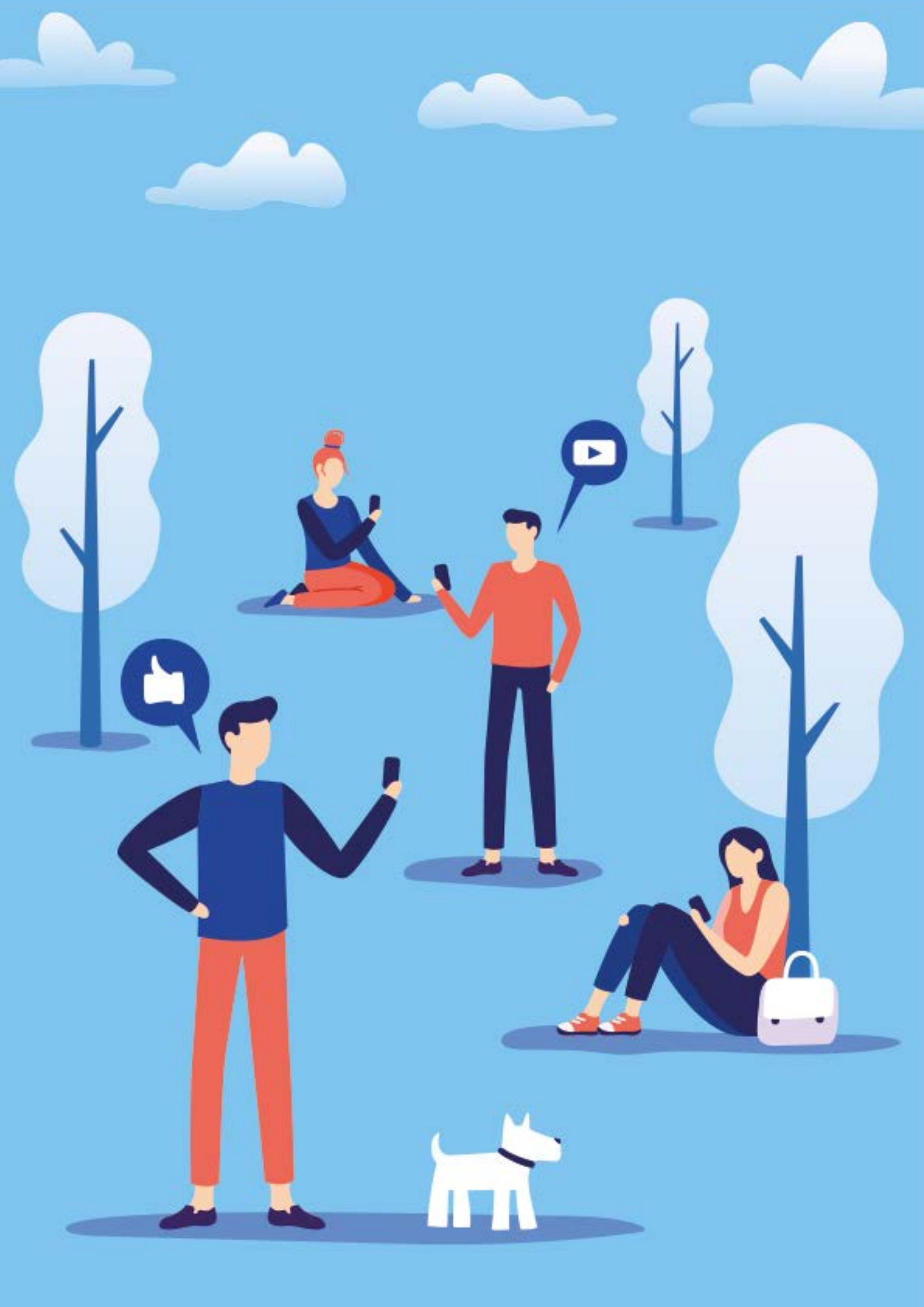
OXFORD ECONOMICS

HUAWEI

RESTRICTING COMPETITION IN 5G NETWORK EQUIPMENT THROUGHOUT EUROPE

AN ECONOMIC IMPACT STUDY

JUNE 2020



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EXECUTIVE SUMMARY

The next generation of mobile technology, 5G, offers enormous opportunities for countries who facilitate its widespread provision. During the global coronavirus crisis, telecoms networks have kept vital health, education and emergency services online, helped many businesses to smoothly shift to remote-working patterns and allowed friends and family to stay connected.

