The impact of spectrum prices on consumers

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Contents

1. Executive summary

The radio spectrum that governments license to operators is central to the quality and affordability of mobile broadband services. However, some government policies – inadvertently or not – result in high prices being paid to access spectrum. This study presents strong, new evidence that high spectrum prices can cause negative consumer outcomes, including lower coverage levels and slower data speeds.

Mobile networks are regularly upgraded to offer improved benefits to consumers in terms of service quality and cost – for example, better coverage and faster and more affordable data. However, there are significant variations in these metrics between countries. This report assesses whether high spectrum prices, and other aspects of spectrum management, can be a cause of such differences in service quality and cost. Governments and regulators can therefore take this into account when planning spectrum assignment approaches.

While previous research[1] has shown a link between high spectrum prices and negative consumer outcomes, more work has been needed to establish whether this is a causal relationship rather than a correlation. Meanwhile, some economists and spectrum policy experts have argued that the cost of spectrum is sunk and so should not affect operators' consumer pricing or investment decisions.

This study is, to our knowledge, the first that uses econometric models to consider the impact of spectrum pricing on a broad range of consumer outcomes. The analysis is applied to both developed and developing countries. The results show there is significant evidence to suggest a causal link between high spectrum prices, and certain other spectrum management decisions, and negative consumer outcomes. Specifically, we find the following for the period 2010–2017:

1. In developed countries, high spectrum costs played a significant role in slowing the rollout of 4G networks and drove a long-term reduction in 4G network quality.
2. In developing countries, spectrum prices were, on average, almost three times more expensive than in developed countries in relation to expected revenues. In these countries, high spectrum costs slowed down the rollout of both 3G and 4G networks and drove long-term reductions in overall network quality.
3. In the countries studied with the highest spectrum prices, the average mobile operator's 4G network would cover 7.5% more of the population[2] if they had acquired spectrum at the median spectrum price.
4. The timing of spectrum awards has a significant impact on mobile coverage. For example, if an operator was assigned 4G spectrum at least two years earlier, their 4G network population coverage would on average be 11–16 percentage points higher (all else being equal). The rollout of 3G networks was also significantly delayed in markets that licensed spectrum late, with 3G coverage levels up to 12% lower during the rollout period in those markets.
5. The amount of spectrum licensed to operators had a significant impact on network quality. Over the period of analysis, an additional 20 MHz of 4G spectrum increased average download speeds by between 1 and 2.5 Mbps (equivalent to an increase of up to 15%).

These findings have important ramifications for governments and regulators – particularly those betting on 4G and 5G as enablers of growth and sustainable development.

The study concludes the following:

1. **High spectrum costs lead to negative consumer outcomes by restricting the financial ability for network investment.**
2. **Maximising revenues from spectrum awards should no longer be a measure of success.** Excessive spectrum prices can cause serious harm to consumers that outweigh any potential benefits obtained through higher auction revenues.
3. **Auctions can and often do go wrong when poorly designed.** But when well designed, auctions can be effective in allocating spectrum to those that can generate most value from it.
4. **Artificially limiting the supply of spectrum, including through set-asides, comes with great risks.** When additional spectrum is instead made available for the benefit of all, consumers experience higher quality mobile services.
5. **Spectrum should be released to the market as soon as there is a business case for operators to use it.** Early release of spectrum drives better consumer outcomes, which is important in markets where high coverage and affordable services are prioritised.
6. **Policymakers should work with stakeholders to enable timely, fair and effective spectrum licensing to the benefit of society.** A coordinated approach to mobile sector regulation by different parts of government is essential if ambitious digital inclusion and industrial policy objectives are to be realised.

1. Spectrum pricing in developing markets, GSMA Intelligence, 2018; Effective Spectrum Pricing, GSMA and NERA, 2017; The effects of spectrum allocation mechanisms on market outcomes, T. Kuroda and M. Forero, 2016.
2. By the end of the study period.

2. Consumer benefits from mobile services

2.1 Improving mobile services

With more than 5 billion unique subscribers worldwide, mobile communications is a general-purpose technology vital to innovation in most industries and sectors. It can increase business competitiveness, drive productivity growth and help improve living standards more broadly.

2.1.1 Technology cycle evolution

Mobile markets are characterised by frequent cycles of technology change, with new mobile services introduced regularly, that improve the quality of existing services. They have also revolutionised and drastically changed the definition of the service itself. For example, the introduction of 4G delivered a completely new set of experiences and benefits to end users. Innovation also introduces cost savings for consumers.

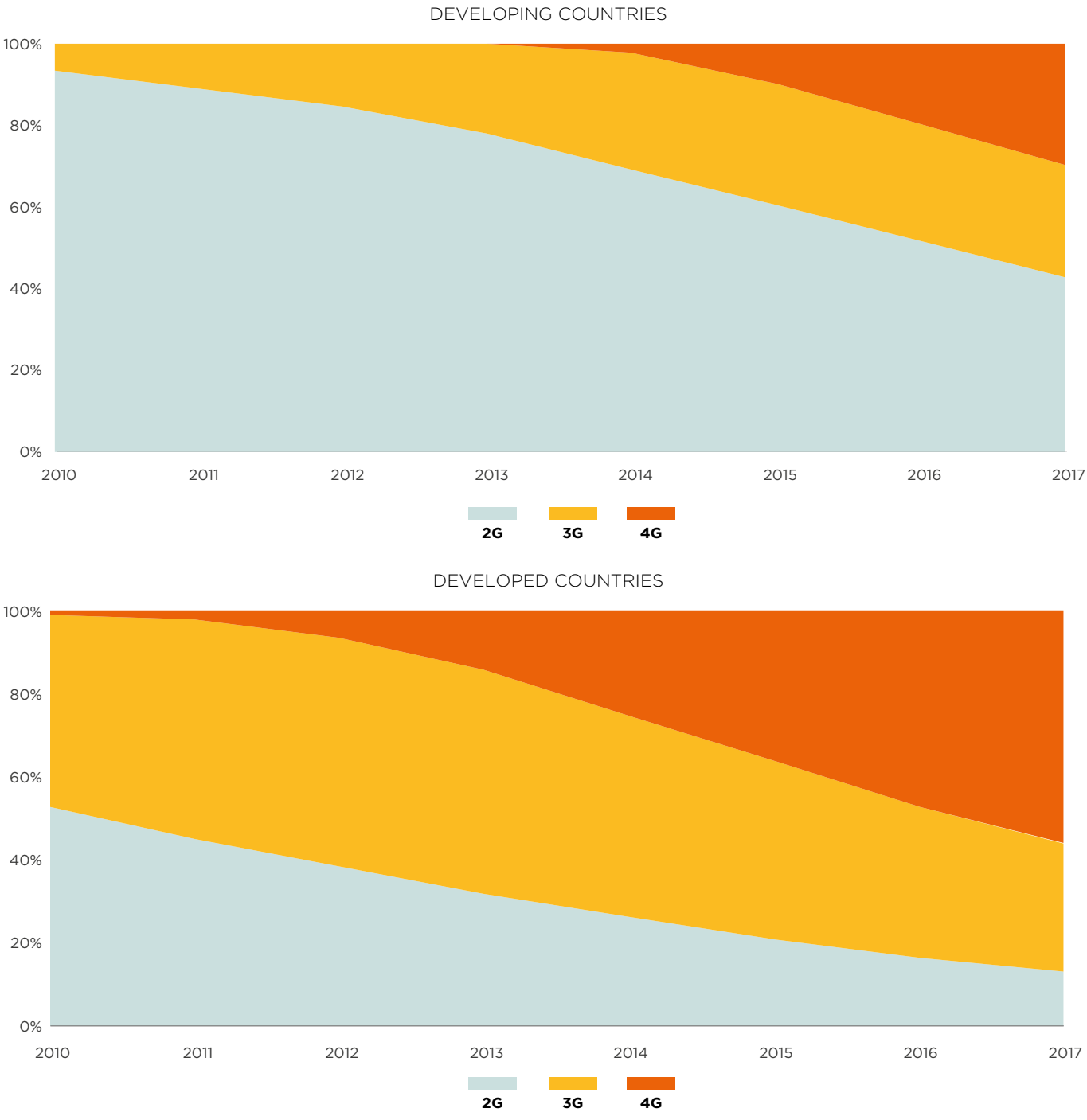
CHARACTERISTICS OF MOBILE TECHNOLOGY CYCLES

	1G	2G	3G	4G	5G
Commercialisation	1980s	1990s	2000s	2010s	2020s
Applications	Voice calls	Voice calls, SMS, MMS, browsing (limited)	High-speed browsing, applications	Video conferencing, mobile TV	Multipurpose (Internet of Things, AR/VR, others)
Typical speed	14.4 kbps	56-115 kbps	5.8-14.4 Mbps	100-300 Mbps	100-5,000 Mbps

In this report, we evaluate the impact of spectrum prices, as well as a variety of other factors, on key consumer outcomes over the period 2010–2017. 4G became the dominant technology in developed countries[3] by the end of the period. In developing countries, the majority of consumers were still using 2G and 3G, though by the end of 2017 4G had grown to account for almost a third of connections.

