Maximising the socio-economic value of spectrum

A best practice guide for the cost-benefit analysis of 5G spectrum assignments

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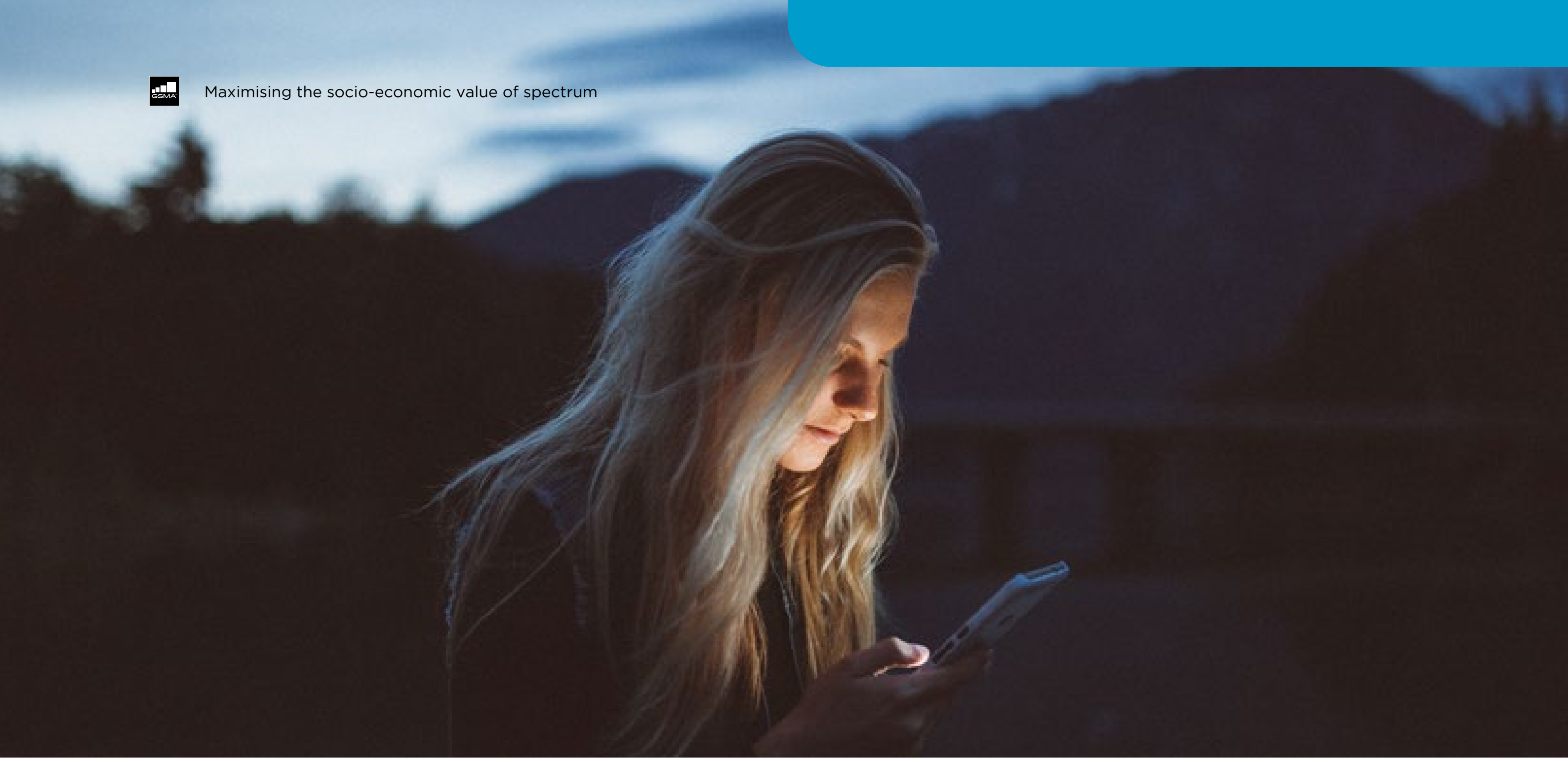

Executive summary

Radio spectrum is a critical and scarce natural resource. It is divided into bands according to frequency, each having features relevant to different applications, such as mobile networks, Wi-Fi or satellite communications. The challenge policymakers often face is having to decide which applicant would use each band most efficiently to deliver the greatest socio-economic benefits overall.

Auctions have become the most common mobile spectrum assignment mechanism over the past few decades. They provide a transparent, impartial and legally robust means of assigning spectrum to those who will use it most efficiently.

Direct assignments (also known as administrative assignments) of frequency bands can also sometimes be justified, but only when market-based assignments of spectrum do not deliver the best outcomes for society overall (e.g. set-asides when competition is limited or when a direct assignment can deliver greater benefits for society than the results of an auction).

When governments and national regulatory authorities have concerns that a market-based mechanism to assign spectrum might not deliver the greatest benefits, they should conduct regulatory impact assessments (RIAs) to identify the best option for spectrum assignments. An RIA is a best-practice framework that can be used by policymakers in order to improve decision-making by systematically assessing the positive and negative effects of existing and proposed regulations, or non-regulatory alternatives.[1]

Since spectrum assignment policies have measurable benefits and costs that can be monetised, a quantitative impact assessment in the form of an *ex-ante*[2] cost-benefit analysis (CBA) is generally a necessity when deviating from a market-based assignment of spectrum. However, conducting a CBA may often appear challenging and onerous in terms of costs and time.

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[1] https://www.oecd.org/regreform/regulatory-policy/ria.htm
[2] *Ex-ante* analysis refers to prediction of outcomes for project appraisal 'before the event', whereas *ex-post* analysis is concerned with the results 'after the event'.

This report provides practical guidance for the implementation of a CBA to quantify the impact of different spectrum assignment strategies, as a key part of an RIA. To facilitate the application of CBAs further, we illustrate the theory in practice by quantifying the costs and benefits of two case studies that some regulators are either currently facing or might face in the context of 5G:

- Should set-asides for local users be made in prime 5G bands?
- Are set-asides for new entrants justified?

The illustrative results from carrying out a CBA on these alternative choices indicate that, with today's standard market conditions, deviations from market-based spectrum assignments do not seem to be generally justified. We find that setting aside 100 MHz of mid-band spectrum for local use licences or for a new entrant in the 5G services market would have a net negative impact on society. Based on three illustrative country profiles for low-, mid- and high-income countries, consumers and producers would be worse off by up to $92 per capita and the broader economy could forgo up to $52 per capita in terms of lower socio-economic benefits associated with 5G.

Overall, and based on these two examples, it is clear that the conditions needed to deviate from market-based assignments are not generally met according to central assumptions in low-, mid- and high-income countries today. In situations where governments and regulators have concerns about market-based assignments leading to the most efficient outcome, we recommend taking the following steps before reaching a decision:

- **Develop an RIA** and follow RIA best practice to determine the reasons that could justify deviations from market-based allocations and identify potential policy alternatives.
- **Carry out an *ex-ante* CBA** to explore the net impact on society of different policy alternatives, to identify the option that maximises benefits at least cost.
- **Monitor market developments** to ensure that the chosen policy is delivering its expected outcomes.
- **Be prepared to intervene** whenever the chosen policy is not delivering its expected outcomes.

01

Regulatory impact assessments for spectrum assignments

Efficient spectrum allocation (assigning spectrum to those users that deliver the most value for society overall) helps to ensure the socio-economic benefits from the services that spectrum enables can be maximised.[3] The ITU recommends[4] that spectrum management goals and objectives should include:

- making the radio spectrum available for government and non-government uses to stimulate social and economic progress
- making efficient and effective use of the spectrum.

The core objective of spectrum management is therefore to enable spectrum to be used in a manner which will bring the greatest benefits to society.

An extensive body of research and empirical evidence has highlighted the many social and economic benefits that arise from mobile connectivity,[5] and 5G technology has the potential to impact societies even more deeply by driving innovation and transforming the digital landscape across different industries and sectors.[6] However, there are alternative uses of these frequency bands of radio spectrum that may also deliver some benefits to society.

National regulators use a variety of methods to assign frequency bands to specific services, such as (i) national or regional market-based licences to service providers, (ii) national or local set-asides of frequency bands for specific services and (iii) unlicensed use. They may also design the regulation to allow secondary market mechanisms (leasing, voluntary spectrum sharing).

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[3] Introducing Spectrum Management, GSMA, 2017
[4] Handbook on National Spectrum Management, ITU, 2015
[5] 5G and economic growth: an assessment of GDP impacts in Canada, GSMA Intelligence, 2020
[6] Regional Spotlight: Impact of mmWave 5G, GSMA, 2019

The amount of spectrum available and the conditions in which it is assigned will directly influence the quality, availability and affordability of mobile services. When the assignment is conducted in a fair and transparent way, it gives service providers the confidence to invest in spectrum, as well as the resulting infrastructure, enabling the general public to benefit from the best possible services.[7] The overall challenge that governments and national regulators face is to determine the approach that delivers the greatest socio-economic benefits to society. Therefore, national authorities should conduct an RIA to identify the best policy option for radio spectrum assignments, if not a market-based approach. RIAs can significantly contribute to the efficiency, transparency, accountability and coherence of public policymaking.

The ITU defines an RIA as a systematic, structured, evidence-based analysis of the prospective impacts of a proposed policy measure against possible alternatives.[8] The national regulatory authority must determine the nature of the spectrum assignment problem at hand and whether there are any market failures that could justify a departure from a market-based approach (e.g. auctions).

The wider societal impact of each spectrum assignment option can then be assessed either using a qualitative or quantitative approach, considering the anticipated net benefit via changes to competition, innovation or any spillover effects in the wider economy. Methodologies for assessing the net benefit to society should consider the effect on all relevant stakeholders such as existing licensees of a spectrum frequency band, potential licensees and consumers.

The use of RIAs has expanded to become a key part of policy decisions across many OECD countries, and RIA requirements have been often promoted by the World Bank to its client countries.[9] For example, in the UK, impact assessments are generally required for all government interventions of a regulatory nature. However, as noted by the ITU, the use of RIAs in the appraisal of telecommunications policies is often less common than in other sectors.[10] In some countries this is because ICT policies are dealt with by regulatory authorities that are independent of government and exempt from the obligation to carry out an RIA.[11]

Many recent key spectrum assignment decisions were carried out by the corresponding national regulatory authorities without publishing a formal RIA. For example, in Germany, the Federal Network Agency (BNetzA) set aside spectrum in the 3.5 GHz band for private use by vertical industries without a publicly available RIA on the effects of a deviation from a market-based mechanism.[12] Similarly, decisions on the allocation of the 6 GHz band in several countries, such as the US and Brazil, were not supported by an RIA. Given the magnitude and measurability of the economic and societal benefits at stake, there is a strong argument for the application of a quantitative RIA in spectrum assignments.

There are, however, some cases where regulators carried out appropriate policy appraisals. An example of an RIA in the telecoms sector is a quantitative study by the European Commission on the economic and social impact of repurposing the 700 MHz band for wireless broadband services in the European Union. Another example of an RIA, but a qualitative one, in regard to spectrum allocation was carried out by ComReg in Ireland. The regulator assessed potentially deviating from the market-based assignment mechanism by identifying the stakeholders in relation to a reallocation of the 3.6 GHz band, and set out a qualitative discussion on the assumed preferred assignment process for each stakeholder.[13] [14]

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[7] Introducing Spectrum Management, GSMA, 2017
[8] Regulatory Impact Assessment, OECD, 2020
[9] Using regulatory impact analysis to improve decision making in the ICT sector, ITU, 2014
[10] Ibid.
[11] Ibid.
[12] After BNetzA's decision, Vodafone undertook a regulatory impact assessment and cost benefit analysis to analyse the potential impact of BNetzA's decision, given that neither BNetzA nor the German government had provided one. See An Industrial 5G Spectrum Policy for Europe, Vodafone, 2019
[13] Including the FWALA operators that currently operate within the band, the parties with potential interest in the spectrum, consumers and the effect on competition.
[14] Response to Consultation & Decision on Proposed 3.6 GHz Band Spectrum Award, Commission for Communications Regulation, 2016

Best practice guidance for spectrum assignments

The focus of spectrum management varies over time and geographies, and the national regulator must consider the specific spectrum allocation options relevant to them. The policy options will vary based on:

- the frequency band
- the policy objectives
- the relevant stakeholders, which vary depending on current licensees and interested parties (e.g. new entrants to the market for the provision of mobile services).

Regardless of specific conditions, there are a number of key steps that RIAs should follow when considering spectrum allocation decisions:

1

What is the spectrum policy problem? Is there any evidence of a market failure or a regulatory failure?

Market failures are defined as situations where the free market leads to an inefficient distribution of goods and services in a society. They include positive or negative externalities, imperfect information and/or high market concentration such as monopoly power.

Regulatory failures exist when a current set of rules or policies do not achieve the optimal outcome for society.

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2

What is the nature of the market (or regulatory) failure and associated spectrum allocation problem?

What are the main drivers, what is the relevant timeframe and who are the stakeholders that would be impacted by different allocation options?

For example, a spectrum assignment problem could exist if there are spectrum use cases that have a positive effect on society (that is a positive externality) and whose value to society is not priced into auction bids, so that a market-based assignment such as an auction would not achieve the optimal outcome for society.