As social distancing has become the norm (in the short run, at least), digital infrastructure has played an ever-more important role in keeping the wheels of the economy turning. Furthermore, the faster connection speeds achieved using the 5G network, and the potential new-use cases for this technology, will be crucial in boosting productivity levels as countries seek to bounce back from financial collapse. Moreover, the act of 5G infrastructure building can provide a stimulus for recovery in the short term.

However, the recession associated with the coronavirus pandemic is set to delay its rollout, endangering the extent to which these opportunities can be realised. Slower economic growth and heightened uncertainty has led telecommunications operators to pullback on investment—an action that will inevitably slow the rollout of 5G.

€3 billion

Estimated additional annual cost of building 5G infrastructure across 31 European countries if competition is restricted, in our central cost scenario.

RESTRICTING COMPETITION IN THE 5G MARKET

In Europe as well as globally, the telecommunications network infrastructure market is dominated by three players: Ericsson, Huawei, and Nokia. These companies were largely responsible for the rollout of 4G networks via the deployment of mobile base stations which facilitate connections to mobile user devices.

However, the participation of one of these organisations—Huawei—in the rollout of 5G is likely to be constrained by a series of political decisions. The US and Australia have sought to restrict competition for further 5G infrastructure contracts. In several other markets, respective governments have indicated that they are either considering exclusion or have imposed partial restrictions. In May 2020, the UK initiated a fresh review of Huawei's participation in the UK telecoms market.[1]

The European Commission (EC) regulatory guidance on the issue does not make any direct references to Huawei but recommends that member countries should make their own decisions by balancing security implications against other economic and industrial priorities.

Economic theory suggests that restricting competition leads to higher prices—as such, it can be expected that restricting a large player from competing in the 5G network will lead to higher investment costs, delaying the speed of rollout. This, in turn, will result in slower technological growth and innovation, lower incomes for households, and slower recovery from the recession across the economy.

[1] The Financial Times. 2020. "UK draws up plans to restrict Chinese inward investment". The Financial Times, 24 May

ECONOMIC IMPACTS OF RESTRICTING 5G COMPETITION

In this context, Huawei commissioned Oxford Economics to assess the economic costs of restricting competition in 31 European countries.[2] To reflect the uncertainty inherent in such a process, we modelled three alternative scenarios termed "low cost", "central cost", and "high cost". All give results relative to our (post-coronavirus) baseline scenario, in which no competition restrictions are imposed on the 5G infrastructure market.

Under the central cost scenario, our modelling suggests that restricting a key supplier of 5G infrastructure in our 31 European countries **would increase total 5G investment costs by almost €3 billion per year on average** over the next decade, in 2020 prices. This represents an annual cost increase of 19%, which translates to €3 million per year in Iceland but as much as €479 million per year in Germany.

The associated restriction in competition for 5G infrastructure would lead to delays in the network rollout. Under the central cost scenario, we estimate that around **56 million fewer people across Europe would be covered by the 5G network in 2023**.

A delay in the rollout of 5G would also result in slower technological innovation and reduced economic growth. In our central cost scenario, this would result in reductions to national GDP in 2035 ranging from €13 million in Iceland to €7.3 billion in France. **The total GDP in 2035 lost in the 31 countries in our study is estimated to be €40 billion** in 2020 prices.

When interpreting these results, it is important to note that **we have not made allowance for costs that network operators would face if they were to need to replace existing equipment built by the restricted provider**. Such additional costs would further delay rollout and technological innovation resulting in higher productivity losses.

€40 billion

Estimated reduction in Europe's annual GDP in 2035 if competition is restricted (central scenario, 2020 prices).