FIGURE 1

MOBILE CONNECTIONS BY TECHNOLOGY



Source. GSMA Intelligence

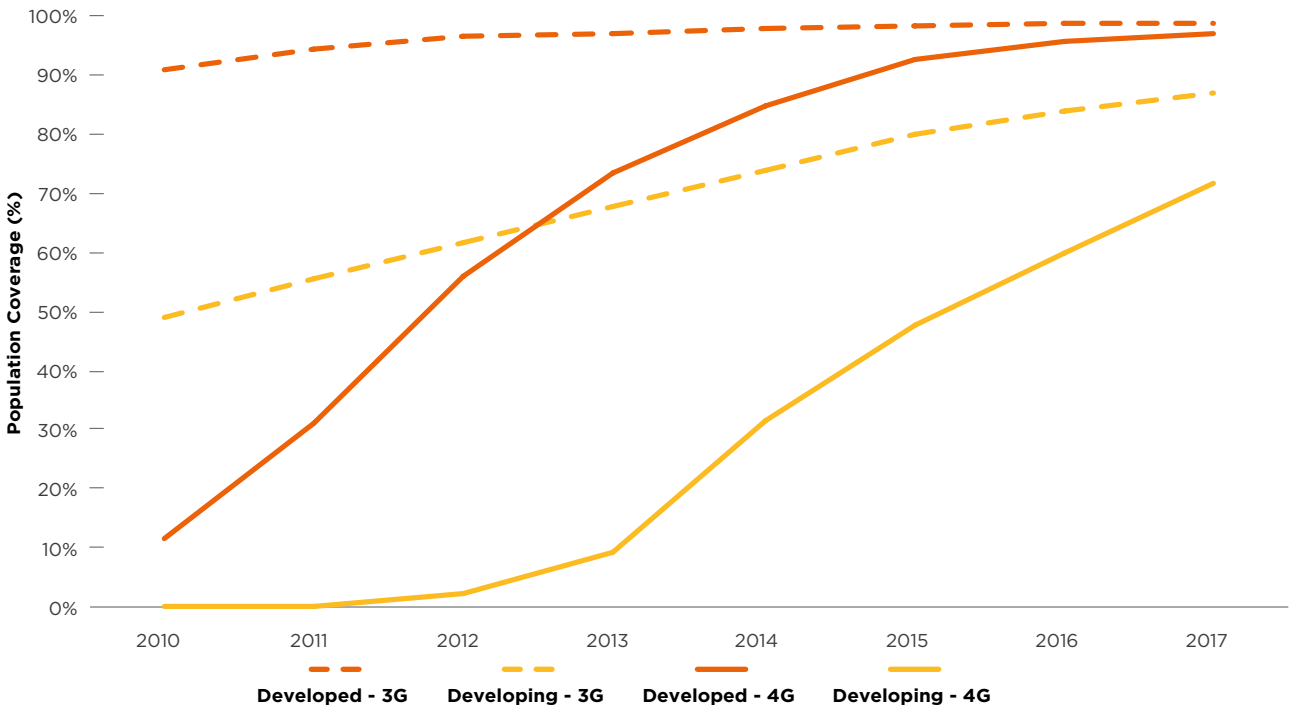
3. Countries were categorised by income according to the World Bank classifications in 2017, with high-income countries defined as 'developed' and low- and middle-income countries defined as 'developing'

2.1.2 Mobile service quality improvements

Mobile markets delivered significantly improved consumer outcomes across all relevant metrics over the period of study. In developed countries, 4G networks were rolled out and covered more than 95% of the population by 2017. In developing countries, 3G networks covered almost 90% of the population by 2017. At the same time more than 70% lived within a 4G footprint. Network quality also saw continuous improvements globally, with consumers benefitting from faster speeds and lower latencies.

FIGURE 2

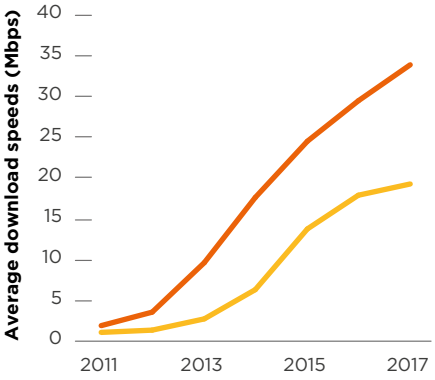
MOBILE COVERAGE IMPROVEMENTS, 2010–2017



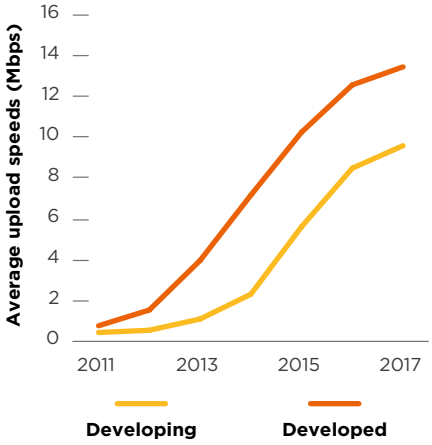
Source. GSMA Intelligence

FIGURE 3

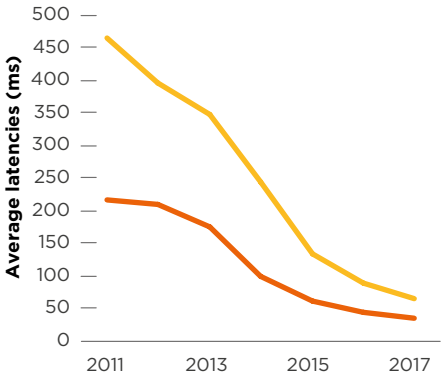
MOBILE DOWNLOAD SPEED IMPROVEMENTS, 2011–2017



MOBILE UPLOAD SPEED IMPROVEMENTS, 2011–2017



LATENCY IMPROVEMENTS, 2011–2017



Source: GSMA Intelligence calculations based on data provided by Ookla® Speedtest Intelligence®. Average speeds and latencies for each country were calculated based on the mean average of all tests performed by consumers in a given year (including on 2G, 3G and 4G networks). We then took the averages for developed and developing countries to produce the trends, with developed countries those classified as "high income" by the World Bank Income Classifications and developing countries those classified as "lower", "lower-middle" and "upper-middle" income countries.

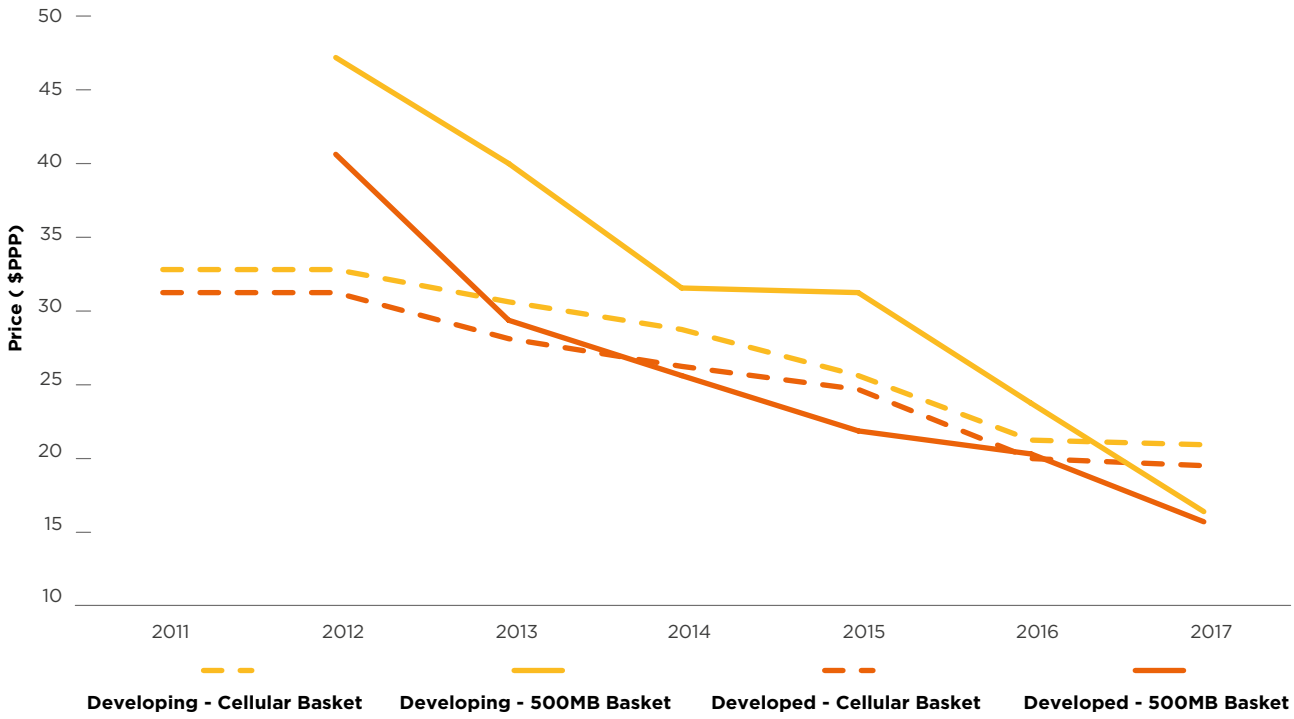
2.1.3 Falling data package prices

Consumers also benefitted from lower mobile voice and data prices over the period. This trend is consistent with declining operator ARPU. Figure 4 shows declining trends in two pricing baskets tracked by the International Telecommunications Union (ITU):

- A 'mobile-cellular sub-basket' or 'voice basket' of 30 outgoing calls per month and 100 SMS messages
- A 'mobile broadband basket' of 500 MB per month (based on prepaid tariffs)

FIGURE 4

AVERAGE PRICE TRENDS, 2011–2017



Source: GSMA Intelligence calculations based on ITU pricing data. Definition of baskets and methods of data collection can be found in the ITU's annual Measuring Information Society Reports. Developed and developing pricing data is calculated by taking the mean average of high-income and non-high-income countries respectively (based on World Bank Income Classifications).