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3

What are the possible policy options to solve the spectrum allocation problem and what are their direct costs and benefits?*

What are the likely indirect impacts? Is there any risk of regulatory failure?

For example, an alternative assignment process such as a set-aside may have benefits to society, but there will also be direct and indirect opportunity costs (e.g. lower mobile networks performance) associated with a spectrum set-aside.

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4

Is there any option that can achieve the same benefits from the spectrum at less cost?

For example, the existence of spectrum licensing agreements which allow access to spectrum without set-asides.

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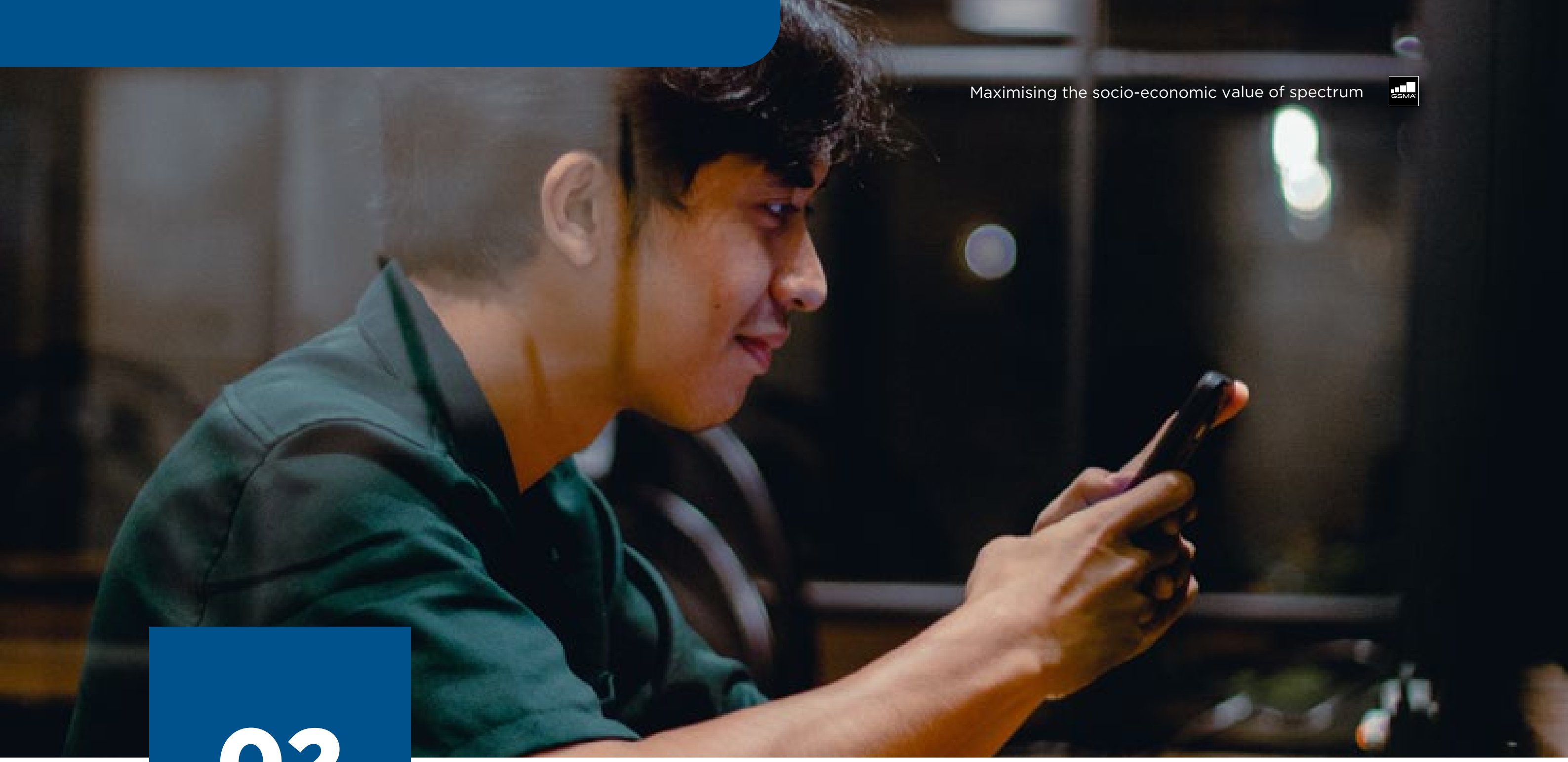
* As part of this stage, the ‘zero’ or ‘do nothing’ option must be included in the list of regulatory alternatives. This is also known as the baseline scenario and is a forecast of the scenario without regulatory intervention.



02

Appraising the impact of spectrum assignments with a cost-benefit analysis

Background

A variety of methodologies can be used to assess the socio-economic impact of different policy options as part of an RIA (step 3 in the RIA checklist above). The ITU (2014) highlights some of the methodologies that are most often used in RIAs: least-cost analysis; cost-effectiveness analysis; cost-benefit analysis; and multi-criteria analysis.

The methodological choice for any given analysis will depend on the types of direct impacts to be assessed, their magnitude and the existence of indirect costs and benefits. In the case of a CBA, it requires that all major direct and indirect costs and benefits of the regulatory options are identified and monetised.

The advantage of a CBA over other alternatives is that it uses an objective unit of measurement (monetised values) to compare alternative options and choose the one that maximises societal welfare as described in mainstream economics.[15]

Ex-ante CBAs are generally appropriate for radio spectrum assignment policies since these have measurable benefits and costs which can be monetised. For example, when a decision is made to license less spectrum for mobile networks, there will be additional rollout costs to meet mobile data traffic demand and/or a fall in the quality of mobile services provided.

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[15] Using regulatory impact analysis to improve decision making in the ICT sector, ITU, 2014

In addition to this, less licensed spectrum can lead to a slower rollout and lower adoption of new mobile technologies. Since there is an extensive consensus[16] that new mobile technologies such as 5G will have large positive economic impacts, a delay in the rollout can also create an opportunity cost in terms of forgone socio-economic benefits. Conversely, there are benefits from alternative radio spectrum uses if more spectrum is available.

In this report, we consider two alternatives to a market-based assignment to 5G spectrum that can potentially deliver benefits. These are contingent on the scenario itself and there are various ways to monetise the impacts of these allocations. Each policy scenario will have a corresponding net benefit (or cost) to society, and the one that maximises the size of the pie is generally the preferred policy option.[17] The CBA framework set out in this report is flexible and can consider different spectrum policy proposals and their context, which will vary by geography and over time.

When contemplating the choice of a spectrum assignment policy among a range of alternatives involving different costs and benefits, the choice to perform a CBA must be made in light of the principle of proportionate analysis. This means that the depth of the CBA exercise, including the time and the resources devoted to it, should be contingent on the expected impact of the proposal.

Generally, the net benefits of the spectrum allocation options are of a magnitude that justifies the effort required according to the principle of proportionate analysis. The results of the two case studies in this report, alongside RIAs already carried out for spectrum assignments, provide further evidence that the outcomes of the CBAs are proportional to the effort required to carry out the analysis.

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[16] For example, see The 5G Economy, IHS Markit (2019) and The Impact of 5G on the European Economy, Accenture (2021)

[17] Once the overall benefits (or costs) have been measured, distributional analysis of the allocation of the costs and benefits can be layered on top of that if the policy maker believes they will vary greatly between scenarios.

Best practice guidance for spectrum assignments

This section sets out the general methodological approach for an *ex-ante* CBA related to spectrum assignment policies. The aim is to provide a flexible framework for practitioners – including those in national regulatory authorities, industry or academia – that can serve as a guide to carry out CBAs, which can be tailored to the relevant spectrum decision options.

Spectrum assignment policies can affect several stakeholders in different manners and generally their effect can be classified as direct or indirect.

Direct effects are those that impact stakeholders that are directly affected by the policy alternatives. Assuming a regulator's objective is to maximise total welfare, analysing the direct effect of policies entails looking at changes in the following:

- **Consumer surplus (CS):** the difference between the price that consumers pay and the price that they are willing to pay for a product or service.
- **Producer surplus (PS):** the amount that producers benefit by selling at a market price that is higher than the minimum price they would be willing to sell for.

Indirect effects of spectrum assignment policies can be generalised as changes in spillover effects (GDP benefits), that is the economic value generated from spillovers to the wider economy. For digital technologies, this is an important consideration since these are widely regarded as general-purpose technologies that enable economic growth via improvements in productivity and efficiency, and through decreases in search and information costs.

It should be noted that indirect effects are not necessarily additive to direct effects since, depending on their estimation strategy, they could capture part of the changes in CS and PS. This means that in practice there is sometimes a risk of double counting the benefits (or costs) if indirect effects are added to direct effects. For example, it is possible that changes in PS could be reflected in GDP via adjustments to the value-add of a firm or sector. Therefore, direct and indirect effects in some cases may not be purely additive and it is appropriate to quantify and report the costs and benefit effects separately.

In the context of spectrum allocation policies, national regulators should take into account the following when considering spectrum allocation decisions:

Direct effects:

Changes in consumer surplus: How do the assignment alternatives impact consumers? Is one alternative expected to cause an increase in consumer prices or a quality degradation with respect to the counterfactual?

Changes in producer surplus: How do the assignment alternatives impact companies? Is one alternative expected to cause an increase in costs?

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Indirect effects:

Changes to GDP benefits: Do the changes in consumer and producer surplus impact other sectors or agents in the economy? Is the impact an opportunity cost or a benefit?

03

Putting theory into practice: two quantified examples of CBAs

Mobile operators worldwide will invest $1 trillion by 2025 in 5G.[18] 5G use cases are expected to significantly benefit the global economy, with yearly improvements in the range of 0.5% and 1.3% of GDP, depending on the estimation methodology and the timeframe considered (Table 1).

Given the order of magnitude of the impact of 5G technologies, regulators and governments should carefully consider spectrum assignment alternatives to maximise the expected benefits of 5G at the lowest cost.

Table 1: 5G GDP benefits by study

Source: GSMA Intelligence (see References for full list of sources)

Author	Period	Scope	Yearly average % of GDP enabled by 5G
GSMA Intelligence	2020–2040	Global	0.5%
Accenture	2021–2025	US	1.3%
PWC	2020–2030	Global	0.5%
IHS Markit*	2020–2035	Global	0.2%
BCG	2020–2030	US	0.6%

* Includes only the expected 5G contribution to GDP and not higher sales enabled by 5G.

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[18] GSMA Intelligence

5G needs sufficient spectrum in the low (<1 GHz), lower-mid (1 to <3 GHz), upper-mid (e.g. 3.5, 4.8 and 6 GHz) and high bands (mmWave). Several countries are considering different assignment policies for 5G spectrum.

While the 3.5 GHz range has been the basis for the first implementations of 5G globally, other upper-mid-bands, such as 6 GHz and 4.8 GHz, also provide a balancing point between coverage and capacity that can enable the perfect environment for city-wide 5G connectivity. now and for the years to come.[19]

To illustrate the importance of RIAs, and following the ongoing debates on international trends for 5G spectrum, we put theory into practice by building CBAs of two different upper-mid-band spectrum assignment policies in the context of 5G that are currently being considered by regulators and governments around the world. When assessing the impact of spectrum assignment policies, appraisers need to define a baseline amount of spectrum for mobile networks, given expected growth in data traffic demand, and then understand how changes in this baseline will impact mobile network stakeholders.

Table 2: Policy option examples considered

Source: GSMA Intelligence

Baseline	Scenario
Auctioning 400 MHz in the 3.5 GHz band	Setting aside 100 MHz out of 400 MHz in the 3.5 GHz band for industry verticals and auctioning 300 MHz for licensed use
	Setting aside 100 MHz out of 400 MHz in the 3.5 GHz band for a new entrant and auctioning 300 MHz for licensed use

The nature of the spectrum assignment alternatives above is related to assigning precious and scarce mid-band spectrum to different use cases. In the two examples we consider, this entails correcting for potential market failures through set-asides.

Potential market failures that can be assessed by appraisers include negative externalities (for instance, if there is substantiated reason to expect that a market-based mechanism would negatively impact vertical industries), monopoly power or risk of coordination among market players.

Appraisers should gather evidence on these potential market failures in their specific markets, to justify a departure from a market-based assignment.

It should be noted that there are other policy alternatives that could, depending on the specific situation of each market, achieve the same benefits at least cost, such as spectrum sharing, spectrum leasing, and service-level agreements. Appraisers should also consider the impact of these other alternatives when assessing the best course of action.

While each policy example impacts different stakeholders in different manners, the decision to assign more or less spectrum for mobile telecommunications services impacts the two scenarios in a similar way. We therefore set out below a common framework to quantify impacts of spectrum assignment policies on mobile networks.