Fig. 1: Total Europe-wide impacts of restricting a major participant in 5G network provision, under our three modelling scenarios

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€1.4 billion (9%)	€3.0 billion (19%)	€4.5 billion (29%)
Absolute number of people who will have delayed access to 5G by 2023	29 million (6%)	56 million (11%)	78 million (15%)
Estimated permanent loss in Gross Domestic Product (GDP) due to delay in 5G rollout in 2035	€12 billion	€40 billion	€85 billion

[2] In this study, we cover the following 31 countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom. In a previous report published in December 2019, we had covered France, Germany and the United Kingdom using the same methodology. The results for these three countries presented in this report differ from those presented in the previous study due to differences in 5G rollout forecasts and macroeconomic projections (particularly in light of coronavirus).

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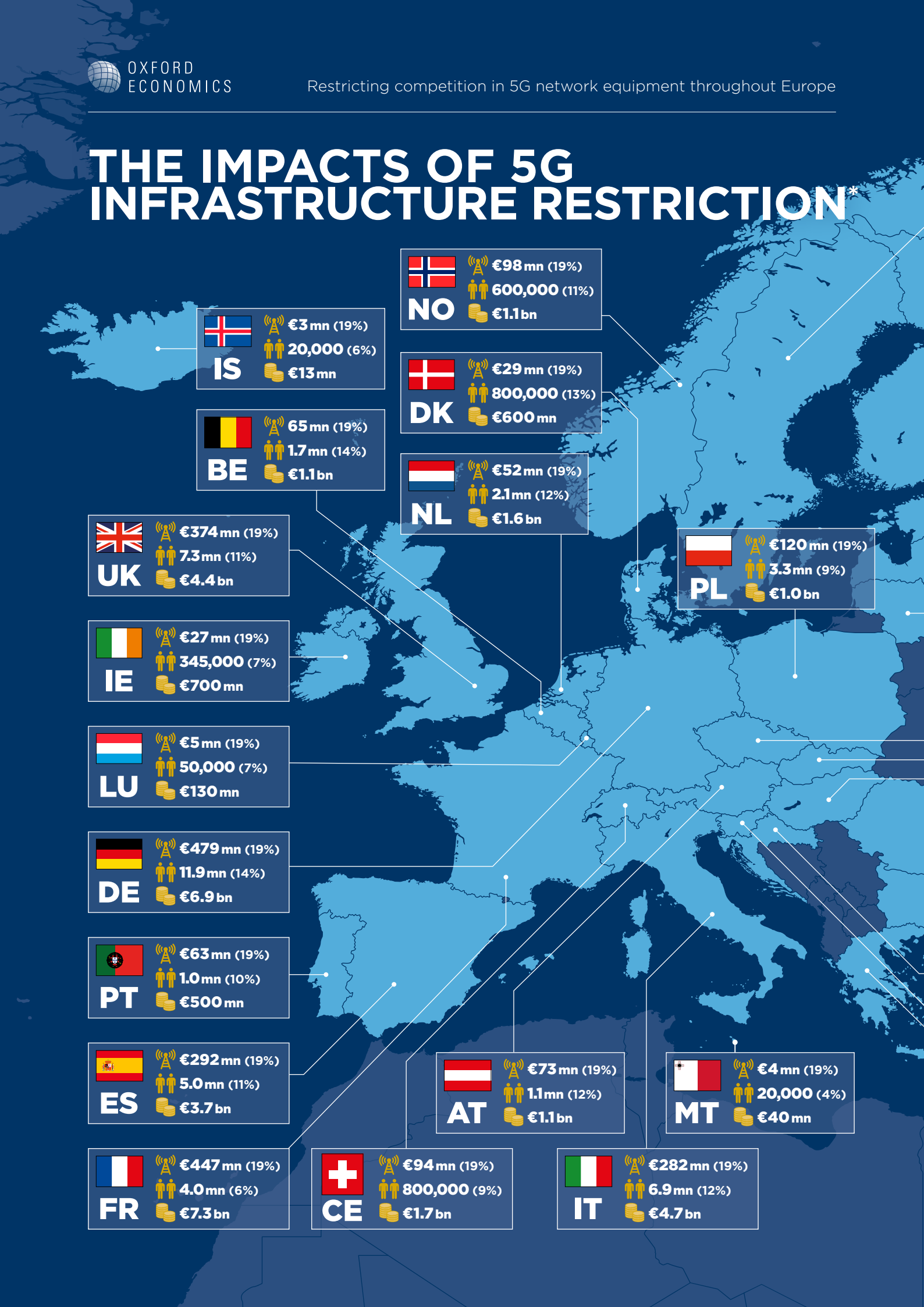
Restricting competition in 5G network equipment throughout Europe