2.2 Differences in consumer benefits between countries

Despite consumer outcomes generally improving over the period studied, there were significant differences as to the extent of these improvements across countries. For example, in 2017 almost 1 billion people were not covered by a 3G or 4G network, and 3.9 billion people in developing countries (more than 60% of the population) did not have a mobile internet connection.[4]

Many factors are likely to be at play, given the wide variations across countries in both demand- and supply-side factors such as disposable income, competition, upgrades in equipment and phone technologies, and geographic characteristics that impact the cost of rolling out networks.

Different policy environments across countries, including spectrum management, may also have played an important role. For example, markets where more spectrum has been assigned to mobile operators are likely to face lower network costs and therefore are more likely to see networks rolled out quickly and with better quality. Spectrum prices can also play a significant role by influencing investment and pricing decisions. High spectrum prices can impact the mobile sector by reducing the funds available to undertake investments and generating upward pressure on consumer tariffs. The following section discusses in more detail how spectrum prices evolved over this period.

4. Source: GSMA Intelligence

3. Spectrum prices and how they may impact consumer benefits

3.1 Comparing spectrum prices around the world

Spectrum costs typically comprise upfront costs, annual fees and other licence obligations.[5] This study focuses solely on upfront spectrum fees as they are usually the most significant cost and the most commonly applied.[6] There is also more publicly available data on upfront spectrum costs than ongoing fees, so a larger sample of countries can be studied.

To compare the total spectrum prices faced by mobile operators across time and countries, we have adjusted prices by the total amount of spectrum that each operator was awarded (i.e. the "unit cost") and the length of the licence.[7] We have also adjusted spectrum prices for market size, general price levels and purchasing power across countries.

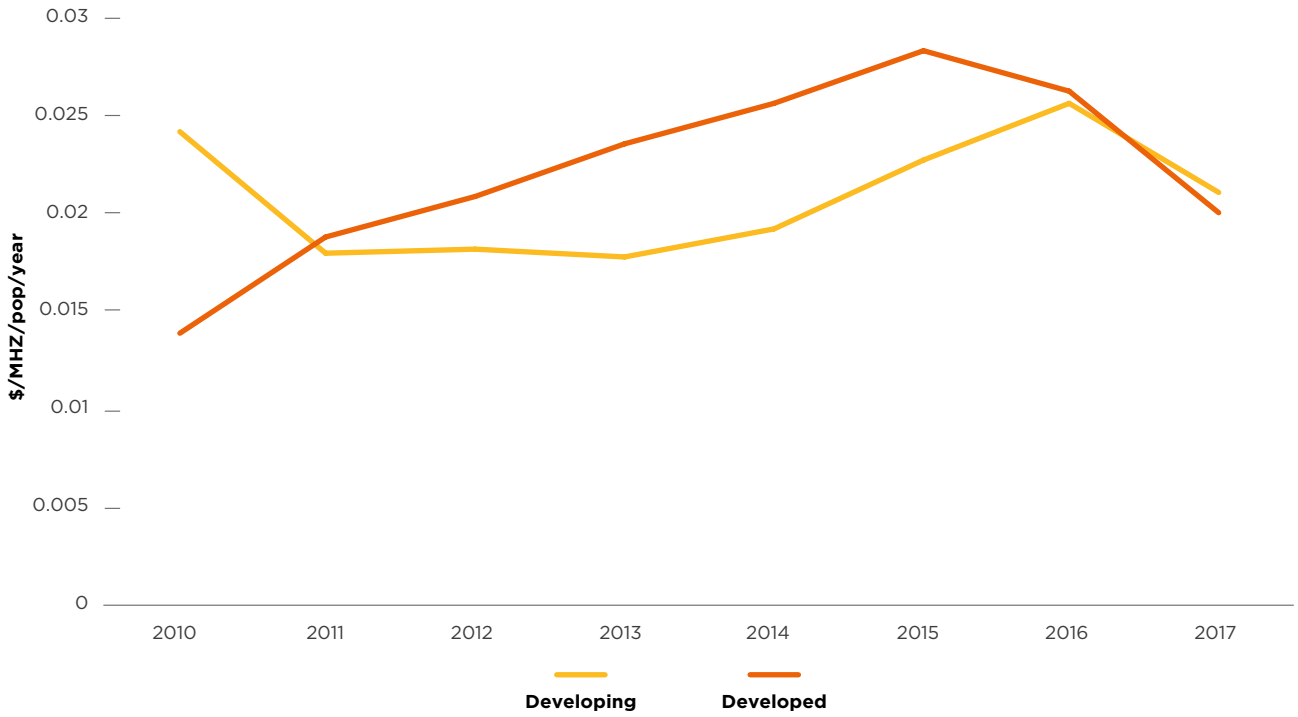
5. A number of obligations that regulators attach to spectrum licences have cost implications. For example, network quality and coverage obligations, base station build-out obligations, or other social obligations.
6. While annual fees generally represent a smaller share of total spectrum costs than one-off fees, there are exceptions. For example, in China and Mexico annual fees are significantly larger.
7. We define a single unit as 1 MHz of spectrum. Regarding duration, if one considers spectrum as a production input, the licence length effectively represents the useful life of the asset. An operator would therefore pay more for a licence that lasts 20 years compared to one that last five years.

Once these basic adjustments are made, we use two metrics to analyse the effects of spectrum prices:

- The **unit cost of spectrum per person** ($PPP[8] per MHz per person per year) – this gives an indication of spectrum costs faced by operators to serve the potential customer base in a country during the spectrum licence period
- The **unit cost of spectrum as a percentage of revenues** – this includes total revenue generated by operators over the relevant period, including both recurring and non-recurring revenues. It gives an indication of the profitability or returns on spectrum costs as an investment. The higher the unit costs, the lower the rate of return made on the spectrum licence.

FIGURE 5

SPECTRUM PRICES PER PERSON, 2010–2017



Source: GSMA Intelligence. Spectrum prices have been adjusted by inflation, PPP (2016 prices) and licence duration, and aggregated by country, band, generation and assignment. All spectrum bands for which relevant data was available are included. Outliers outside the 'inner fence'[9] have been excluded from the analysis. The analysis is based on three-year moving averages.

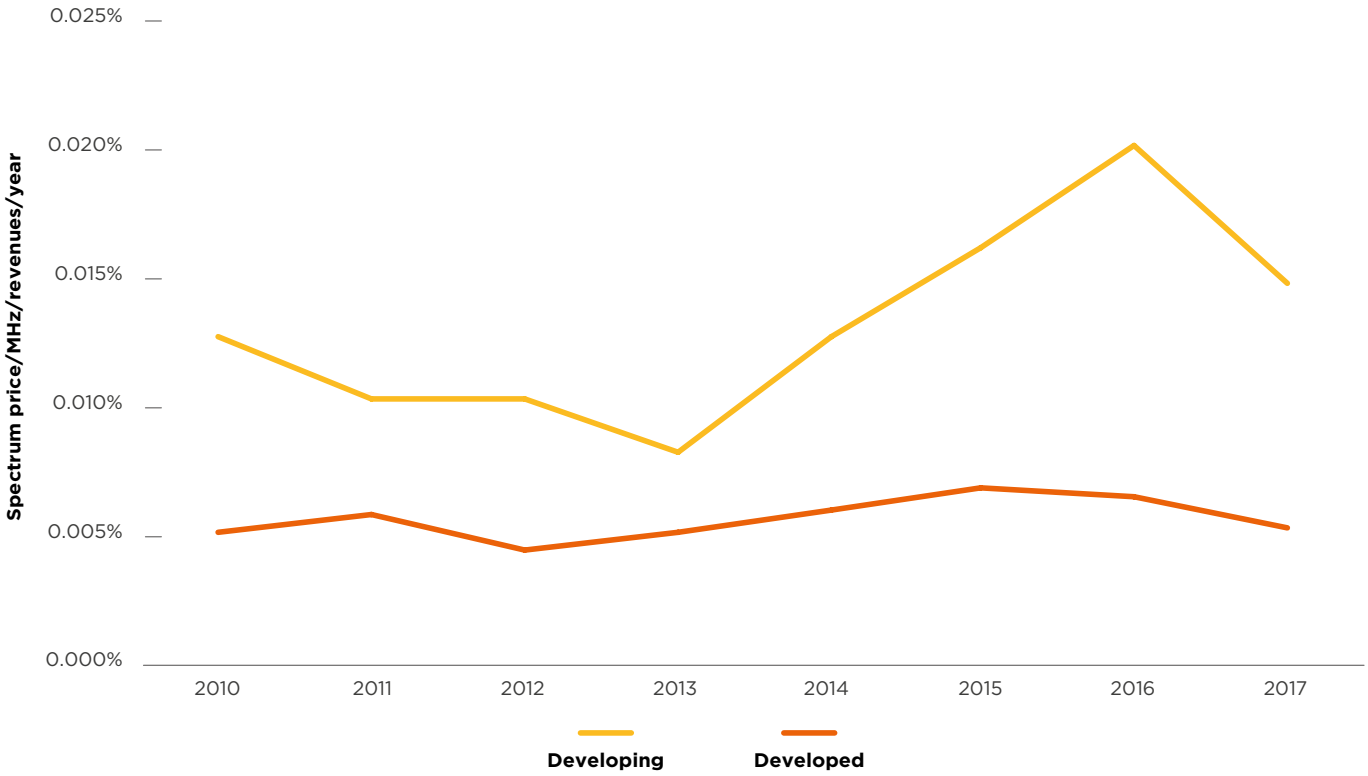
The trends for average spectrum prices adjusted by population across both developed and developing markets over the period 2010–2017 show an increase between 2011 and 2016 (see Figure 5). This was partly driven by several expensive assignments including Austria, India and Iraq.