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[19] Estimating the mid-band spectrum needs in the 2025–2030 time frame, Coleago Consulting, 2021

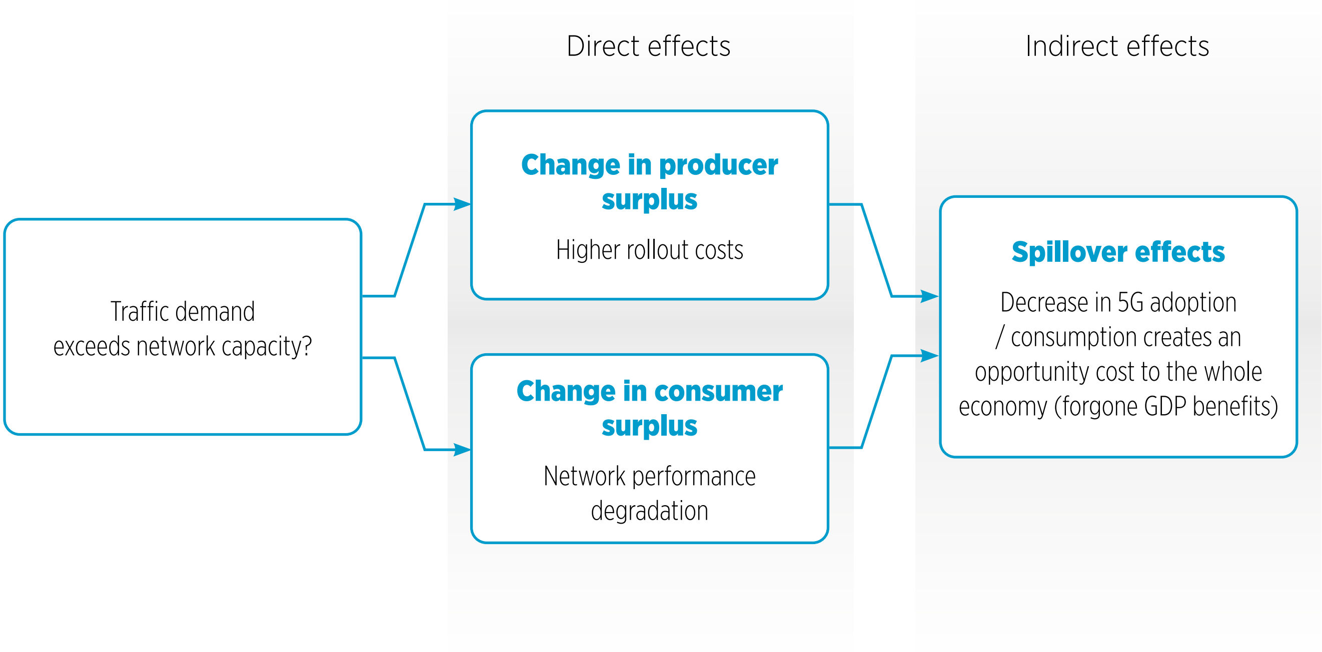
Figure 1 details the differential impacts of assigning distinct spectrum amounts for 5G. Since spectrum adds to mobile network capacity, whenever mobile traffic demand exceeds capacity and spectrum availability is constrained, mobile operators generally face two choices. They must either densify their network to meet traffic demand and/or accept a degree of quality degradation in the performance experienced by users:

- Network densification generally entails higher rollout costs for mobile networks and therefore impacts PS and CS (if part of the cost increase is passed on to consumers in the form of higher prices).
- Quality degradation impacts subscribers of the service since they would experience poorer network performance, so CS would be negatively affected. Higher densification, as described above, can also lead to interference and therefore poor quality of service.

The actual outcome is likely to be a combination of the two impacts. However, site densification in a given area is constrained by the risk of interference and the need to obtain relevant permissions from local authorities and landlords, as well as the financial constraints operators face in terms of investment, which are usually set as a fixed percentage of revenues. Therefore, we consider that the quality degradation scenario gives a more accurate representation of the likely impact on 5G network stakeholders and we focus on the presentation of these results. The results of the higher rollout cost approach are presented in Annex 2.

Figure 1: Impact of spectrum assignment policies on mobile networks

Source: GSMA Intelligence



In practice, to quantify the impacts highlighted above, a CBA appraiser can make several simplifying assumptions on the distribution of the impact across economic agents. In particular, the model for this report proposes a quantification strategy that is based on two alternative approaches:[20]

1. A scenario where mobile operators would not densify their networks to meet traffic demand, so that any capacity gap that arises would be absorbed by subscribers in terms of lower speeds.

a. Some subscribers would be willing to pay more for higher speeds, and not being able to obtain those means that they would experience a loss in CS ('quality degradation estimation').

    b. Since some subscribers would experience lower speeds than the minimum required for 5G,[21] they would not subscribe to 5G services because the service provided would not be 5G, therefore impacting 5G adoption.

    c. In the economic literature, there is a range of evidence demonstrating the positive spillover effects of mobile technology upgrades on the wider economy, which are likely to continue with 5G.[22]

    d. This means that lower 5G adoption would create an opportunity cost to the country's economy, in the form of forgone GDP benefits ('quality degradation estimation'). This approach estimates changes in CS and GDP benefits, assuming that the change in PS is null.

2. A scenario where mobile operators would not accept any degree of quality degradation and would densify their network to cover any capacity gap,[23] so that the loss in unit capacity due to lower bandwidth availability would be absorbed in the form of higher rollout costs.

    a. If the CBA appraisers expected that some of these higher rollout costs would be passed on by operators to consumers in the form of higher prices, they should also expect some consumers would delay their subscription or not adopt 5G services at all.

    b. Similar to the quality degradation estimation, this means that lower 5G adoption would create an opportunity cost to the country's economy, in the form of forgone GDP benefits ('higher rollout costs estimation'). This approach estimates changes in PS, CS and GDP benefits.

Annex 1 describes the CBA approach and detailed assumptions. The underlying spreadsheet can be made available under request from practitioners looking to appraise 5G spectrum assignment decisions.

It should be noted that the results largely depend on the specificities of each market. The conclusions below are based on central assumptions meant to reflect representative countries according to their level of development, but practitioners should assess their validity and adapt them to the specific market situations that they are considering. In particular, they should adapt the following assumptions to their market context:

- demographic assumptions and forecasts
- total spectrum assignments for 5G
- the minimum speeds that should be enabled by the 5G network
- the share of connected users and the share of connected users that are active at peak hour as well as their likely evolution in the next 10 years
- the share of 5G traffic likely to be offloaded to Wi-Fi
- the evolution of 5G connections penetration in the next 10 years
- the capex and opex of 5G base stations
- the cost pass-through ratio to consumers and the price elasticity of demand
- the impact on GDP of increases in 5G adoption
- the most appropriate discount factor to discount future impacts.

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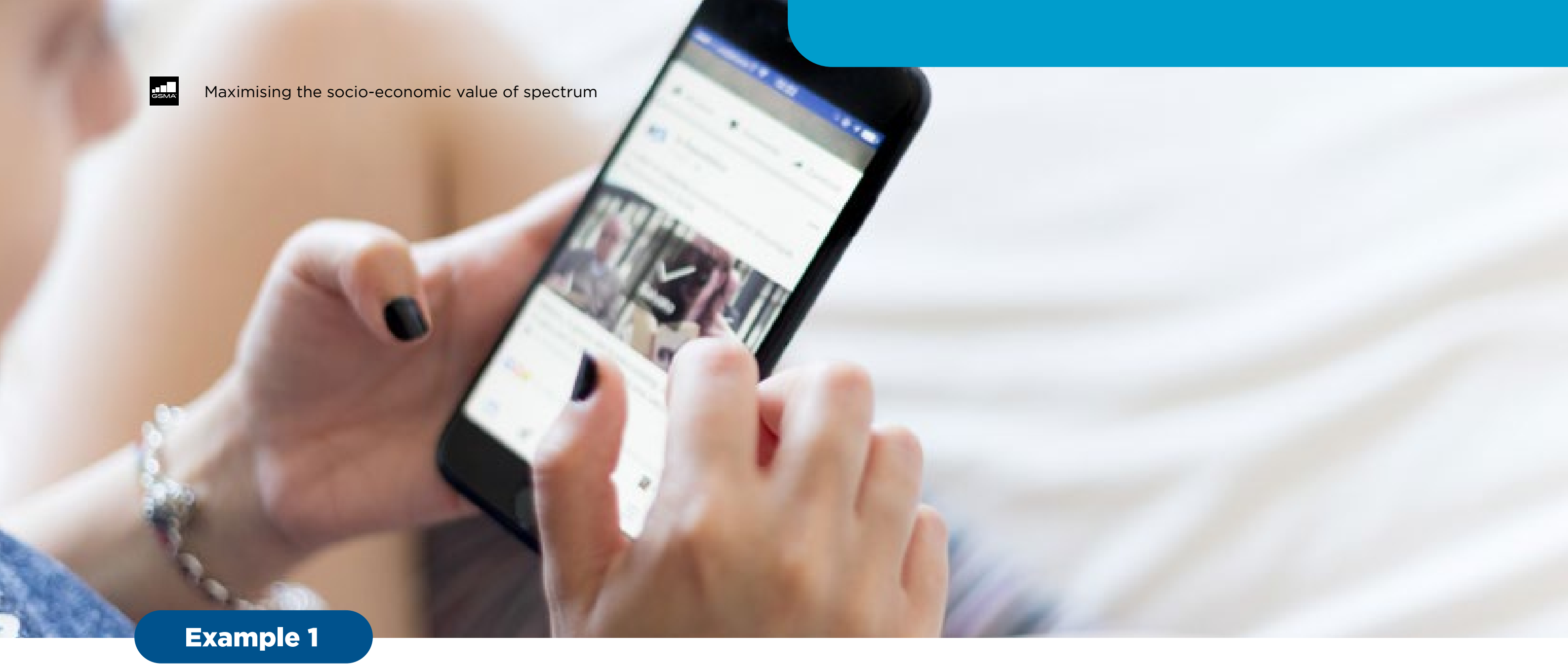
[20] We note that there is a range of other possible impacts on mobile networks that appraisers can take into account and that we have not modelled in our examples, such as the impact of lower adoption of 5G services on 4G, 3G and 2G networks (further loading), energy efficiency related to the use of 5G technologies and opportunity costs of not achieving new types of services such as fixed wireless access.

[21] Report ITU-R M.2410-0, Minimum requirements related to technical performance for IMT-2020 radio interface(s), ITU, 2017

[22] The Mobile Economy 2021, GSMA Intelligence, 2021; The global economic impact of 5G, PWC, 2020; The 5G Economy, IHS Markit, 2019.

[23] This is a simplified assumption since interference and planning permissions limit the extent an operator can densify its network to meet traffic demand. In practice, we expect the outcome of less spectrum assigned to 5G networks to be in between more site densification and lower quality of service.



Example 1

Setting aside 100 MHz in the 3.5 GHz band for local use licences

Policy issue and options considered

There is an ongoing debate on how to best enable 5G private networks in vertical industries. Some countries, such as Germany, have set aside spectrum for local use licences, while other countries, such as the UK, are exploring spectrum sharing between mobile operators and industry verticals.

An argument for setting aside spectrum for vertical use is that it ensures the availability of spectrum to support enterprise use cases via private or dedicated networks, or that it would lead to faster development of private networks and therefore a greater accumulation of economic benefits over time by expediting the increase in productivity associated with private networks.

Another argument is that mobile operators may not be as well positioned to deliver the service requirements for certain enterprises compared to allowing enterprises to develop their own network. However, it has also been argued that all these benefits could be achieved under alternative policies that do not require a set-aside of spectrum, such as spectrum leasing or sharing.[24] For example, Ofcom in the UK announced that it intends to introduce ‘spectrum sharing’, whereby spectrum that is licensed to a mobile operator but is not being used in a given area can be licensed to private companies.

There are numerous studies that outline the benefits of 5G for industry verticals,[25] for example via ultra-reliable low-latency communication (URLLC) and massive IoT (mIoT) use cases. Some sectors are set to benefit from the 5G rollout more than others according to the readiness to adopt new technologies and on the relevance of the identified 5G use cases for each sector.[26] These use cases require 5G connectivity, which can be offered by mobile operators directly, by third parties or by companies building their own private 5G networks – all of these options are possible through licensing spectrum to 5G services in an open auction.

In this case study we consider the impact of the following spectrum assignment options:

- auctioning 400 MHz in the 3.5 GHz band for 5G networks (the ‘baseline’)
- reserving 100 MHz in the 3.5 GHz band for industry verticals (non-mobile operator users).

In our baseline scenario, 400 MHz in the upper-mid-band frequency range is available in an open auction. In the counterfactual scenario, 100 MHz of the frequency band is set aside and only available to industry verticals to form their own private networks, leaving 300 MHz available to auction in the upper-mid-band.

The main stakeholders directly impacted in this example are consumers, mobile operators and the producers of goods and services in the vertical industries that would benefit from increased productivity via 5G enabled technologies. Society overall would be indirectly impacted through spillover effects.