THE IMPACTS OF 5G INFRASTRUCTURE RESTRICTION*



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SE
€64 mn (19%)
1.4 mn (13%)
€1.1 bn

FI
€79 mn (19%)
600,000 (11%)
€400 mn

EE
€10 mn (19%)
130,000 (10%)
€60 mn

LV
€8 mn (19%)
180,000 (10%)
€70 mn

LT
€8 mn (19%)
200,000 (9%)
€60 mn

CZ
€57 mn (19%)
1.2 mn (11%)
€400 mn

SK
€31 mn (19%)
200,000 (4%)
€200 mn

HU
€55 mn (19%)
500,000 (5%)
€300 mn

RO
€59 mn (19%)
2.4 mn (13%)
€80 mn

BG
€20 mn (19%)
700,000 (10%)
€100 mn

HR
€23 mn (19%)
200,000 (6%)
€80 mn

SI
€15 mn (19%)
120,000 (6%)
€150 mn

GR
€37 mn (19%)
800,000 (8%)
€600 mn

CY
€7 mn (19%)
38,000 (4%)
€40 mn

EU27
€2.4 bn (19%)
46.9 mn (11%)
€32.4 bn

TOTAL for all 31 countries

€3.0 bn (19%)

56 mn (11%)

€40 bn

Increase in average annual investment costs for 5G infrastructure over the next decade; € millions (%)

Absolute number of people that will have delayed access to 5G by 2023; number of people (% of population)

Estimated permanent loss in Gross Domestic Product (GDP) due to delay in 5G rollout in 2035; €

*Results for each country show the central cost 5G impact scenarios

1. THE 5G OPPORTUNITY

As the next generation of mobile wireless network technology, 5G will provide a better consumer experience and improve business performance through faster data transmission and more reliable connectivity. 5G will reduce the cost of mobile internet use, with prices expected to drop 10-fold per gigabyte of data, compared with current 4G mobile networks.

5G will also unlock new income streams for businesses in all sectors of the economy, and increase their productivity levels, through enhanced capabilities including higher data speeds, lower latency[3], and network slicing[4] (see Fig. 2).

As European economies emerge from the Coronavirus pandemic, the building of digital infrastructure, especially 5G networks, is expected to play a significant role in recovery from the recession. The construction of 5G networks will support jobs, and this spending on suppliers and employees is expected to have significant multiplier effects[5] across the wider economy. Should remote working become more common in the long run after restrictions are lifted, the connectivity provided by 5G networks will help boost productivity levels beyond the new-use cases that 5G is likely to enable, and which are discussed below and in Fig. 3.

Businesses are preparing for millions of new wireless devices—from smartwatches and other wearable items to sensors embedded in industrial products—to be connected to the next generation of 5G mobile networks. These devices, which together constitute the Internet of Things (IoT), will not use a lot of data (a sensor built into a highway, for example, will need to send only small amounts of digital information across the network every couple of hours). But when combined, these hundreds of millions—potentially billions—of new sensors will require almost universal connectivity, forcing operators to extend their networks to practically every corner of a country. Fig. 3 gives an indication of how 5G and the IoT will affect people and businesses across a wide range of activities.

Fig. 2: Summary of 5G's key benefits to businesses and consumers

Faster connection speeds	5G, characterised as Enhanced Mobile Broadband (eMBB), is expected to improve mobile internet use with higher speeds and seamless user experience in dense or high-mobility environments. It will support high-bandwidth services such as Augmented Reality (AR) and Virtual Reality (VR) apps.
Greater bandwidth for more devices	5G will enable Massive Machine-type Communications (mMTC). Put simply, it will enable the connection of a very large number of connected devices, which together comprise the Internet of Things.
Quicker response times	5G will also provide Ultra-reliable and Low Latency Communications (URLLC). Low latency means the response times for 5G will be much quicker than for previous generations of mobile technology, and that access to 5G will be far more reliable. This will allow the development of "mission critical" applications—for example, in transport (vehicle-to-vehicle communications), healthcare (remote monitoring), and logistics (drone delivery).