Looking beyond the price paid and examining the average spectrum price as a proportion of operator revenues uncovers a different story. Figure 6 shows that spectrum prices in developing countries were, on average, almost three times more expensive than in developed countries.[10] This highlights the importance of considering spectrum affordability, not just the absolute value of spectrum.

8. Purchasing power parity dollars level the differences in purchasing power across countries.
9. The inner fence refers to prices that fall above the threshold of the 75th percentile plus 1.5 times the interquartile range and below the threshold of the 25th percentile minus 1.5 times the interquartile range.
10. This study presents spectrum costs as a proportion of current annual revenues (i.e. revenues at the time of the auction). As operators take into account future revenues when purchasing spectrum (particularly in growing markets), it also makes sense to consider spectrum affordability in terms of future revenues. When we use future revenues to calculate affordability, the overall results and trends in Figure 6 do not change. In our econometric analysis, we estimate spectrum price as a proportion of both current and future revenues.

FIGURE 6

SPECTRUM PRICES AS A PROPORTION OF REVENUES, 2010–2017

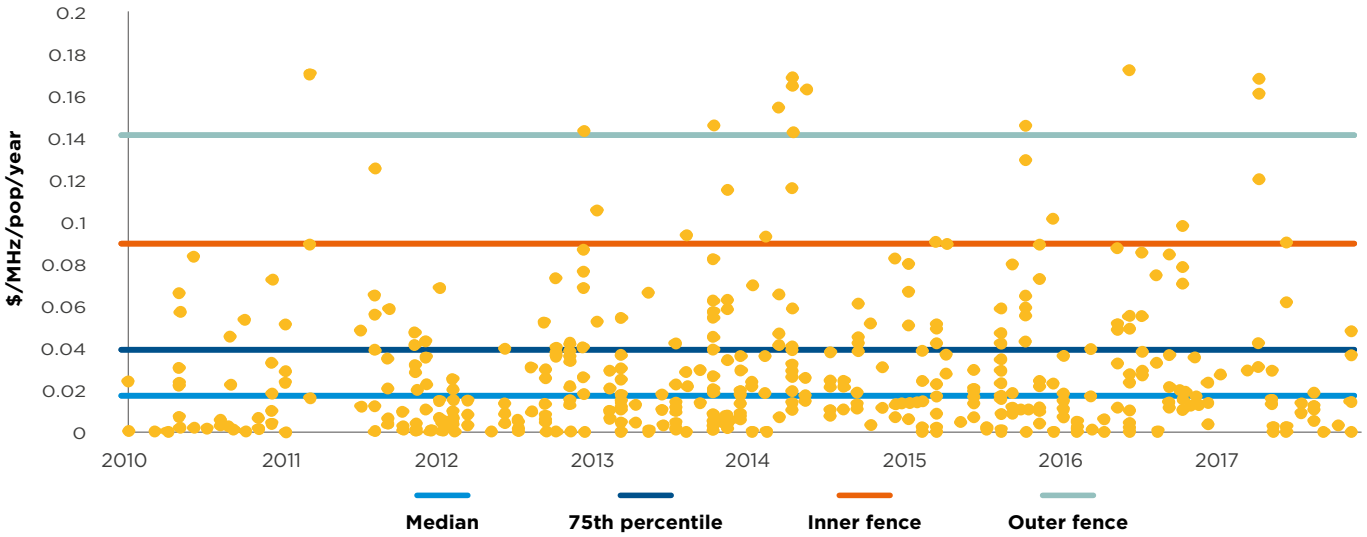


Source: GSMA Intelligence. Spectrum prices are aggregated by country, band, generation and assignment. They are then divided by current annual revenues. Only countries with a comprehensive set of pricing data between 2010 and 2017 were included in the analysis. The analysis is based on three-year moving averages. The spike between 2014 and 2016 is mostly due to a number of expensive assignments in India, Thailand, Jordan and Egypt, among others.

Aside from differences between developed and developing countries and their evolution over time, Figure 7 shows there was also significant variation in the price of spectrum assignments paid over the 2010–2017 period, with many spectrum assignments selling for more than five times the average median value.

FIGURE 7

SPECTRUM PRICES INCLUDING OUTLIERS, 2010–2017



Source: GSMA Intelligence. Spectrum prices ($/MHz/pop/year) have been adjusted by inflation, PPP (2016 prices) and licence duration, and aggregated by country, band, generation and assignment. All spectrum bands for which relevant data was available are included. The IQR is defined as the difference between the 1st and 3rd quartile. Outliers are classified as being above an "inner fence", i.e. above 3rd quartile + 1.5*IQR. Extreme outliers are classified as being above an "outer fence", i.e. above 3rd quartile + 3*IQR.

3.2 What drives spectrum prices?

The preceding charts beg the question: what explains the striking variation in the amount paid for spectrum in different countries? In principle, prices should reflect market value, especially when determined using a market-based mechanism like an auction. Typically, conditions such as market penetration as well as current and expected revenues per user drive prices. Sometimes, high prices may simply be the result of strong competition between current and aspiring service providers.

We have found, however, that high spectrum prices are also linked to spectrum management decisions by the government or regulator. This includes setting high reserve prices, limiting the supply of spectrum, an unclear spectrum roadmap and/or bad award rules (e.g. auction formats, packaging of spectrum lots etc).[11] Governments or regulators have an even more direct role in determining the price of spectrum where it is assigned via non-auction methods (e.g. beauty contests), though one cannot underestimate the ways even market-based mechanisms such as auctions are influenced by policy decisions. In other words, government policies can increase spectrum prices.

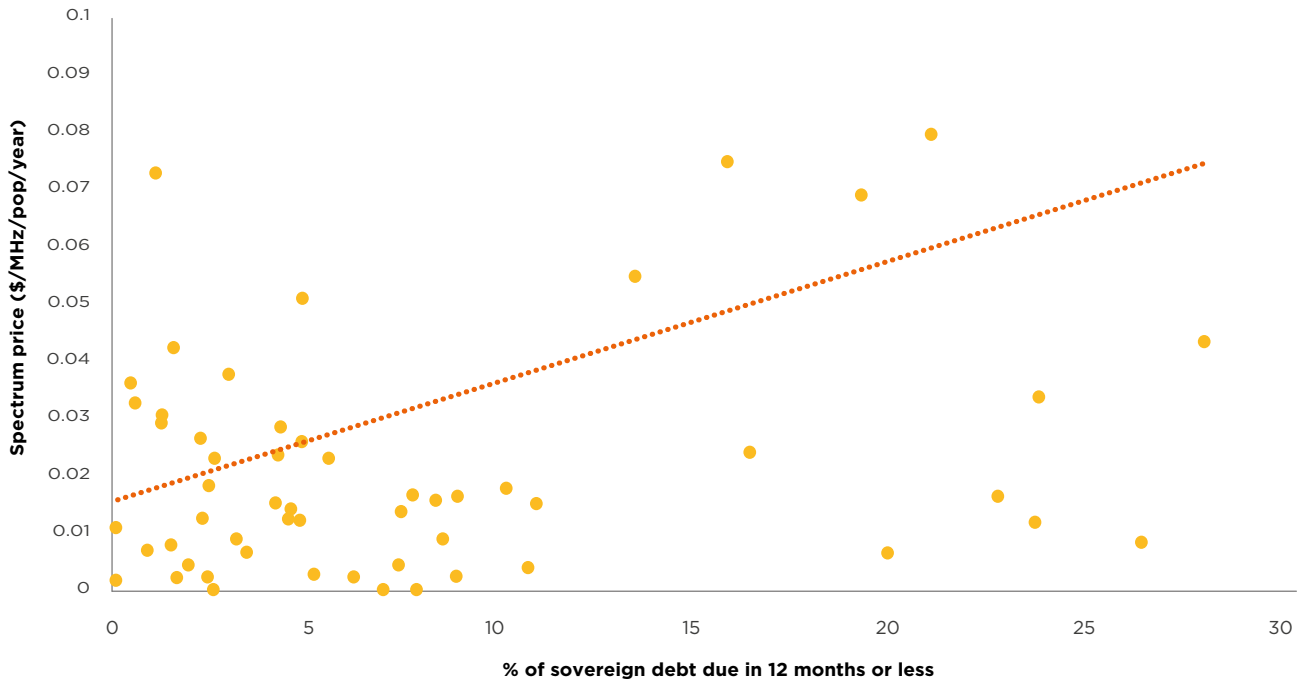
This arises because there is a single "seller" of spectrum (the government or regulator) that effectively has market power that it can exploit in order to increase auction revenues. Raising money from spectrum awards is not unusual and is one of the benefits of auctions – alongside discovering the market value of the spectrum. However, it also has major downsides.