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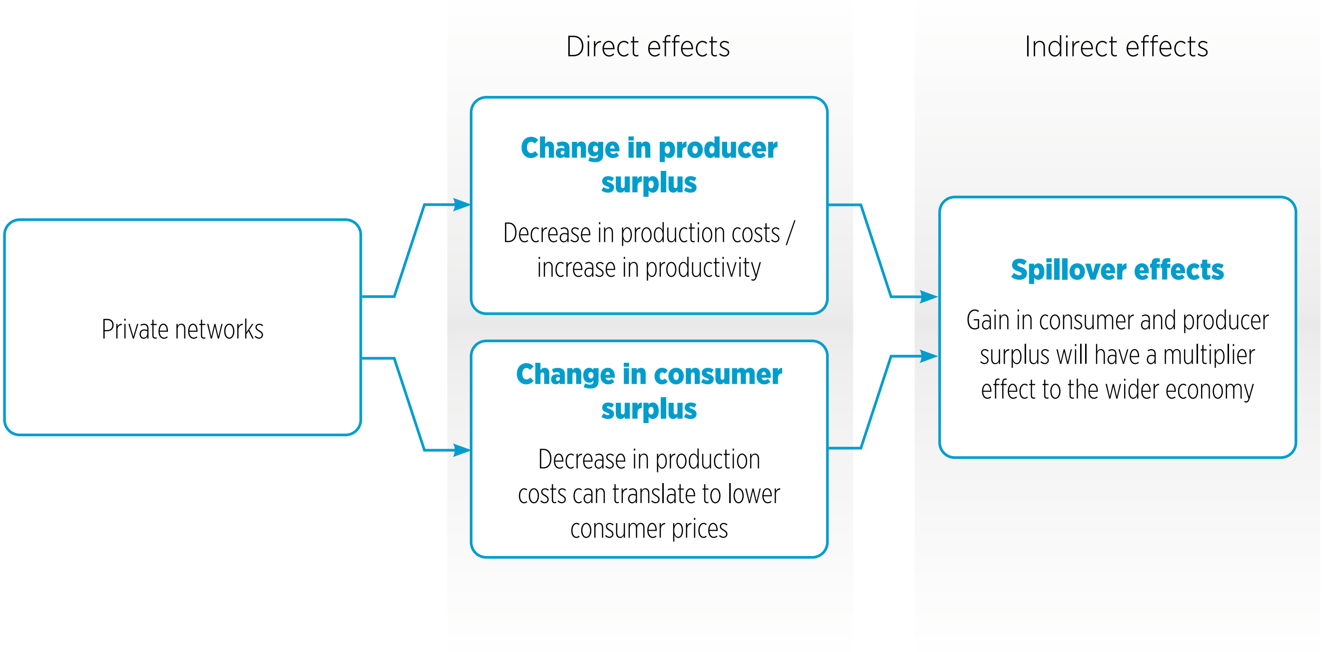
[24] 5G IoT Private & Dedicated Networks for Industry 4.0, GSMA, 2020; An industrial 5G policy for Europe, Vodafone, 2020
[25] Verticals are defined here as companies, industries and public sector organisations operating in a specific sector.
[26] 5G and economic growth: An assessment of GDP impacts in Canada, GSMA Intelligence, 2020

Proposed CBA approach

Figure 2 presents the expected impact on PS, CS and spillover effects of private networks on industry verticals stakeholders. Private networks are expected to improve productivity of industry verticals, thus positively impacting PS. Improvements in productivity are expected, to some extent, to be passed on to consumers in the form of lower downstream prices and/or improved product quality, generating a positive impact on CS. These two effects are expected to have a positive indirect multiplier effect on the wider economy.

Figure 2: Impact of private networks on industry verticals stakeholders

Source: GSMA Intelligence



A sensible CBA approach would rely on estimating the expected impact of private networks on industry verticals, assuming that a given share of this impact would not be realised if no spectrum is set aside. Appraisers should gather evidence of changes in PS and CS associated specifically with setting aside spectrum for industry verticals. This would require bottom-up calculations of cost and price changes for every good impacted by 5G technologies in each industry vertical.[27] It should be noted that, in theory, changes in GDP would capture some of the changes in PS reflected in higher value-add; however, isolating this effect in the GDP data would require several assumptions on changes in costs, prices and demand that are not widely available.

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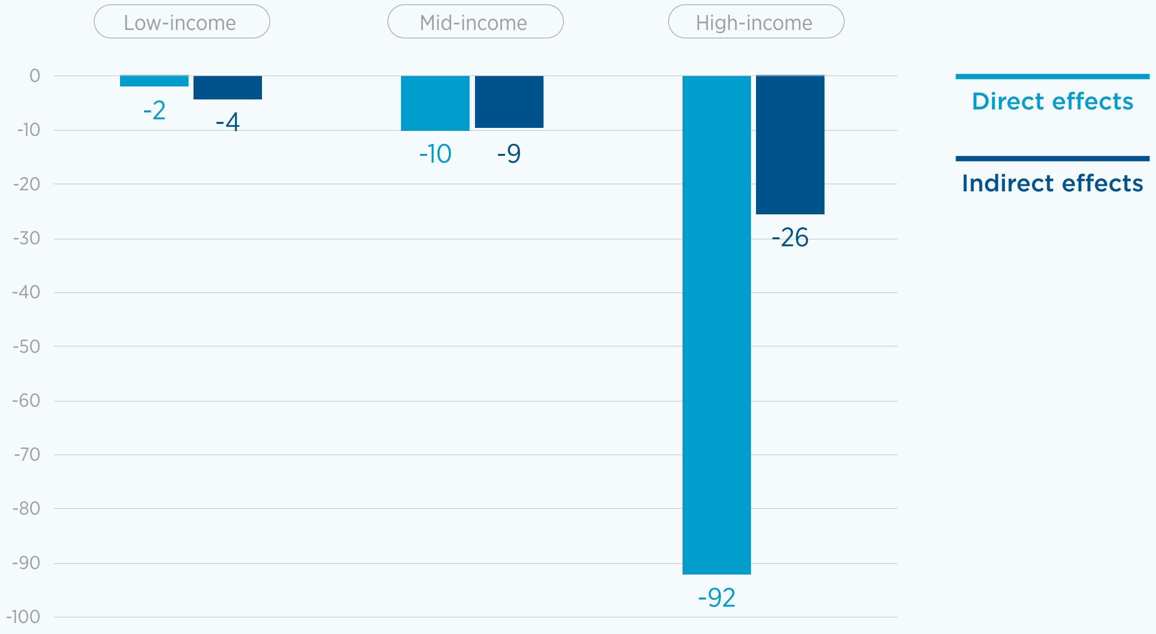
[27] Given data requirements and expected variations by country, we do not model this effect in our CBA template.

Illustrative results

When 5G benefits associated with private networks can be realised without set-asides, the net impact of setting aside 100 MHz of 3.5 GHz spectrum for industry verticals would generate no benefit to society. Figure 3 presents the results. According to the quality degradation approach, the direct effect in terms of changes in consumer and PS would be a respective decrease of $2, $10 and $92 per capita for the low-, mid- and high-income countries and the indirect effect in terms of changes in GDP benefits would be a decrease of $4, $9 and $26 per capita respectively.

Figure 3: 10-year NPV of net impact of setting aside 100 MHz of 3.5 GHz spectrum for industry verticals (USD per capita)

Source: GSMA Intelligence (see Annex 1: Technical annex)



The results above are based on the central assumption that the full benefits of private 5G networks can be achieved in all industry verticals without setting aside spectrum. Depending on their market situation, appraisers will need to gather evidence of positive impacts on CS, PS and GDP that can be achieved only by setting aside spectrum and that can counterbalance the costs to 5G network stakeholders.

Example 2

Reserving 100 MHz in the 3.5 GHz band for a new entrant in the mobile market

Policy issue and options considered

Some countries, such as Belgium and Canada, have considered facilitating entry of a new competitor or promoted the growth of smaller operators in the 5G market through spectrum set-asides.[28]

The nature of this particular assignment problem is related to facilitating entry in the market of a new competitor, for example when a regulator or government believes that the market is too concentrated and that this can lead to poor consumer outcomes. A regulator or government can encourage a new entrant into the market with different regulatory mechanisms.

One mechanism is via set-asides, which can be used to ensure access to spectrum and facilitate potential new market entrants. Set-asides are usually considered in markets where regulators are concerned that incumbents would overbid for available spectrum to avoid the entry of a new competitor, or where they consider that a new entrant will increase consumer welfare. The stakeholders directly impacted by this policy are mobile operators and consumers of mobile connectivity, while society overall would be indirectly impacted through spillover effects on prices and investment.

In this policy example, we consider the impact of two alternative spectrum assignment options:

- auctioning 400 MHz in the 3.5 GHz band for licensed use (the ‘baseline’)
- reserving 100 MHz in the 3.5 GHz band for a new entrant in the 5G services market (the ‘scenario’).

The economic literature has studied both theoretically and empirically the relationship between changes in market concentration,[29] prices and investment in mobile markets.

Economic theory suggests that an increase in market concentration can have both positive and negative effects, depending on the circumstances, incentives and consumer attitudes in the relevant market. Lower market concentration can be associated with greater competition, which can increase incentives to reduce prices and innovate and therefore benefit consumers. However, it can also increase average deployment costs, reduce efficiency[30] and decrease margins and returns on investment. This can limit the ability and incentives of operators to invest and innovate, to the detriment of consumers.

Empirical studies have found mixed evidence of the impact of concentration on prices in mobile markets, while most have found a positive relationship between concentration and investment.[31]

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[28] See for instance the impact assessment commissioned by the Belgian regulator on the likely impact of a new entrant in the 5G market.

[29] Historically, market concentration has been measured using indicators such as the number of players or the Herfindahl-Hirschman index (HHI).

[30] For example, not being able to efficiently use spectrum and deploy sites. See Mobile market structure and performance in Europe: Lessons from the 4G era, GSMA, 2020

[31] See A Review of the Empirical Evidence on the Effects of Market Concentration and Mergers in the Wireless Telecommunications Industry, Fruits, Hurwitz, Mann, Morris and Stapps, 2019 for an extensive literature review on economic studies analysing the impact of mergers in mobile prices and investment. It concludes that results on prices are inconclusive, while most studies find a positive link between concentration and investment.

Regarding prices, several economic studies have analysed the empirical relationship between higher or lower concentration and different measures of prices, with mixed findings. These studies focused on the following pricing metrics:[32]

- **Average revenue per user (ARPU):** operator revenues divided by subscribers or connections.
- **Basket-based pricing:** based on defining a basket of mobile services (e.g. 1 GB of data) in order to assess differences in prices across countries.
- **Unit-based pricing:** effective price per MB (or other units such as minutes).

To our knowledge, studies that have focused on ARPUs have generally found no impact. In contrast, studies that have focused on tariffs or basket prices have generally found a positive relationship or no relationship between higher market concentration and tariffs.[33] Finally, studies that have focused on unit prices, that is prices per unit of data delivered, found that increases in concentration could lead to lower prices.

Table 3: **Findings on the impact on concentration on prices**

Source: GSMA Intelligence

Study	Measure of price	Concentration or consolidation	Effect of higher concentration on prices
Abate, Castells, Bahia (2020)	ARPU	Concentration in general	No impact
Frontier (2015)		Concentration in general	No impact
Genakos, Verboven, Valletti (2018)	Baskets of services	Concentration in general	Rise[34]
Ofcom (2016)		Impact of disruptive new entrant	Rise (drop if new entrant)
CERRE (2015)		Four to three	Rise
DG COMP (2015)		Four to three[35]	Rise[36]
RTR (2016)		Four to three[37]	Rise
DG COMP (2015)		Five to four[38]	Drop
Houngbonon (2015)	Unit prices	Four to three[39]	Data: drop
HSBC (2015)		Four to three[40]	Data: drop
Jeanjean (2015)		Concentration in general	Data: drop

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[32] See Abate, Castells and Bahia (2020) for a comparison of the pros and cons of the use of these different metrics

[33] That is, they found that higher concentration generally leads to lower prices.

[34] Genakos, Verboven and Valletti (2018) found that increases in concentration could lead to tariff increases in the order of 10%.

[35] Evaluation of the 2007 T-Mobile/Orange merger in Holland

[36] DG COMP (2015) in their analysis of two mergers in the Austrian and Dutch mobile markets found no post-merger tariffs increase in Austria and increase in tariffs of between 10% and 17% in the Netherlands (*Ex-post* analysis of two mobile telecom mergers: T-Mobile/tele.ring in Austria and T-Mobile/Orange in the Netherlands, DG COMP, 2015).

[37] Evaluation of the 2012 Hutchison/Orange merger in Austria

[38] Evaluation of the 2006 T-Mobile/Tele.ring merger in Austria

[39] Evaluation of the 2012 Hutchison/Orange merger in Austria

[40] Evaluation of the 2012 Hutchison/Orange merger in Austria

Regarding investment, several economic studies found that more concentrated markets are linked to higher investment per operator and argue that the relationship is non-linear, suggesting an inverted U-shaped relationship between investment and competition. Several studies have also found a positive link between concentration and network quality. To our knowledge, no empirical study to date has found that higher market concentration reduces operator investment.

Overall, the economic literature surveyed suggests that, depending on market structure, there can be a price-investment trade-off in allowing for a new entrant in mobile markets (i.e. a decrease in market concentration may lead to lower prices), but that it generally leads to lower investment, thus impacting coverage and quality of service.