Source: Ofcom, Oxford Economics

[3] Latency is the amount of time between a command and its corresponding action over the internet.
[4] Network slicing allows the physical infrastructure to be split into several virtual networks that can be tailored to different end-users, thereby facilitating dedicated disruption-free networks for critical users such as health and transport services that are free from disruption from other consumer and business uses.
[5] The multiplier effect comes about because the money paid to suppliers and employees will be create demand for other goods and services in the wider economy, which in turn will stimulate further rounds of spending. The eventual final effect on employment and output could be bigger than the initial spending on infrastructure.

Fig. 3: Examples of 5G and IoT applications by sector

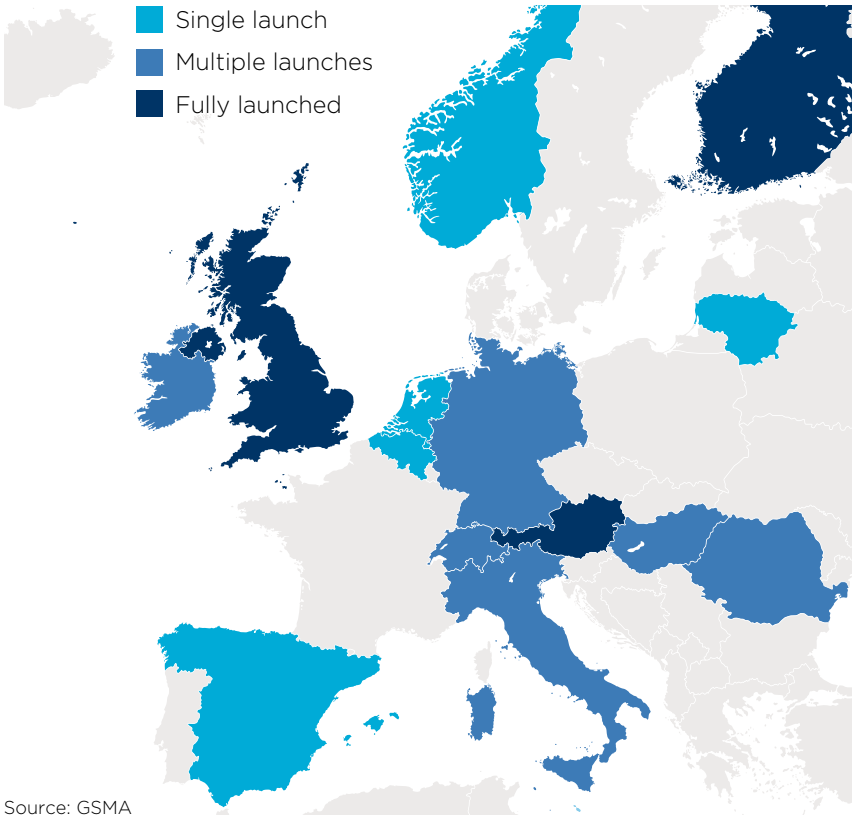
Sector	Examples of applications
Health and social care	IoT enables remote health monitoring, creating timely alerts for patients, nurses, or carers.
Automotive	Connected smart cars for tracking mechanical diagnostics, autonomous vehicles (e.g., driverless cars), locations, and media streaming.
Smart cities	Optimisation of street lighting, monitoring of parking, rubbish collection timing, and environmental monitoring.
Utilities	Smart meters and smart thermostats allowing for more accurate billing and better control of energy consumption.
Manufacturing	Digitisation and automation of production lines, and remote control of industrial processes.
Logistics	Connected containers to record and share the item's location and temperature to streamline production and reduce the risk of damage to temperature-sensitive produce.