The reason some public authorities pursue and actively drive high spectrum prices is often connected to the need to raise revenues for the public sector. This is most noticeable in developing countries where the public sector is experiencing financial distress (see Figure 8).[12] Given that spectrum prices are unlikely to determine government debt, the more plausible interpretation is that governments in developing countries experiencing financial distress are driving up spectrum award revenues to help pay it off.

11. For further information, see Auction Best Practice, GSMA, (2019)
12. As discussed in the technical paper, the link between short-term public debt and spectrum prices is particularly strong in developing countries and robust to controlling for other factors in a regression analysis. The relationship is less strong in developed countries.

FIGURE 8

SPECTRUM PRICES AND PERCENTAGE OF SOVEREIGN DEBT DUE IN 12 MONTHS OR LESS IN DEVELOPING COUNTRIES, 2010–2017



Source: GSMA Intelligence and World Bank.Spectrum prices have been adjusted by inflation, PPP (2016 prices) and licence duration, and aggregated by country and year over the period 2010–2017. Only countries with a comprehensive set of pricing data between 2010 and 2017 were included in the analysis.

There are, of course, cases where high prices are not the result of governments trying to maximise auction revenues. Other objectives such as driving further competition in the sector (using measures such as set-asides or reserved spectrum for a new entrant or existing operator) may have led to the choice of the award design.

While these are legitimate policy objectives, they may have the unintended consequence of driving higher prices. For example, when artificially restricting or delaying the amount of spectrum that is licenced to mobile operators, competition for access to spectrum can increase prices at the expense of the development of the mobile market.

3.3 How spectrum prices can impact consumers

3.3.1 Can spectrum prices impact consumer outcomes in principle?

A long-term economic dispute exists about the impact high spectrum prices can have on the development of mobile services, their quality and final consumer prices. This is particularly important in the context of mobile communications. As a general-purpose technology that has spill-over effects on other industries, consumers and market outcomes, it will have a knock-on impact for a country's productivity growth and economic prosperity.

On one side of the dispute, some economists argue spectrum licence payments are sunk costs.[13] Therefore, they are not taken into account in subsequent decisions that a mobile operator makes around where and how quickly to roll out its network, or around its pricing strategies.[14] Governments have often used this position to justify measuring the success of auctions by the total amount of revenues they obtain.

While the sunk-cost argument has strong foundations in economic theory, many economists argue that its application to mobile communications is limited.[15] In fact, if mobile operators set prices or investment decisions disregarding fixed costs, they would not be able to make a return on investment.[16] As one-off spectrum fees increase the average cost for mobile operators, in the long term they will impact the level at which an operator can make a return on investment. Spectrum fees are, according to this view, fundamental inputs into the investment and pricing decisions made by mobile operators.[17]

Operators bid for spectrum based on their forward-looking costs and expected revenues, which are determined by a range of factors (including demand, input costs, regulation, policy and competition). Given these expectations, they will estimate what profits or returns they can generate over the relevant timeframe and thereby identify the maximum amount they are willing to pay for spectrum. So long as they acquire the spectrum below their valuation, investment and pricing decisions should be unaffected.

However, there are two important considerations here. First, the manner in which spectrum is assigned will itself have a direct impact on operators' forward-looking costs and revenues, and therefore the commercial strategy they adopt. For example, if regulators restrict the amount of spectrum being licensed, this will have implications on network rollout and demand, in which case operators may have to reconsider their planned investment and pricing strategies.[18] Another example is in relation to reserve prices: if these are set above an operator's original valuation, they may have to adjust their approach and instead bid at the higher price but based on an alternative commercial strategy that involves higher prices or less investment.

Second, there is an intrinsic difficulty in predicting future developments in the mobile market; for example, who could have predicted 10 years ago that voice and messages would be effectively given away for free? This can exacerbate the likelihood of the 'winner's curse' where the market player that has the more optimistic expectations about future revenues will also be the one to bid more for spectrum. After obtaining the licence, and faced with lower revenues than expected, it may look to raise prices or cut back on investment plans. In a market such as mobile, it is not uncommon for new technologies to generate big expectations, with 5G perhaps the most recent example in some markets. In fact, there can be a tendency for 'group-think' to develop where the media, commentators and broader industry ecosystem set high expectations and everyone becomes convinced of them.[19]

Finally, mobile operators generally face capital constraints and have to deliver a return to investors. If a mobile operator fails to deliver on expectations and becomes less profitable compared to other industries and in other countries, this will increase the cost of capital in the long term and impact future pricing and investment decisions. Even when spectrum costs are financed internally, high spectrum prices can deter further investment and impact pricing strategies. Mobile operators are typically part of large multinational groups with centrally managed budgets. Recurring high spectrum costs in a country will make a particular operation less attractive and will likely lead headquarters to reduce, delay or change investment plans.

13. Sunk costs are those costs that a business has incurred in the past and that it can no longer recover.
14. "Are spectrum auctions ruining our grandchildren's future?", Cave and Valetti in Info, 2000
15. See the report, Effective Spectrum Pricing: Supporting better quality and more affordable mobile services, GSMA, 2017, for a summary of some of these arguments.
16. This is why the economic concept of "marginal cost" is not generally applied in telecoms, with the focus instead being on long-run incremental costs.
17. "Spectrum auctions: yesterday's heresy, today's orthodoxy, tomorrow's anachronism. Taking the next step to open spectrum access". Noam in The Journal of Law and Economics, 1998; "Spectrum auctions, pricing and network expansion in wireless telecommunications", Bauer in arXiv preprint cs/0109108, 2001
18. Less spectrum generally means that an operator has to build more sites and capacity into its network for a given level of demand. Otherwise, for a given level of investment, less spectrum will mean reduced network coverage and quality (and therefore less demand).
19. "Governance and game theory: When do franchise auctions induce firms to overbid?", French in Telecommunications Policy, 2009

3.3.2 What does the evidence say?

In summary, several arguments support the idea that spectrum costs can indeed have an effect on mobile operators' investment and pricing decisions, and therefore the quality and prices of mobile services that consumers experience. However, since reasonable arguments can also be made in the opposite direction, a conclusive answer to this debate becomes an empirical question.

There are very few empirical studies that have been able to shed light on the debate. While it has been established that there are some links between high spectrum prices and negative consumer outcomes in both developed and developing countries[20], more sophisticated analysis is needed to establish a causal link. Although one-to-one correlations are informative and a first step to understanding the nature of any impact, there may be other, confounding factors driving these trends. This means these links have to be interpreted with some caution.

Few studies have gone beyond simple correlations when analysing the potential effects of spectrum prices on consumer outcomes. To our knowledge only two studies have so far attempted to isolate the effect of other confounding factors from the impact of spectrum prices on non-price consumer outcomes. Cambini and Garelli (2017) find that spectrum prices and market revenues are positively linked, but under their preferred model they found the effect of spectrum prices on market revenues not to be statistically significant. Kuroda and Baquero (2017) find that high spectrum prices driven by auctions led to lower take-up of 3G.

While these studies constitute significant positive steps, there remain fundamental gaps in the evidence base. No studies have so far considered developing countries and the broad range of outcomes that matter to mobile consumers. Furthermore, we are not aware of a study that has looked at the impact of spectrum pricing in the '4G era'. More importantly, proving a causal effect requires proving the direction of the effects. One of the challenges in isolating the impact of spectrum prices on consumer outcomes is that the direction of any impact can work both ways. For example, the expectation of high consumer prices may lead to operators showing a greater willingness to pay more for spectrum, meaning that it is consumer prices driving spectrum prices (rather than the other way around). This means no conclusive and robust conclusions can be drawn from the existing evidence base.

20. Spectrum pricing in developing countries, GSMA, 2018 and Effective Spectrum Pricing, GSMA and NERA, 2017

4. Analysis and results

4.1 Approach

The analysis presented in this report addresses all the aforementioned methodological and data gaps by developing an econometric model that evaluates the impact of spectrum prices on market outcomes over the period 2010–2017. The study offers a number of innovations compared to previous research, in particular:

- **Consumer outcomes** – it looks at consumer prices, network coverage and network quality (measured using download speeds, upload speeds and latencies). Network coverage and quality have not been addressed in any of the existing literature.
- **Scope** – it is based on the spectrum costs of 229 operators in 64 countries (covering 30 developing countries and 34 developed countries).[21] No previous study has comprehensively assessed the impact of spectrum prices in developing countries.
- **Other factors** – it captures the additional factors, both on the supply and demand side, that have an impact on mobile market outcomes beyond spectrum prices (for example, income per capita, market concentration and operator scale).
- **Other spectrum policy impacts** – in addition to assessing the impact of spectrum pricing, the study considers the impact of other spectrum policy factors on market outcomes – in particular, the amount of spectrum released and delays in spectrum assigned.

The main innovation of the study is to isolate the impact of spectrum pricing on consumer outcomes by establishing as clearly as possible the direction of effect. We implemented a number of empirical techniques and carried out a series of sensitivity analyses to determine whether the findings were robust. These are outlined in detail in a separate technical paper. In summary, we identified the causal links using two approaches:

(i) The first was to analyse the impact of spectrum cost as a percentage of revenues. By measuring the 'affordability' of spectrum from an operator's perspective, our analysis should capture the impact of spectrum prices on consumer outcomes and not conflate it with the impact of consumer outcomes on spectrum prices.[22]

(ii) The second was to analyse the impact of spectrum cost per person (in $PPP) and control for the direction of effect by employing an 'instrumental variable' model. This leverages factors that have a direct impact on spectrum prices (for example, short-term government debt and spectrum assignment method) but not the consumer outcomes considered.