Table 4: Findings on the impact of higher concentration on investment and network quality

Source: GSMA Intelligence

Study	Quality and Innovation	Investment	Scope
Motta, Tarantino (2017)	NA	Lower	Theoretical
Federico, Langus, Valletti (2018)	NA	Ambiguous	Theoretical
Julien, Lefouili (2018)	NA	Ambiguous	Theoretical
Genakos, Verboven, Valletti (2018)	NA	Higher per operator, inconclusive at market level	OECD countries 2002–2014
Bourreau, Jullien (2017)	NA	Higher	Theoretical
GSMA (2017)	Higher	NA	Austria 2012 merger
GSMA (2019)	Higher	'Inverted-U' at operator level	Latin America 2013–2016
Abate, Castells, Bahia (2020)	Higher	'Inverted-U'	29 European countries 2011–2018
Houghbonon and Jeanjean (2016)	NA	'Inverted-U' at operator level	110 operators 2005–2012
HSBC (2015)	NA	'Inverted-U' at operator level	66 markets 2003–2013

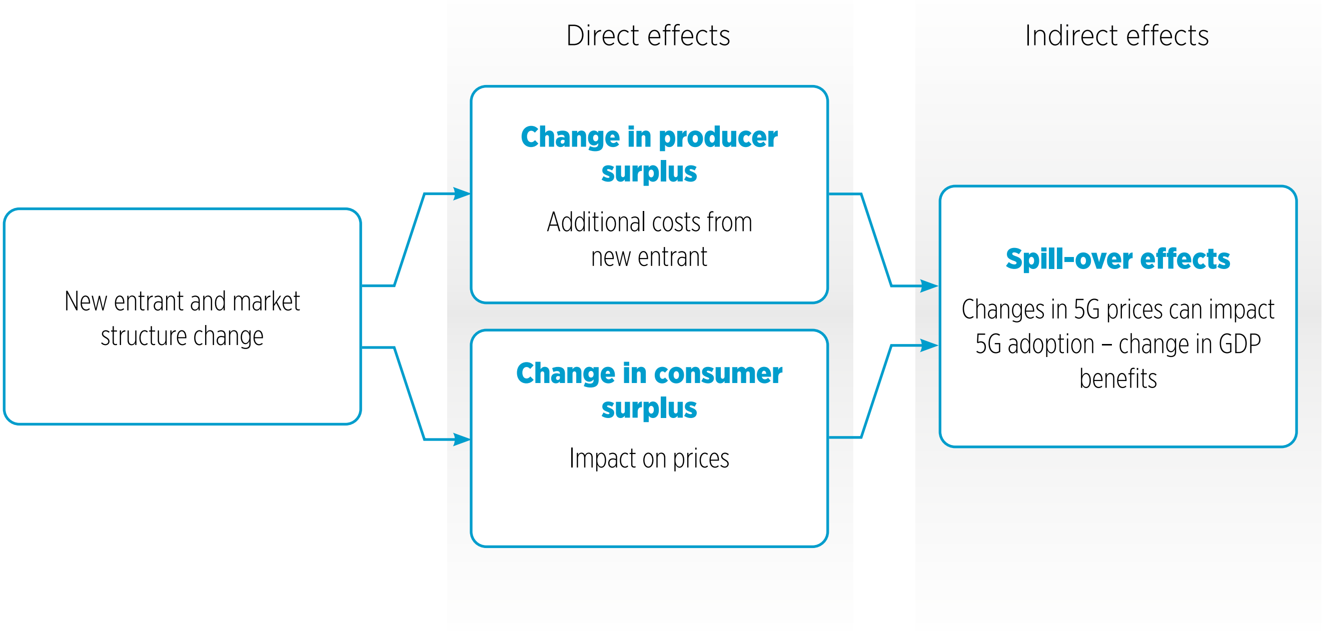
Proposed CBA approach

Figure 4 below presents a schema on the expected direct and indirect effects in terms of changes in PS, CS and spillover effects from setting aside spectrum for a new entrant. Depending on the structure of the market (i.e. the degree of concentration), setting aside spectrum for a new entrant could generate the following:

- A negative change in PS, since the new entrant would have to invest to set up their own network to service the part of the market they conquer, creating duplication in costs and thus lower market-level profit margins.
- A short-term change in CS, depending on the impact of the new entrant on mobile tariffs:[41]
  - In our example we assess the effects of entry when these generate a reduction in tariffs and no impacts on long-term investment incentives, other than the change in market-level costs.
  - However, appraisers should also consider the dynamic incentive for the new entrant to raise tariffs. The new entrant is expected to differentiate its tariffs in the short term to gain market share, and once it has achieved sufficient subscribers, it could raise prices to become profitable. If an appraiser considers that these incentives exist, the short-term positive change in CS would be counterbalanced by a negative change in CS,[42] so that the net impact on CS will depend on these two countervailing incentives.
  - Moreover, appraisers should also consider the dynamic effect on investment that has been identified by most studies to date. If the new entrant differentiates its tariffs to gain market share and incumbents follow suit, investment could be further impacted negatively since mobile operators set investment objectives according to revenues.
- An impact on the expected GDP benefits from 5G due to changes in 5G adoption since lower or higher tariffs would encourage or discourage some consumers to subscribe to 5G services[43].

Figure 4: Impact of setting aside spectrum for a new entrant in the 5G market

Source: GSMA Intelligence



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[41] To our knowledge, the economic literature has not identified any causal link between changes in concentration and ARPUs, focusing instead on headline mobile tariffs.

[42] Assuming 5G tariffs in case of entry can be higher than in the baseline.

[43] It should be noted that this reasoning applies to mobile technologies in general.

In practice, a sensible CBA approach could rely on the following strategy to estimate the costs and benefits of setting aside spectrum for a new entrant:

- Regarding the change in PS, the new entrant costs to set up a network to service its subscribers can be quantified:
    - The new entrant is expected to target an urban population and to partially build the network it needs to service the demand it faces while relying on other mechanisms, such as national roaming agreements, to service the rest[44].
    - Appraisers should also consider that the existing mobile operators would face lower costs in the case of market entry because part of the demand they would have serviced would be diverted to the new entrant. They would also incur higher unit costs than those they would have incurred in the case of no entry because of less spectrum being available to service traffic demand.
- Regarding the change in CS, a decrease in market concentration could cause a decrease in mobile tariffs, and appraisers can rely on an elasticity parameter taken from the relevant literature to quantify it:
    - However, they should consider that the new entrant would face higher rollout costs than existing operators and part of those costs could be passed on to consumers in the form of higher tariffs, so that the net impact on tariffs would depend on these two countervailing forces.
    - Also, practitioners should assess the relevant share of subscribers that would churn each year following a change in tariffs, as it is unlikely that the whole stock of subscribers would change plan each year.
- Regarding the change in spillover effects, an appraiser could assume that higher or lower tariffs would impact 5G adoption according to an assumption on the price elasticity of demand. The impact on adoption would then directly translate to higher or lower 5G benefits with respect to the baseline.

In our CBA template, appraisers should adapt the following assumptions to their market situation:

- the number of players in the market and the likely evolution of market share of the new entrant over 10 years
- the cost structure for the new entrant and the share of sites needed to service its demand that are expected to be deployed
- the expected 5G tariffs and the expected impact of changes in the Herfindahl–Hirschman Index on 5G tariffs
- the share of subscribers that are expected to change mobile plan each year
- the share of cost increases or decreases that would be passed on to consumers in the form of higher or lower prices as well as the price elasticity of demand.

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[44] One can expect that in markets with several players, new entrants are less likely to build their own infrastructure, while in concentrated markets, new entrants are more likely to build their own infrastructure. Under our central assumptions, we assume that the share of sites that would be built to service demand by the new entrant is inversely proportional to the number of players in the market.

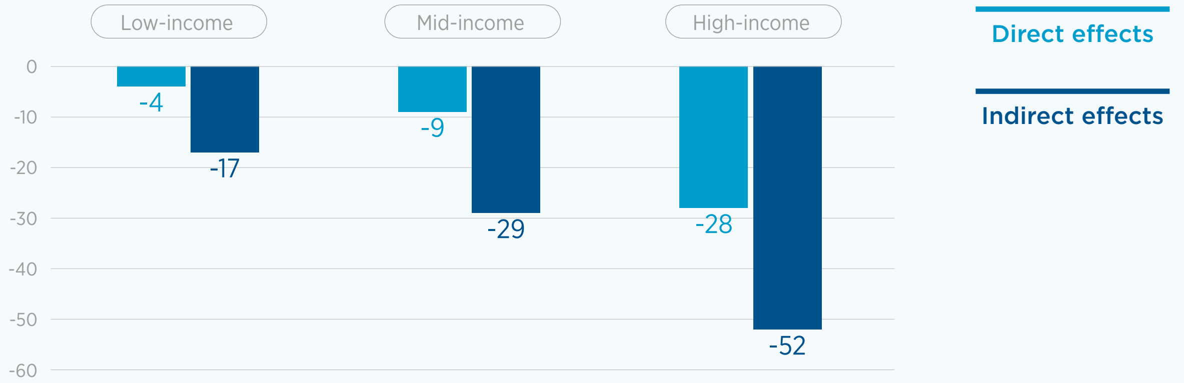
Illustrative results

Assuming a new entrant (or fourth player) gains 10% market share in 10 years in a three-player market and builds 25% of the network required while relying on national roaming agreements for the rest,[45] reserving 100 MHz out of 400 MHz in the 3.5 GHz band for a new entrant in the 5G market would have a net negative impact on society in the three hypothetical countries we study, with the short-term decrease in mobile tariffs due to increased competition counterbalanced by an increase in tariffs due to higher network-wide rollout costs with respect to the baseline situation. Figure 5 presents the results.

According to the quality degradation estimation, the direct effect of reserving 100 MHz for a new entrant in terms of changes in CS and PS would be a respective decrease of $4, $9 and $28 per capita for low-, mid- and high-income countries, and the indirect effect would be a decrease of $17, $29 and $52 per capita, depending on the country. It should be noted that these results are based on the assumption that the new entrant would not build a new national network and would rather rely extensively on network sharing. Assuming the new entrant would build a new national network would increase the net negative impact on society.

Figure 5: **10-year NPV of net impact of reserving 100 MHz in the 3.5 GHz band for a new entrant (USD per capita) – central assumptions**

Source: GSMA Intelligence (see Annex 1: Technical annex)

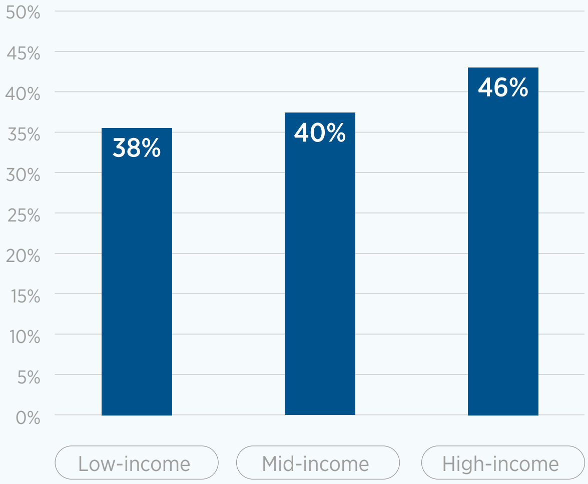


The results above are mainly driven by central assumptions, so the net impact will depend on each market situation and its expected developments in the next 10 years. Figure 6 presents the approximate implied 5G tariffs reduction, holding everything else constant, for a set-aside of 100 MHz for a new entrant to have a net positive impact on society, according to the two estimation strategies highlighted above.

It shows that the entry of a new competitor would have to cause a reduction in 5G tariffs in 10 years of respectively 38%, 40% and 46% in the low-, mid- and high-income countries. This compares to an expected increase in tariffs following a merger in the order of 10% found for instance by Genakos, Verboven and Valletti (2018) and of between 10% and 17% found by DG COMP (2015) in the 2007 merger in the Netherlands.

Figure 6: **Implied 5G tariffs reduction in 10 years for the net impact of setting aside 100 MHz in the 3.5 GHz band to be positive**

Source: GSMA Intelligence (see Annex 1: Technical annex)



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[45] See Annex 1: Technical Annex for a detailed overview of our assumptions.

04

Conclusions

The main objective of this report is to provide guidance for the implementation of a CBA to quantify the impact of spectrum assignment options as part of a broader RIA best practice, illustrated by two examples of current trending non-market oriented approaches around the globe.

Since spectrum assignment policies have measurable benefits and costs, governments and regulators should always carry out a cost-benefit impact assessment before making spectrum assignment decisions.

To facilitate the application of CBAs, we illustrate the theory in practice with two examples that consider spectrum assignment questions that some regulators are currently facing or might face in the context of 5G:

- Should set-asides for local users be made in prime 5G bands?
- Are set-asides for new entrants justified?

We find that setting aside 100 MHz of mid-band spectrum for local use licences or for a new entrant in the 5G services market would have a net negative impact on society. Based on three illustrative country profiles for low-, mid- and high-income countries, consumers and producers would be worse off by up to \$92 per capita and the broader economy could forgo up to \$52 per capita in terms of lower socio-economic benefits associated with 5G.

Overall, and based on these examples, it is clear that the conditions needed to deviate from market-based assignments are not generally met according to typical circumstances of low-, mid- and high-income countries. Despite this, under particular circumstances it is possible that regulators in some markets consider that a deviation from a market-based approach could be justified. In those cases, we recommend policymakers to take the following steps:

- **Develop an RIA** and follow RIA best practice to determine the reasons that could justify deviations from market-based allocations and identify potential policy alternatives.
- **Carry out an *ex-ante* CBA** to explore the net impact on society of different policy alternatives, to identify the option that maximises benefits at least cost.
- **Monitor market developments** to ensure that the chosen policy is delivering its expected outcomes.
- **Be prepared to intervene** whenever the chosen policy is not delivering its expected outcomes.

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Annex 1:
Technical annex

Table A1 presents the assumed demographic profile of the three policy examples in three hypothetical countries (low-, mid- and high-income) over the period 2021–2031.