Source: Ofcom, Oxford Economics

1.1 5G ROLLOUT IN EUROPE

Amid hype and high expectations, the 5G rollout has begun. Before the onset of coronavirus, GSMA[6] had forecast that there would be 1.2 billion 5G mobile users globally by 2025, with network coverage extending to roughly a third of the planet's population.[7] Due to the restrictions in response to the pandemic, the rollout of 5G services is expected to be delayed in the short run. GSMA expects that 5G connections in 2020 will be 25% lower than the levels planned before the onset of the coronavirus.[8]

Fig. 4: 5G rollout in Europe as of May 2020



Source: GSMA

[6] The GSM Association (commonly referred to as 'the GSMA' or Global System for Mobile Communications, originally *Groupe Spécial Mobile*) is an industry organisation that represents the interests of the mobile network operators worldwide.
[7] GSMA. 2018. The Mobile Economy 2018
[8] Mobile World Live. Intelligence Brief: How will Covid-19 impact 5G?

The European Commission (EC) established a Public Private Partnership on 5G (5G PPP) in 2013 to accelerate research and innovation in 5G technology. The EC had earmarked public funding of €700 million through its Horizon 2020 Programme to support the development and deployment of 5G in Europe. EU industry was expected to amplify this investment by up to five times, to more than €3 billion. These activities have been accompanied by an international plan to ensure a standardised implementation of 5G.[9]

Fig. 4 offers a snapshot of 5G networks as of October 2019. Multiple operators have launched services in Austria, Finland, Germany, Hungary, Italy, Ireland, Romania, Switzerland and the United Kingdom. The first operators have also switched on their 5G networks in Belgium, Latvia, Norway, the Netherlands, and Spain.

Commercial 5G networks began going live in 2019, and the rate of new launches is expected to pick up in 2020, with an estimated $160 billion being invested each year in the construction of 5G networks globally.

However, concerns expressed about cyber security have led several countries to consider imposing restrictions on Chinese network providers from selling 5G network equipment to telecoms companies. In particular, as of June 2020, Huawei has been blocked from competing in any 5G provision tenders in the United States and Australia, despite the company stating that it has never engaged in industrial espionage, nor allowed its technology to be knowingly hacked by the Chinese state.[10]

Within Europe, the EU has introduced regulatory guidance that allows countries to balance the security risks from a vendor against other priorities—including the economic implications of restricting any vendor from participating in 5G network deployment. In July 2019, the Intelligence and Security Committee (ISC) of the UK Parliament issued an official statement on 5G suppliers that "limiting the field to just two [...] would increase over-dependence and reduce competition, resulting in less resilience and lower security standards".[11] More recently, in May 2020, the UK initiated a fresh review of Huawei's role in 5G deployment.[12]

1.2 THE IMPACT OF CORONAVIRUS ON 5G ROLLOUT

The restrictions put in place across Europe to tackle the spread of coronavirus and the associated delays in spectrum auctions have had a significant impact on 5G rollout plans. In the short-to-medium term, a number of European mobile network operators are expected to delay their investments in 5G networks. As of early April 2020, delays were already confirmed in a number of countries due to the coronavirus pandemic such as France and Portugal and potentially others[13]. Further, the shutdown of government offices has slowed the process of granting permits to mobile operators to build new cell sites. However, in the medium-to-long term, it is likely that this crisis will increase the appetite for digital solutions (such as remote medical check-ups) for services that traditionally required face-to-face interaction.

[9] Towards 5G. European Commission. https://ec.europa.eu/digital-single-market/en/towards-5g
[10] The Guardian. 2019. "Huawei boss: UK 'won't say no to us' over 5G rollout." The Guardian, 16 August.
[11] The Intelligence and Security Committee, UK Parliament. "Statement on 5G suppliers", 19 July 2019..
[12] The Financial Times. 2020. "UK draws up plans to restrict Chinese inward investment". The Financial Times, 24 May.
[13] The European Commission. 2020. "5G Observatory Quarterly Report 7". March 2020.

BOX 1: HOW 5G CAN BOOST RECOVERY FROM THE CORONAVIRUS CRISIS

In common with the rest of the world, Europe is currently experiencing a deep recession. At the time of writing, we are expecting a decline in real GDP this year of nearly 7.6% in the Eurozone, compared with a 2.8% contraction globally.

Deployment of the 5G network will play an important role in stimulating the region's economic recovery. The investment in network building will not only spur activity on-site, but also boost the economy through associated supply chain spending, and as a result of employees spending their wages in the wider consumer economy.