21. A list of countries is included in the accompanying technical paper.

22. If spectrum prices are measured in absolute dollars or local currency, the expectation of high consumer prices or high coverage or network quality could influence the amount an operator is willing to pay for spectrum. However, if we use spectrum cost as a percentage of revenue, there is an obvious link between 'less affordable' spectrum (i.e. where spectrum costs account for a high proportion of revenues) and reduced investment or higher consumer prices. However, there is no logical reason to think that improved consumer outcomes would have a negative impact on the affordability of acquiring a spectrum licence.

4.2 Key findings

The key findings for developed and developing countries are summarised in Figure 9. In developed countries, high spectrum costs played a significant role in slowing the rollout of 4G networks and drove a long-term reduction in 4G network quality. In developing countries, high spectrum costs slowed the rollout of 3G and 4G networks and drove long-term reductions in overall network quality. In terms of consumer prices, we find some evidence that higher spectrum costs may have driven higher consumer prices in developing countries. Further research is needed for this set of results to be fully conclusive, and better data on consumer prices is needed to assess the impact in developed countries.

FIGURE 9

KEY FINDINGS

	DEVELOPING COUNTRIES	DEVELOPED COUNTRIES
NETWORK COVERAGE	**Strong evidence** that higher spectrum prices had a persistent negative impact on 4G coverage as well as a negative impact on 3G coverage in the short and medium term.	**Strong evidence** that higher spectrum prices had a negative impact on 4G coverage.
NETWORK QUALITY	**Strong evidence** that higher spectrum prices had a long-term negative impact on average network quality and 3G network quality, including download/upload speeds and latencies. **Some evidence** of negative impact on 4G network quality, particularly upload speeds, though this is not conclusive.	**Strong evidence** that higher spectrum prices had a long-term negative impact on 4G download speeds. **Some evidence** of a negative impact on 4G upload speeds.
CONSUMER PRICES	**Some evidence** that higher spectrum prices may have driven higher ARPU and voice and data prices, though the results are not conclusive because they are not robust to all analytical approaches.	**Inconclusive evidence** – as results are not consistent we are unable to determine whether spectrum prices had an impact on consumer prices. More data is required to investigate.

Source: GSMA Intelligence

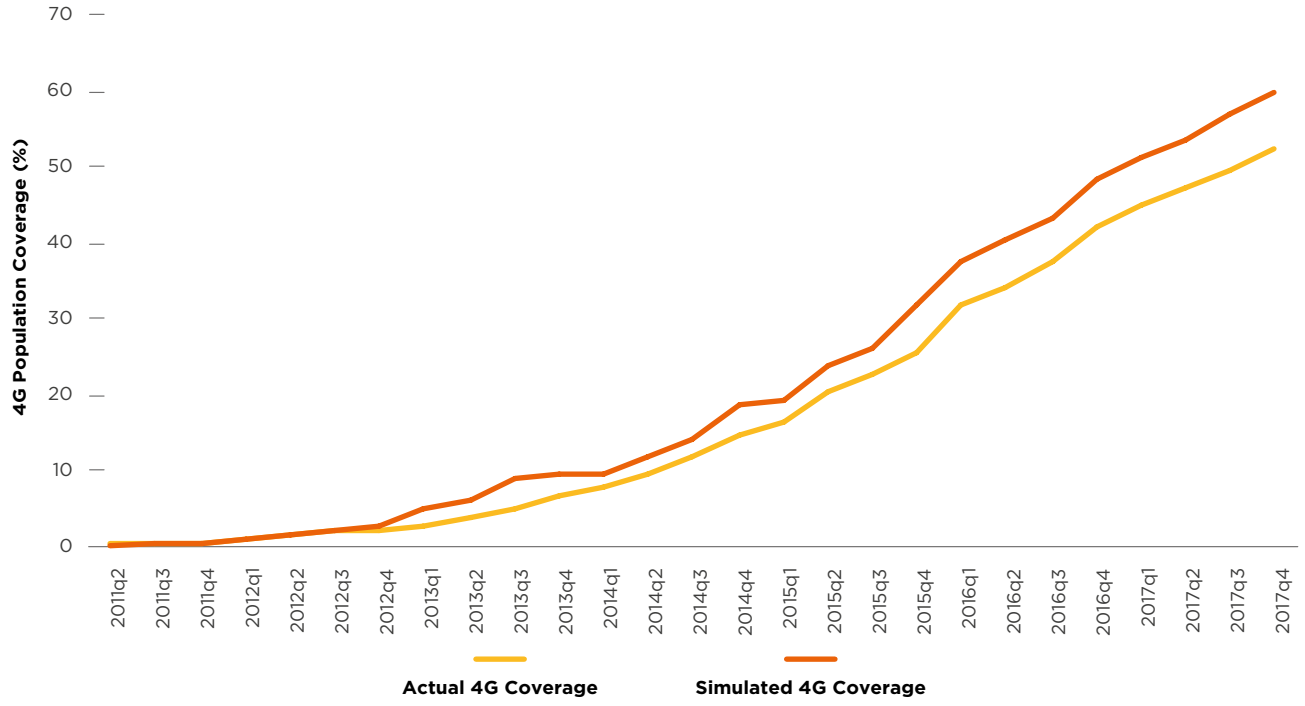
4.3. Impact on consumer outcomes

a) Network coverage

In both developing and developed countries, there is strong, compelling evidence that high spectrum prices had a consistently negative and statistically significant impact on 4G coverage. 4G coverage levels for those operators who paid very high spectrum prices (as defined as outliers in the technical report) are presented in Figure 10. Actual coverage levels are compared to the 4G coverage that would have been achieved if spectrum prices had been in line with the median spectrum price globally. On average, these operators would have achieved 7.5 percentage points higher coverage by the end of 2017 if spectrum prices as a percentage of revenues had been in line with global averages.

FIGURE 10

SIMULATED 4G COVERAGE IF OUTLIER PRICES HAD BEEN IN LINE WITH GLOBAL MEDIAN LEVELS, 2011–2017



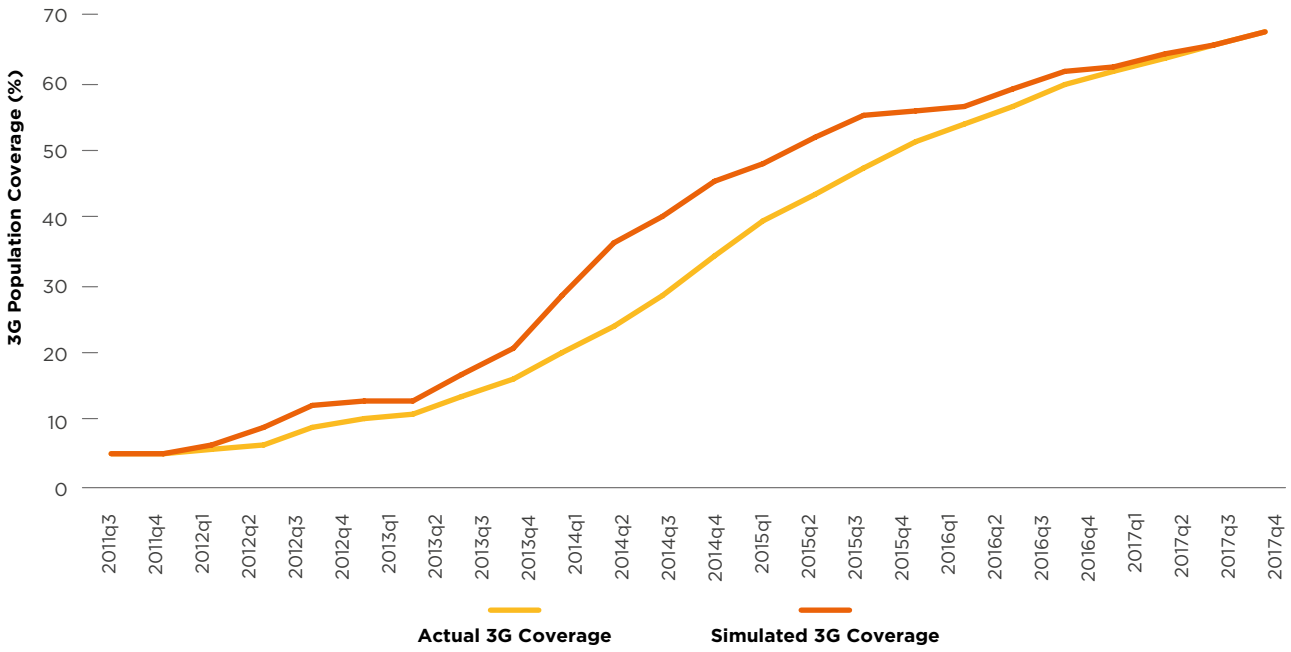
Source: GSMA Intelligence. Covers 17 operators that experienced significant price outliers over this period, operating in Thailand, Jamaica, Austria, Pakistan, Jordan, Venezuela, Israel, Kenya, Moldova, Colombia and Costa Rica.