Table A1: Demographic assumptions

Source: GSMA Intelligence (illustrative)

Population assumptions - 2021

Country	Total population	Urban % of total population	Urban population CAGR (%)	Total population CAGR (%)
Low-income	200,000,000	40%	2.3%	1.0%
Mid-income	200,000,000	60%	1.0%	0.5%
High-income	200,000,000	80%	0.7%	0.3%

Table A2 presents the assumptions on GDP per capita and its growth in the 10-year period.

Table A2: GDP assumptions

Source: GSMA Intelligence (illustrative)

GDP and discounting assumptions

Country	Real GDP per capita - USD 2021	Real GDP growth
Low-income	7,000	2%
Mid-income	15,000	2%
High-income	60,000	2%

Impact on 5G networks

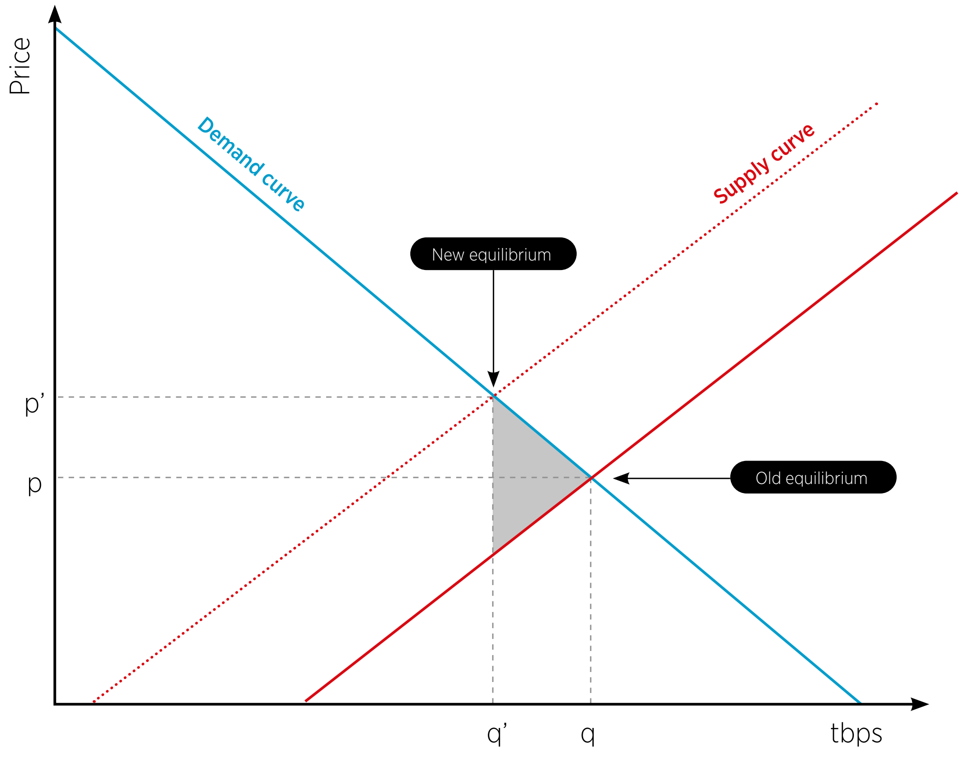
The CBA template estimates the impact on 5G networks of the three policies presented above on the three countries according to two alternative quantification strategies:

- **Higher rollout cost estimation:** This estimates the change in PS, CS and GDP benefits from different spectrum assignment options assuming that 5G mobile networks are densified to meet traffic demand with less bandwidth, keeping quality of service constant.
- **Quality degradation estimation:** This estimates the change in CS and GDP benefits assuming operators would not densify their networks to meet traffic demand, so that reduced bandwidth would directly impact network performance (keeping the number of users served constant) and the maximum number of users that can be served (keeping network performance constant).

Figure A1 presents a stylised representation of the impact that the two approaches aim to estimate. Whenever less spectrum is made available to 5G networks, this creates an upward shift of the supply curve, increasing prices and reducing traffic capacity supply, thus reducing speeds. The red triangle in the middle is the associated welfare loss.

Figure A1: Stylised impact of less spectrum on 5G network stakeholders

Source: GSMA Intelligence

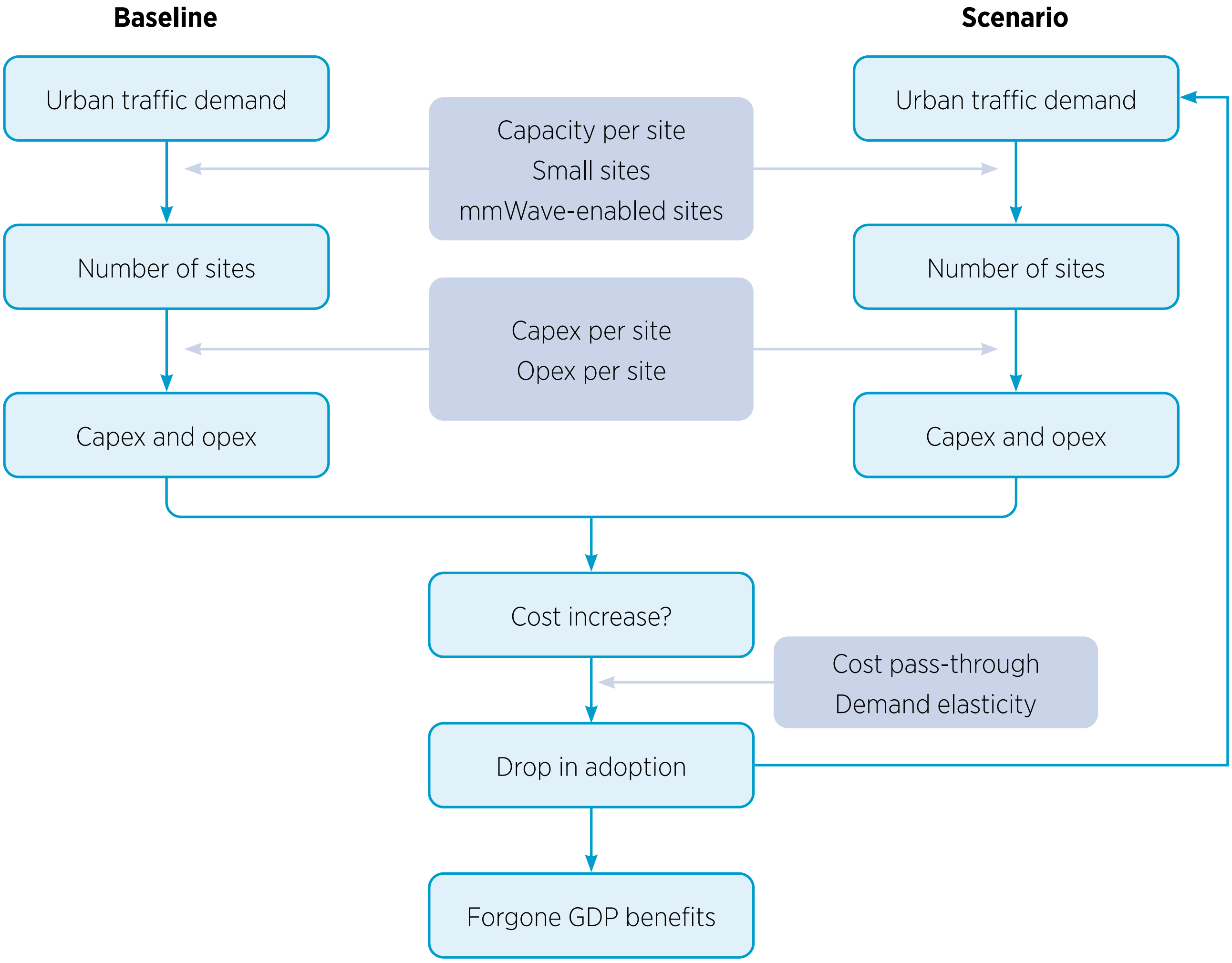


Higher rollout cost estimation

Figure A2 presents a schema of the higher rollout cost estimation approach. The starting point is the estimation of 5G traffic demand in urban areas. Assuming operators would meet the part of 5G traffic demand that is not expected to be offloaded to Wi-Fi, and based on technical assumptions that allow downlink (DL) and uplink (UL) capacity per site to be determined, the number of sites needed to meet traffic demand is estimated in the baseline and in the scenario. Cost assumptions on capex and opex allow the total cost of ownership (TCO) of the two simulated 5G networks to be determined. The CBA template compares the TCO of the two. If there is a cost increase (or decrease) in the scenario with respect to the baseline, part of the cost increase (or decrease) is passed on to consumers in the form of higher prices. An assumption on the elasticity of demand allows the drop (or gain) in 5G penetration in the scenario with respect to the baseline to be determined. This drop in 5G penetration is then fed back to the traffic demand estimation, and the model determines iteratively the numerical equilibrium. The drop in adoption in the scenario is then compared to the baseline 5G penetration to determine the GDP benefits that would be forgone (or gained) in the scenario with respect to the baseline.

Figure A2: **Impact on 5G networks: higher rollout costs approach**

Source: GSMA Intelligence



Traffic demand estimation

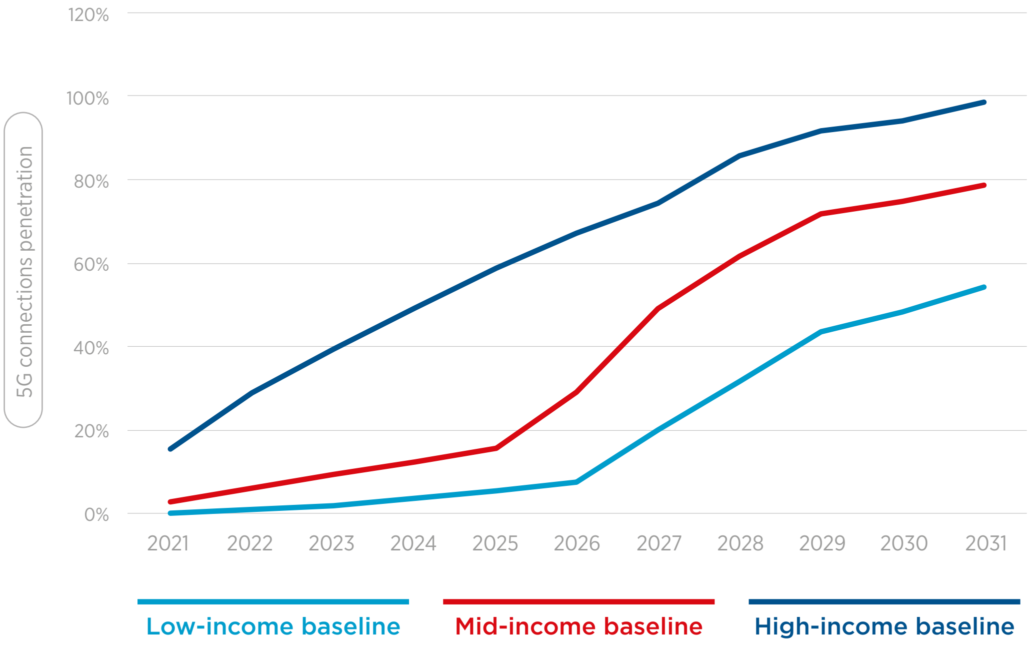
Traffic demand in urban areas is estimated according to assumptions on:

- the share of urban population over total population and its growth over the period
- 5G connections penetration and its evolution over the period
- the minimum UL and DL performance requirements per connection that will be enabled by the 5G networks
- the share of users that are connected to the network at peak and on the share of connected users that are actively using the network at peak, including their growth rate over the period
- the share of traffic that is offloaded to Wi-Fi
- the market share of incumbent operators[46] over the period.

Figure A3 presents the baseline 5G penetration forecasts by country for the period.

Figure A3: **5G connections penetration forecast in the baseline**

Source: GSMA Intelligence (illustrative)



We assume that the 5G networks will have to meet the ITU minimum performance requirements of at least 100 mbps DL and 50mbps UL everywhere.[47] At the beginning of the period, we assume the share of connected users would be 20% and the share of connected users would be 10% in all countries,[48] and we assume they would reach 41% and 20% respectively at the end of the period.[49] Finally, we assume that the share of traffic demand that would be offloaded to Wi-Fi would be 71%.[50]

We use the following equation to determine traffic demand in the downlink and in the uplink:

*Traffic demand =urban population*performance requirement*share of connected users*share of connected users that are active*5G penetration*(1-offload to WiFi)*market share of incumbent operators*

---

[46] This is relevant only for the set-asides for a new entrant scenario. See the dedicated section below for more details.

[47] Report ITU-R M.2410-0, Minimum requirements related to technical performance for IMT-2020 radio interface(s), ITU, 2017

[48] Oughton and Frias (2019) (based on an overbooking factor of 50)

[49] Based on an illustrative assumption that average traffic per user will increase fourfold by the end of the period.

[50] Cisco Visual Networking Index, 2019 update

Number of sites estimation

The estimation on the number of sites required to meet traffic demand in the baseline and in the scenario depends on several factors:

- per-site DL and UL capacity, depending on spectrum assignments and technical assumptions
- the share of small cells to total macro cells
- the share of mmWave-enabled small cells to non-mmWave-enabled small cells
- the share of mmWave-enabled macro cells to non-mmWave-enabled macro cells

For each policy example, we assume the following spectrum assignments, as shown in Table A3.

