_2 \ln(\textit{urbanisation}) + \beta_3 \ln(\textit{hhi}) + \beta_4 \ln(\textit{spec\_cost})$$

The Demand Equation (second stage) is defined as:

$$\ln(\textit{quantity}) = \beta_0 + \beta_1 \ln(\overline{\textit{price}}) + \beta_2 \ln(\textit{gdppc})$$ [50]

The results of the regression are summarised in Table 2.

50 Note: $\ln(\overline{\textit{price}})$ are the predicted values from the price equation.

TABLE 2: REGRESSION RESULTS

| | First Stage Regression | Demand equation |
|---|---|---|
| **Independent variable** | Price | Quantity |
| **Explanatory variables:** | | |
| **Constant** | 4.24** | -0.78 |
| **Price (IV)** | - | -1.15*** |
| **GDP** | -0.60*** | 0.29* |
| **Urbanisation** | 1.15** | |
| **Spectrum cost** | 0.37*** | |
| **HHI** | 0.78* | |
| **$R^2$** | 50% | 54% |

Notes: Significance levels: *** at the 1% level, ** at the 5% level, and * at the 10% level.

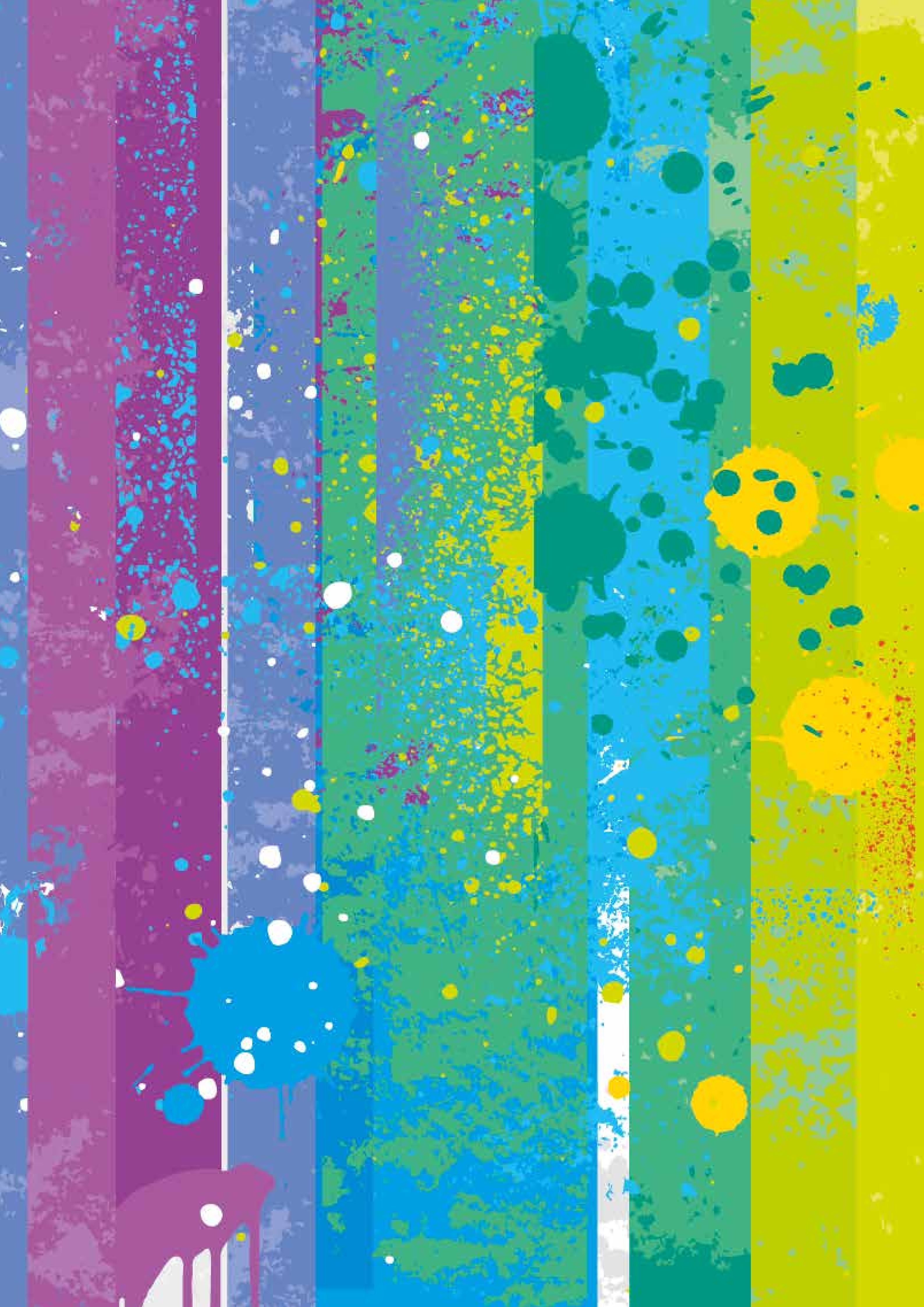
We find that:

- **Spectrum costs have a statistically significant positive impact on prices paid by consumers.**
- **Prices in countries with higher GDP per capita are generally lower. This can be attributed to the fact that mobile networks are more mature in developed countries and thus the cost of delivering a GB of data is lower.**
- **In countries with higher urbanisation, prices are general higher. This may reflect the increased focus on investment in urban capacity to meet 4G demand, and high rental and planning costs of urban sites.**
- **Higher market concentration (as measured by the HHI index) is associated with higher consumer prices, but the statistical relationship is much weaker than for the other factors (only significant at the 10% level).**
- **The quantity of data consumed is negatively affected by price. Higher prices lead to less data consumed. Note that data demand is elastic; if the price increases by 1%, the quantity demanded goes down by more than 1%. This means consumers are sensitive to prices.**

Using the system of equations from the regression, we simulated the shift in the demand curve from reducing spectrum costs, and used this to predict the change in consumer surplus.

To simulate the shift in the demand curve, countries were divided into peer groups based on GDP per capita. The cost of spectrum of all countries with a cost of spectrum above their respective group median was lowered to the peer median. A new demand curve was constructed for each country using the variables and coefficients from the original model except for the decreased cost of spectrum. Once the new demand curve was constructed, we calculated the change in consumer surplus between the original and new demand curves using standard economic techniques, as illustrated in Figure 15. Lost auction revenues, as a result of the price reduction, were set against the gains in consumer surplus, so as to determine the net benefits for society. All values are expressed in US dollars on a purchasing power basis.

# Notes



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