The results also highlight important findings related to other aspects of spectrum policy. Early allocation of spectrum drives significant benefits for consumers. For example, an operator that was able to access 4G spectrum at least two years earlier than another achieved average 4G network coverage levels 11–16 percentage points higher (all else being equal). The amount of spectrum licensed to operators is also important. In the period of our analysis, an additional 1 MHz of 4G spectrum drove a 0.1–0.2 percentage point increase in 4G coverage and an increase in average download speeds of 0.06–0.12 Mbps. Therefore, an additional allocation of 20 MHz to an operator would, on average, increase 4G coverage by between 2 and 4 percentage points and download speeds by between 1 and 2.5 Mbps.

In developing countries there is also some evidence that high spectrum prices had a negative and statistically significant impact on 3G coverage, particularly in the first two years following the purchase of the licence. Similar to the findings for 4G coverage, the results also highlight the importance of other spectrum policies: early release of spectrum is an important factor – an operator that has had spectrum at least two years longer than another operator achieved (on average) 3G coverage more than 20 percentage points higher in developing countries (other factors being equal). Figure 11 shows 3G coverage levels for mobile operators in developing markets that were only awarded spectrum for the first time after 2013. Actual 3G coverage levels are compared with the coverage that would have been achieved if spectrum awards were in line with most other developing markets.

FIGURE 11

SIMULATING 3G COVERAGE IN DEVELOPING MARKETS IF SPECTRUM HAD BEEN LICENCED EARLIER, IN LINE WITH AVERAGE TIMINGS, 2011–2017



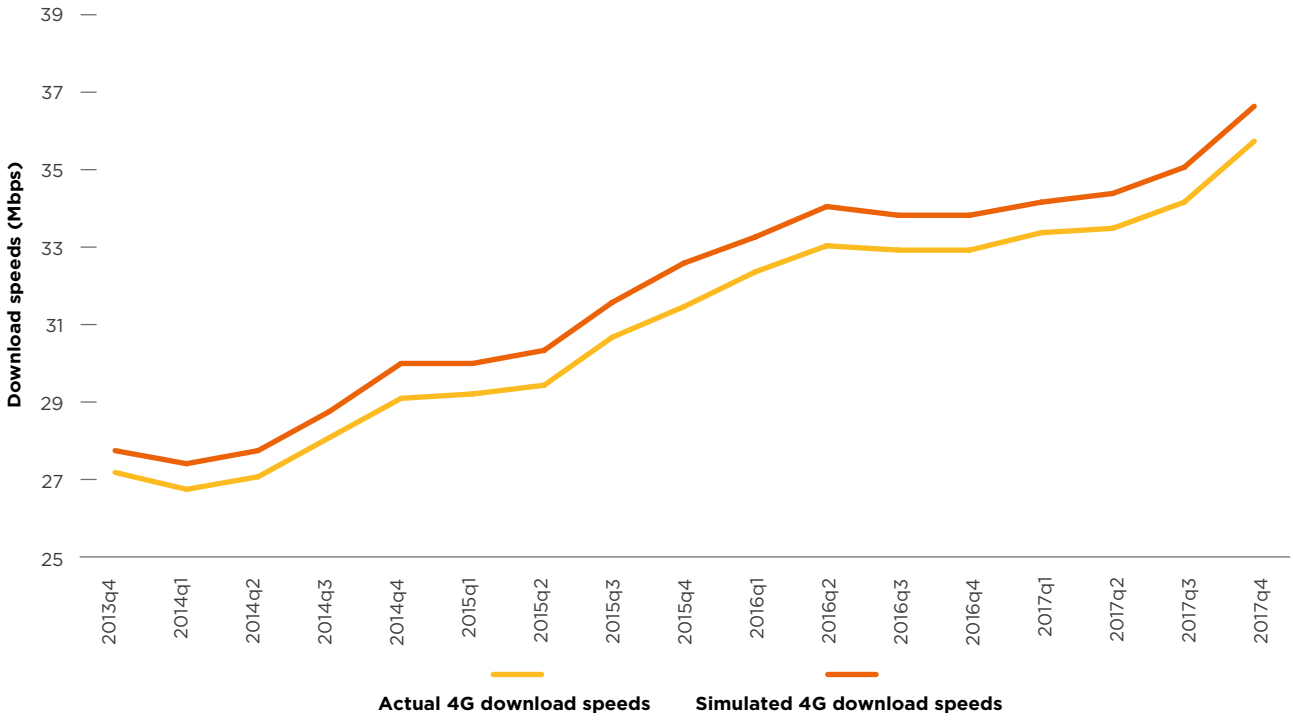
Source: GSMA Intelligence. Covers 20 operators that only licenced 3G spectrum for the first time after 2013. Includes operators from Thailand, Afghanistan, Algeria, Iraq, Niger, Ukraine, Pakistan and Albania.

b) Network quality

In developed countries, there is strong evidence that higher spectrum prices drove lower 4G download speeds. There is also evidence to suggest that higher spectrum prices drove reductions in 4G upload speeds in both developed and developing countries. Figure 12 illustrates this effect by comparing actual download speeds with those that would have been achieved if spectrum prices for the 25% of operators in developed markets that faced the highest spectrum cost as a percentage of revenues had been in line with the median spectrum price in other developed markets. In the period of analysis, consumers in these markets would have experienced on average 1 Mbps higher download speeds.

FIGURE 12

SIMULATING 4G DOWNLOAD SPEEDS IN DEVELOPED MARKETS IF OUTLIER PRICES HAD BEEN IN LINE WITH MEDIAN LEVELS IN DEVELOPED MARKETS, 2013–2017



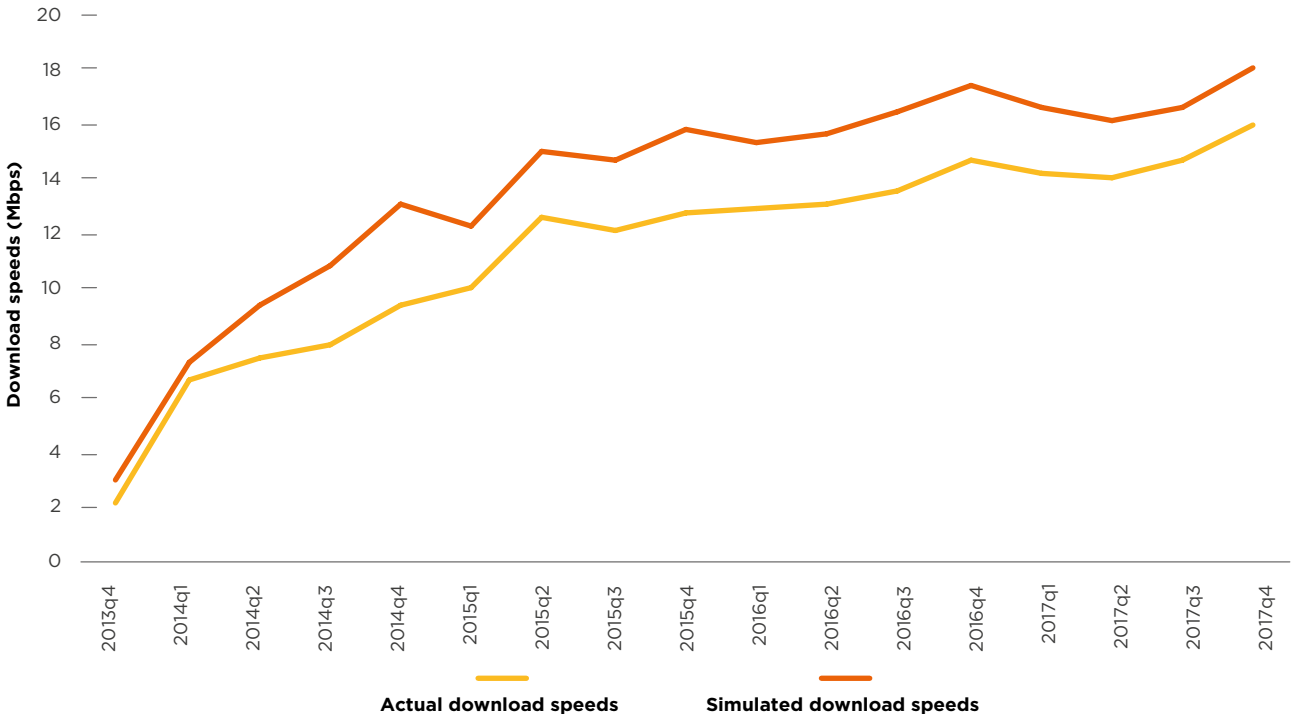
Source: GSMA Intelligence. Covers 31 operators that experienced price outliers over this period, operating in France, Hong Kong, Taiwan, Italy, Austria, Netherlands, Ireland, Singapore, Poland, Greece, Taiwan, New Zealand, Israel, Slovenia and Slovakia.

Higher spectrum prices also had a clear negative impact on developing countries' average network quality and for 3G networks in particular. This applies to all the metrics we consider including download speeds, upload speeds and latencies. For developed countries there is also evidence of a negative impact on 3G network quality but it is less conclusive.

Other policy factors played a significant role in driving overall network quality. The amount of spectrum holdings had a positive impact on download speeds in both developed and developing countries, suggesting that if more spectrum had been released to mobile operators, network quality would have improved. Figure 13 illustrates this effect by simulating the average download speeds that would have been experienced by a selection of operators that had relatively low amounts of spectrum holdings (defined as those operators that had 20 MHz less than the median level for both 3G and 4G spectrum holdings). The results indicate that consumers in those markets would have experienced on average 2.5 Mbps higher download speeds over the period if their spectrum holdings had been at average levels.