Table A3: Spectrum assignments

Source: GSMA Intelligence (illustrative)

Spectrum assignments to mobile networks (MHz)

Band	Low-income		Mid-income		High-income	
	Baseline	Scenario	Baseline	Scenario	Baseline	Scenario
Low band	150	150	190	190	190	190
Lower mid-band	450	450	460	460	460	460
Upper mid-band	1100	1000	1100	1000	1100	1000
High-band	1200	1200	1600	1600	2400	2400

We take the following technical assumptions by spectrum band to determine per-site capacity, as shown in Table A4.

Table A4: Technical assumptions

Source: GSMA Intelligence (illustrative)

Technical assumptions

Band	Duplexing	Spectral efficiency				Small cells?	DL:UL ratio	Sectors	
		DL		UL					
		Macro	Small	Macro	Small			Macro	Small
Low band	FDD	1.8	0	1.8	0	No	0.5	3	1
Lower mid-band	TDD	2.2	0	2.5	0	No	0.75	3	1
Upper mid-band	TDD	6	3.7	4.1	2.6	Yes	0.75	3	1
High-band	TDD	6	3.7	4.1	2.6	Yes	0.75	3	1

The number of sites needed to meet traffic demand each year is determined by solving the system of four equations in four unknowns below, both for DL and UL traffic demand:

1. # of mmWave enabled small sites+

   # of non mmWave enabled small sites=% of small sites over macro sites*

   (# of mmWave enabled macro sites+# of non-mmWave enabled macro sites)
2. # of mmWave enabled small sites=% of mmWave enabled small sites over non mmWave enabled small sites*

   # of non mmWave enabled small sites
3. # of mmWave enabled macro sites=% of mmWave enabled macro sites over non mmWave enabled macro sites*

   # of non mmWave enabled macro sites
4. # of mmWave enabled small sites*capacity of mmWave enabled small sites +

   # of non mmWave enabled small sites*capacity of non mmWave enabled small sites+

   # of mmWave enabled macro sites*capacity of mmWave enabled macro sites+

   # of non mmWave enabled macro sites*capacity of non mmWave enabled macro sites=traffic demand

The central assumptions are:

- the share of small sites over macro sites is 10%, 20% and 50% in the low-, mid- and high-income countries respectively[51]
- the share of mmWave -small sites over non-mmWave-enabled small sites is respectively 30%, 30% and 20%
- the share of mmWave-enabled macro sites over non-mmWave-enabled macro sites is respectively 30%, 30% and 20%[52]
- mmWave-enabled sites would be available in 2025, 2023 and 2022 respectively[53]

The final number of sites is then determined as the maximum of the number of sites required to meet DL traffic demand and the number of sites required to meet UL traffic demand.

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[51] Illustrative

[52] The shares of mmWave-enabled sites are based on an assumption that mmWave bands will carry approximately 30% of traffic demand in 2025 (IMT demand in the 6 GHz band, Coleago, 2021)

[53] Illustrative

Cost estimation

Table A5 presents the central capex and opex assumptions.

Table A5: Cost assumptions

Cost assumptions (USD)				
Country	**Macro / small**	**No mmWave / mmWave**	**Capex**	**Opex**
Low-income	Macro	No mmWave	135,000	53,000
Low-income	Macro	mmWave-enabled	150,000	53,000
Low-income	Small	No mmWave	17,000	7,400
Low-income	Small	mmWave-enabled	19,000	7,400
Mid-income	Macro	No mmWave	135,000	53,000
Mid-income	Macro	mmWave-enabled	150,000	53,000
Mid-income	Small	No mmWave	17,000	7,400
Mid-income	Small	mmWave-enabled	19,000	7,400
High-income	Macro	No mmWave	135,000	53,000
High-income	Macro	mmWave-enabled	150,000	53,000
High-income	Small	No mmWave	17,000	7,400
High-income	Small	mmWave-enabled	19,000	7,400

Source: 5G Norma (http://www.it.uc3m.es/wnl/5gnorma/), GSMA Intelligence

The assumptions above on capex and opex allow the TCO of the 5G networks in the scenario and in the baseline to be determined. The difference in the NPV[54] of the two TCOs times the cost pass-through assumption corresponds to the loss or gain in PS and the loss or gain in CS.

Impact on scenario adoption

Our CBA template assumes that an eventual cost increase (or decrease) in the scenario with respect to the baseline would be passed on to consumers in the form of higher prices, through an assumption on the pass-through rate.[55] Once the price increase (or decrease) due to the cost increase (or decrease) has been determined, an assumption on the price elasticity of demand[56] allows the number of subscribers that would delay their subscription to 5G services to be determined. The corresponding impact on 5G penetration is then fed back to the traffic demand estimation, to take into account that lower 5G penetration translates to lower traffic demand and therefore lower costs.

5G GDP benefits

5G GDP benefits are calculated assuming that a 10 percentage point increase in 5G penetration translates to a GDP improvement of 0.2%, 0.15% and 0.08% in the low-, mid- and high-income countries respectively.[57] The gain or loss in 5G GDP benefits in the scenario with respect to the baseline is then computed as NPV of the difference in 5G GDP benefits.[58]

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[54] Using a social discount rate of 3.5% (The Green Book, HM Treasury, 2020)
[55] Assuming the pass-through rate would be 80% in the three countries (Mobile taxation studies, GSMA and EY, 2020).
[56] Assuming the price elasticity of demand is -0.9, -0.85 and -0.65 in the low-, mid- and high-income countries respectively (Mobile taxation studies, GSMA and EY, 2020)
[57] The Mobile Economy 2021, GSMA, 2021
[58] We use a social discount rate of 3.5% (The Green Book, HM Treasury, 2020)

Quality degradation estimation

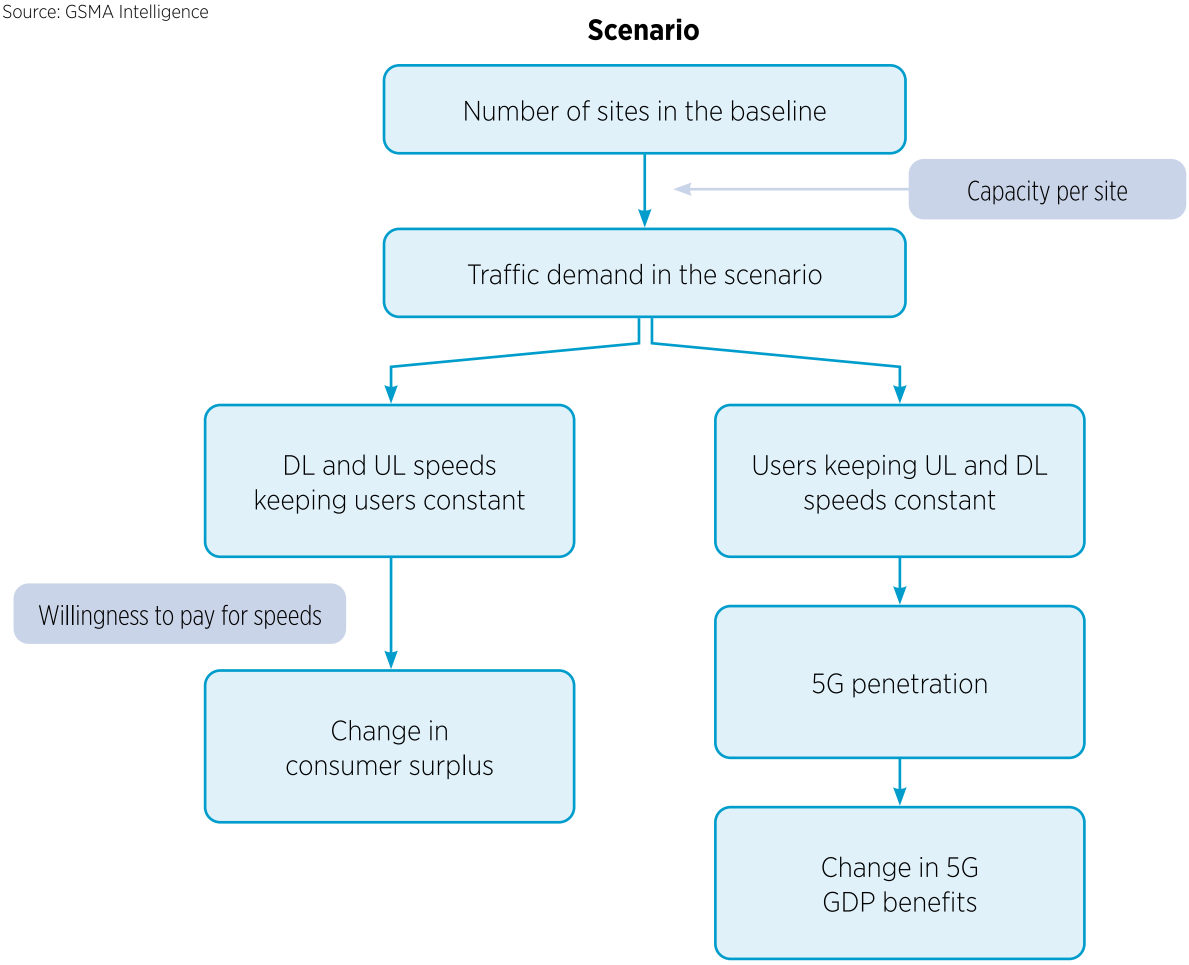
Figure A4 presents a schema of the quality degradation estimation approach. Assuming operators would not further densify their networks to meet UL and DL traffic demand due to lower per-site capacity (because of lower bandwidth availability), our CBA template determines the traffic capacity in the scenario by using the number of sites retrieved from the baseline and the per-site capacity in the scenario. This allows us to retrieve:

- the DL and UL speeds that would be enabled by the 5G network in the scenario, keeping the number of users constant
- the number of users that could be served in the scenario, keeping UL and DL speeds constant.

The difference in the consumer willingness to pay for DL speeds in the scenario versus the baseline corresponds to the change in CS. The difference in the number of users that could be served gives the difference in 5G penetration that is then linked to 5G GDP benefits.

Figure A4: Impact on 5G networks: quality degradation approach

Source: GSMA Intelligence



Consumers' willingness to pay for speeds each month is calculated according to the function 27.206*LN(DL speeds)+25.852.[59] [60] The change in CS is then computed as the difference in willingness to pay in the scenario versus the baseline, times urban population times 5G penetration in the scenario.

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[59] Usage-based pricing and demand for residential broadband, Econometrica, vol. 84, No.2 (March), 441-443, Nevo, A., Turner, J., and Williams, J., 2016; Assessing the Economic Value of Unlicensed Use in the 5.9 GHz and 6 GHz bands, Wi-Fi Alliance, 2020

[60] For the low- and mid-income countries, we adjust the corresponding willingness to pay according to the ratio of real GDP capita to real GDP per capita of the US (approximately $60,000, source: World Bank).

Impact of a new entrant in the 5G market

Figure A5 presents the estimation approach of the impact of setting aside 100 MHz out of 400 MHz in the 3.5 GHz band versus auctioning 400 MHz out of 400 MHz. Our CBA template calculates the net change in 5G tariffs due to the entry of a new competitor, the associated change in CS and change in 5G GDP benefits, through an assumption on the price elasticity of demand and the share of subscribers that change mobile plan each year.