FIGURE 13

SIMULATING AVERAGE DOWNLOAD SPEEDS IF THE AMOUNT OF SPECTRUM LICENCED HAD BEEN IN LINE WITH AVERAGE LEVELS, 2013–2017



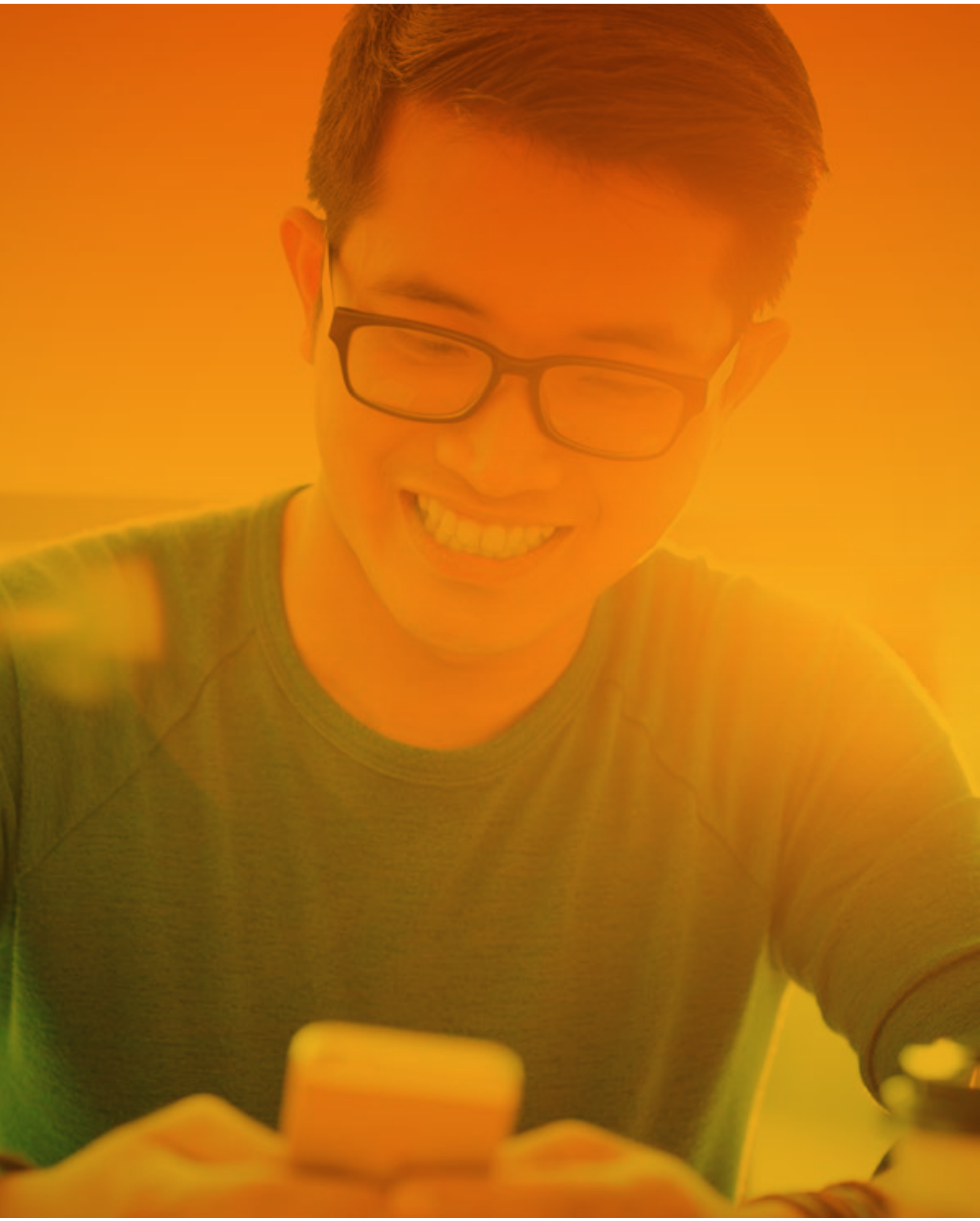
Source: GSMA Intelligence. Covers 10 operators that had 20 MHz less than the median level for both 3G and 4G spectrum holdings, operating in Ukraine, Colombia, Pakistan, Brazil and Taiwan.

c) Consumer prices

There is emerging evidence of a link between higher spectrum prices and higher consumer prices in developing countries. The results show that higher spectrum costs as a proportion of revenue drive higher prices for both voice and mobile broadband. For example, a 1 percentage point increase in the cost of spectrum as a percentage of revenue increases the monthly price of the voice basket by 0.2% and the 500 MB mobile broadband basket by 0.5%. However, the results are not robust to all of the analytical approaches we employed so the results cannot yet be considered fully conclusive.

The evidence for developed countries is inconclusive as the results are not consistent across different analytical approaches. Furthermore, the price baskets considered in this study are unlikely to be representative of consumption patterns in these markets over the 2010–2017 period.[23] Better data on consumer prices is therefore required to investigate the potential impact of spectrum pricing in developed countries.

23. See technical paper for a further discussion on this.



5. Conclusions and recommendations

The results of this study represent, to our knowledge, the first robust evidence showing how expensive spectrum can harm – and indeed has harmed – consumers in mobile markets. In particular, the study shows:

- Higher spectrum prices played a significant role in slowing the rollout of next-generation mobile networks: this was the case for 4G networks in developed countries and both 3G and 4G networks in developing countries.
- More expensive spectrum had a significant effect in reducing the network quality experienced by consumers in both developed and developing countries.
- Higher spectrum prices are associated with higher consumer prices in developing countries, though further research is needed to confirm whether the effect is robust.
- Other policy factors play a significant role in slowing network rollout (i.e. reduced coverage) and reducing the quality of 3G and 4G networks. In particular, early release of spectrum and a sufficient amount of licenced spectrum are both found to be important drivers of consumer welfare.

These findings have important ramifications for regulators, particularly when so many are trying to prioritise improved coverage and increased investment in 4G and 5G. They also highlight how efforts to maximise spectrum revenues are not consistent with government objectives to leverage mobile technology to reduce poverty and achieve economic prosperity, including meeting the UN Sustainable Development Goals. The study provides the following recommendations:

1. **Maximising revenues from spectrum awards should no longer be a measure of success**

   This study shows how spectrum prices can influence investment and pricing decisions and – when excessive – result in inefficient outcomes that have far-reaching negative consequences for consumers and the digital economy that outweigh the benefits from higher auction revenues. The report casts further doubt over the sunk-cost argument often misused to justify obtaining as high a spectrum price as possible.

   The primary objective should therefore be to assign spectrum to those users that will be able to extract most value from this scarce and finite resource for the benefit of society as a whole.

2. **Auctions can deliver inefficient outcomes when poorly designed**

   When well designed, auctions can be effective in delivering market-based solutions that allocate spectrum to those players that can generate most societal value from it. However, auctions can and do go wrong. The notion that "the market" – in this case "the auction" – will automatically deliver an efficient outcome is flawed. Just as the efficient markets hypothesis was often used to claim that financial markets are always right – until the global economy collapsed in 2008 – auctions have often been misused in the name of 'efficiency' when they are sometimes designed with other objectives in mind.

   For example, setting reserve prices aggressively or at levels that are too high is one reason why auctions can deliver inefficient outcomes, because it undermines the key price discovery function. As a result, precious spectrum may go unsold or be sold at such high levels that require mobile operators to reassess their investment plans or apply higher tariffs to recover costs.

3. **Artificially limiting the supply of spectrum, including through set-asides, risks slowing services and inflating prices**

   Governments often design awards with the intention of promoting competition and innovation in the sector – for example set-asides or reserved spectrum for a new entrant (or existing operator). While such policies may be designed with the right objectives in mind, they may also have unintended consequences if they are poorly designed or implemented and result in higher spectrum prices, thus harming consumers.

   Artificial spectrum scarcity is a frequent cause of high prices at auction. This can be a result of regulators holding spectrum back from the market entirely, setting it aside for new entrants or verticals, or using large lot sizes to minimise spectrum supply and thus drive up demand.

   The priority should be on releasing sufficient amounts of spectrum to meet consumer demand for high-speed connectivity and to support growing traffic. The findings from this study show that making additional spectrum available drives a significant impact in delivering high-quality mobile services to users. When operators are spectrum-constrained they are likely to have to invest more on densifying their network in urban areas than they would otherwise. This in turn can constrain their ability to invest in the rest of the network and, especially, improve coverage.

4. **Spectrum should be released to the market as soon as there is a business case for operators to use it**

   The timely release of spectrum bands is vital to ensure that new services can be launched and existing services can handle greater data volumes. Early release of spectrum drives better consumer outcomes, which is important in a market where long-term value, innovation and cost reductions are driven through relatively short technology cycles.

   Unnecessary delays to spectrum awards risk harming mobile broadband service rollouts and leaving more people unconnected. If spectrum is released earlier, operators have more time to invest in making new technologies available nationwide. The spectrum also eases capacity constraints in urban areas so operators are better able to invest in rural areas.

5. **Policymakers should work with stakeholders to enable timely, fair and effective spectrum licensing to the benefit of society**

   Given the often conflicting objectives between maximising auction revenues and supporting affordable, high-quality mobile services, a holistic and coordinated approach to mobile sector regulation by different parts of government is essential if ambitious digital inclusion and industrial policy objectives are to be realised.

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