Figure A5: **Impact of a new entrant in the 5G market**

Source: GSMA Intelligence

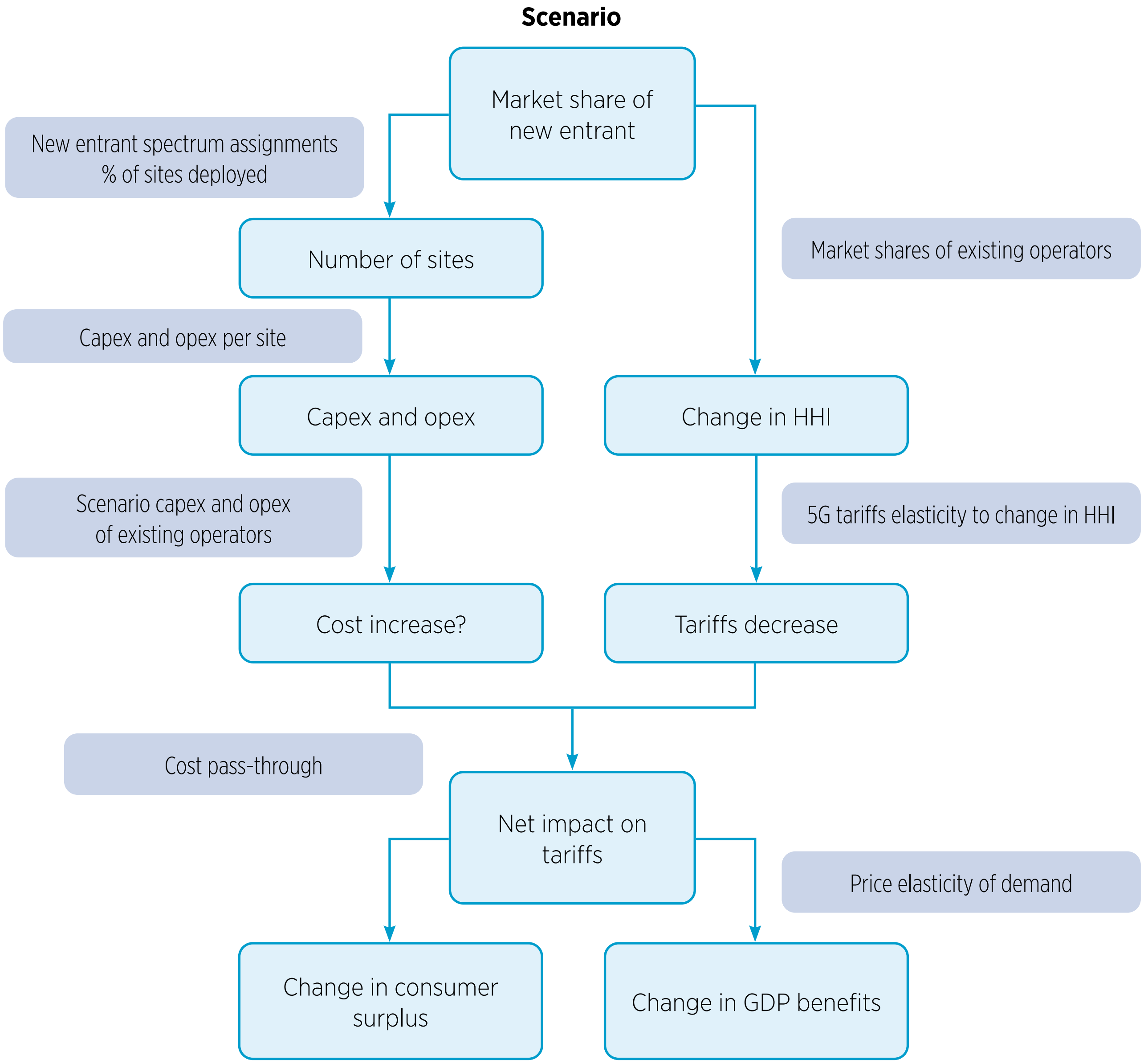
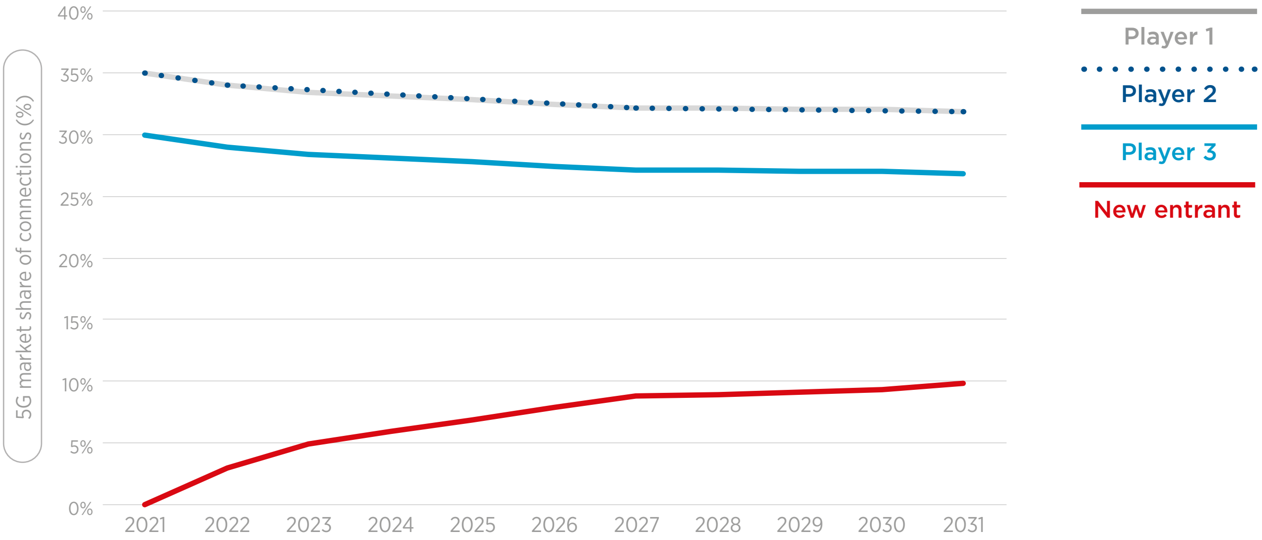


Figure A6 shows the assumption on the change in market structure. The baseline situation is made of three players and it is assumed that the new entrant will gain 10% of total expected 5G connections in 10 years, based on a typical scenario of mobile market entry observed in the past.[61]

Figure A6: Market structure assumption

Source: GSMA Intelligence (illustrative)



Based on the assumption above, our CBA template calculates:

- the percentage point change in the market Herfindahl–Hirschman Index and the corresponding change in 5G tariffs, according to an elasticity parameter[62]
- the new entrant's TCO, according to an assumption on the share of sites that the new entrant is expected to deploy[63] and the new entrant's capex and opex[64]
- the change in total rollout costs between the scenario and the baseline, that is the difference between the costs incurred by operators to deploy 5G networks in the case of no entry and in the case of entry[65]
- the change in 5G tariffs due to the change in total rollout costs, through an assumption on the pass-through rate[66]
- the change in the number of subscribers due to a change in 5G tariffs through a price elasticity of demand assumption, assuming only a given share of the subscriber stock changes plan each year[67] and thus experiences the change in 5G tariffs
- the change in 5G tariffs net of the impact of changes in market structure and the impact of changes in total rollout costs[68]
- the change in CS, multiplying the absolute change in tariffs[69] by the number of subscribers that change mobile plan each year
- the difference in scenario and baseline 5G GDP benefits,[70] which corresponds to the change in spillover effects.

The CBA template calculates direct and indirect effects through the price channel. As discussed in the main report, the evidence base also indicates potential negative impacts on investment and network quality from the introduction of a new player. These effects have not been quantified in this example. If an appraiser identifies these effects might be significant in a given market, they should be taken into account in the CBA analysis by adding these as additional cost elements.

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[61] Spectrum for new entrants, lessons learned, GSMA Intelligence, 2015
[62] We assume an elasticity parameter of 2.037 (Genakos, Verboven and Valletti (2019)).
[63] We assume the new entrant will deploy 25% of sites that will be needed to service the traffic demand it faces (illustrative, based on assuming the share of sites that will be deployed is inversely proportional to the number of players in the scenario).
[64] Assuming the new entrant faces the same cost structure of the existing operators.
[65] Rollout costs for existing operators are calculated according to the estimation strategy presented above.
[66] Assuming the pass-through rate would be 80% in the three countries (Mobile taxation studies, GSMA and EY, 2020).
[67] We assume 10% of the total stock of subscribers changes mobile plan each year (illustrative).
[68] That is, if the new entrant causes a decrease in tariffs of 5% and the increase in total rollout costs causes an increase in tariffs of 10%, the net impact on tariffs is an increase of 5%.
[69] We assume baseline 5G tariffs of $8, $10 and $15 in the low-, mid- and high-income countries respectively (illustrative)
[70] We assume a 10 percentage point increase in 5G penetration translates to a GDP improvement of 0.2%, 0.15% and 0.08% in the low-, mid- and high-income countries respectively. The difference in 5G benefits in the scenario versus the baseline gives the indirect opportunity cost or benefit.

Annex 2:
Higher rollout costs estimation results

Figure A7: **10-year NPV of net impact of setting aside 100 MHz of 3.5 GHz spectrum for industry verticals (USD per capita) – central assumptions – higher rollout costs estimation**

Source: GSMA Intelligence (see Annex 1: Technical annex)

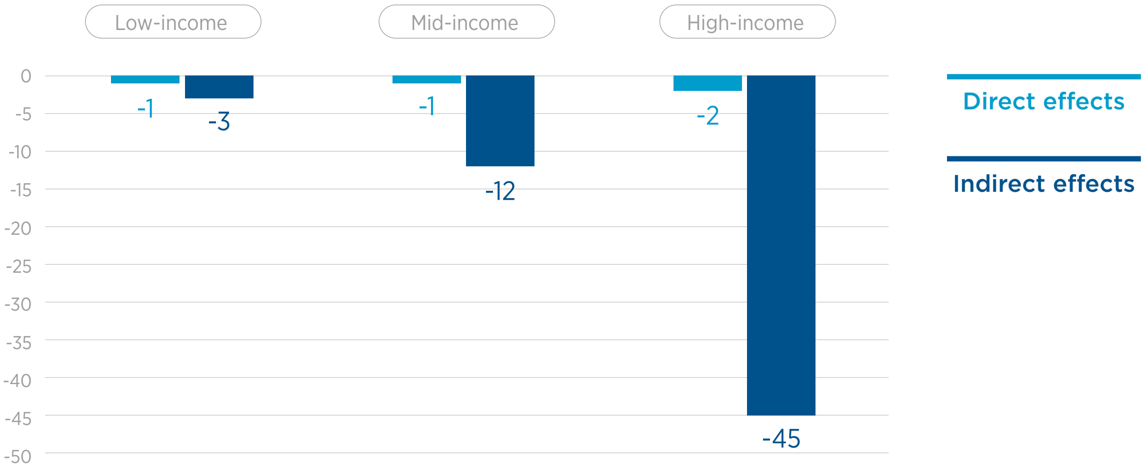
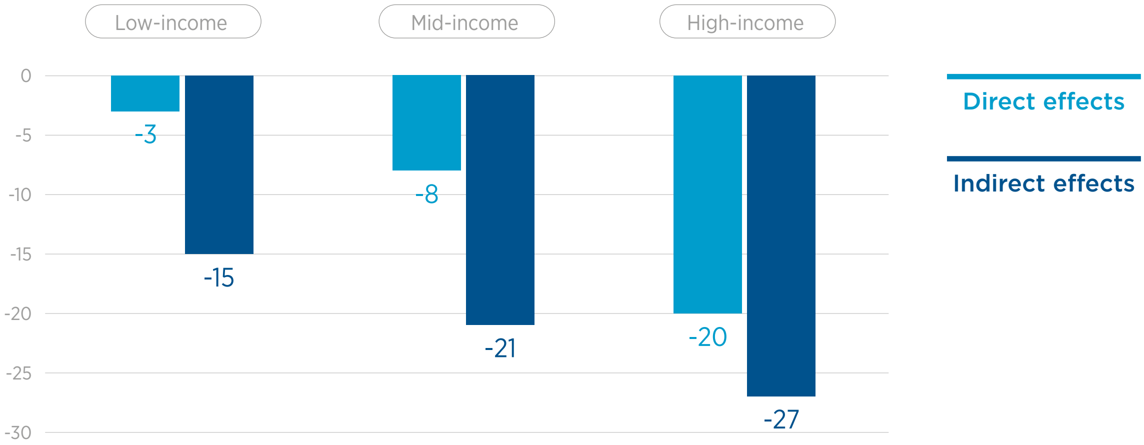


Figure A8: **10-year NPV of net impact of reserving 100 MHz in the 3.5 GHz band for a new entrant (USD per capita) – central assumptions – higher rollout costs estimation**

Source: GSMA Intelligence (see Annex 1: Technical annex)



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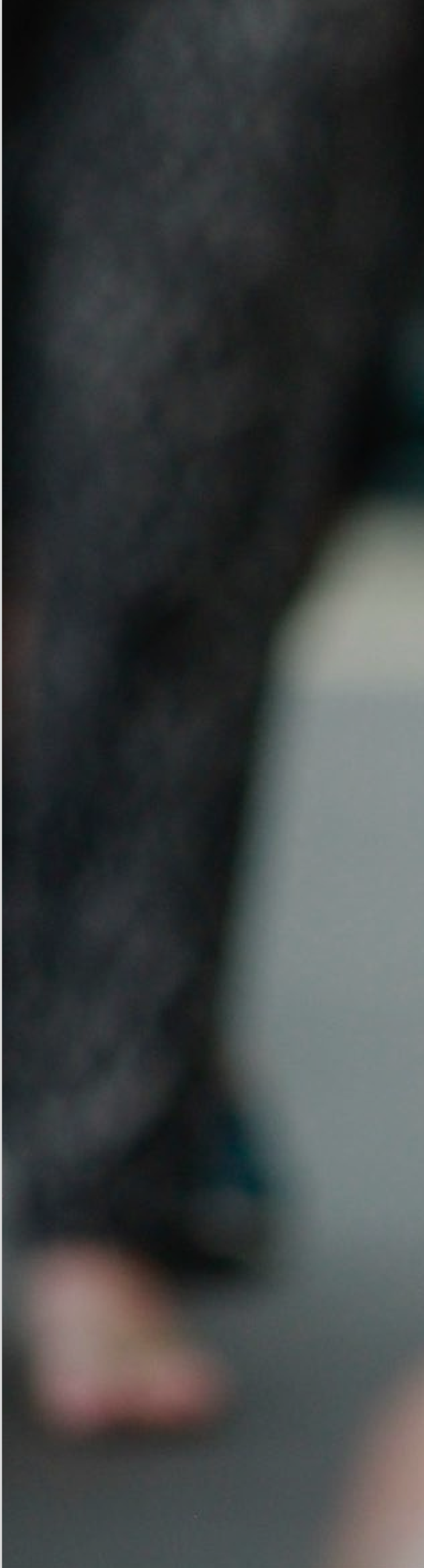

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