In addition to its significant economic benefits, 5G has the potential to bring quality-of-life benefits to both cities and rural communities. Cities are increasingly searching for ways to improve the quality of life for residents by enabling diverse economic activities, reducing environmental impacts, and providing enhanced services and amenities—all of which could be boosted by greater 5G provision.

Moreover, the coronavirus pandemic may well accelerate trends towards remote working and e-commerce. Such trends would place an even greater imperative on ensuring high quality network connectivity.

However, restricting a large player from competing in the 5G network at such a crucial time will lead to increased investment costs, delaying the speed of rollout which, in turn, will result in slower technological growth and innovation, and lower incomes for households and slower recovery from the recession across the economy.

1.3 THE ECONOMIC BENEFITS OF 5G

To date, only a small number of studies have attempted to estimate the macroeconomic impact of 5G around the world. The magnitude of the findings varies greatly across different studies, reflecting different underlying assumptions and methodological approaches taken.

Summarising these findings, 5G-enabled economic activity is forecast to contribute between US$1.4 trillion and US$13.2 trillion to global GDP by 2035. A 2018 study commissioned by GSMA put the total contribution of 5G value chain alone over the 2020–2034 period at $2.2 trillion—5.3% of total GDP growth during this period.

In a 2019 report, IHS Markit predicted that the global 5G value chain would generate a US$3.6 trillion contribution to GDP, and support 22.3 million jobs, by the year 2035. 5G will enable new market opportunities and may even profoundly change some industries. IHS Markit estimates that potential global sales of products and services enabled by 5G could reach $13.2 trillion in 2035 (5% global real output in 2035).

An EC study forecasting the qualitative and quantitative socio-economic benefits of 5G estimated that 5G deployment costs would have been approximately €56.6 billion in EU28 member states in 2020. Analysis focusing purely on the economic benefits of this investment spending suggests that 5G investment will lead to 'trickle-down' or multiplier effects with a value of €141 billion. These effects are likely to create 2.3 million jobs in EU28 Member States.[14]

[14] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. European Commission. 2016.

As previously discussed, various industries will use the improved capabilities of 5G to create new and enhanced products, which will produce a knock-on benefit to consumers and the wider economy. For example, the incorporation of 5G capabilities in vehicles will enable transport authorities to better monitor vehicular flow and manage traffic. An in-depth analysis of these benefits for four key sectors—automotive, healthcare, utilities, and transport—estimated that 5G is expected to generate benefits of €62.5 billion in these industries in 2025—of which 63% will arise for business, and 37% will be provided for consumers and society.[15]

Fig. 5: Estimates of 5G's contribution to GDP growth

Country	5G investment 2020 (€ millions)	Direct multiplier effect (€ millions)	Jobs associated with investment spending and associated multiplier effects
Austria	970	2,170	25,200
Belgium	1,230	3,150	36,300
Bulgaria	840	2,320	128,900
Croatia	480	1,540	64,400
Cyprus	100	470	20,800
Czech Rep.	1,200	3,990	143,000
Denmark	620	1,480	14,800
Estonia	150	560	13,600
Finland	600	1,501	19,900
France	7,030	17,110	224,700
Germany	9,280	20,740	211,100
Greece	1,220	2,180	101,300
Hungary	1,130	3,450	134,600
Ireland	490	1,210	10,700
Italy	6,830	15,700	186,830
Latvia	230	570	16,800
Lithuania	330	700	28,200
Luxembourg	60	122	600
Malta	50	190	3,900
Netherlands	1,870	5,030	68,300
Poland	4,350	13,040	569,553
Portugal	1,170	3,730	127,300
Romania	2,270	4,660	252,300
Slovakia	620	1,980	71,500
Slovenia	240	610	14,700
Spain	5,190	14,600	329,400
Sweden	1,060	2,450	25,300
UK	7,040	16,520	172,100
EU28	**56,640**	**141,840**	**2,394,800**

Source: European Commission (2016)

[15] Identification and quantification of key socio-economic data to support strategic planning for the introduction of 5G in Europe. European Commission. 2016.

2. HOW THE 5G INFRASTRUCTURE MARKET WORKS

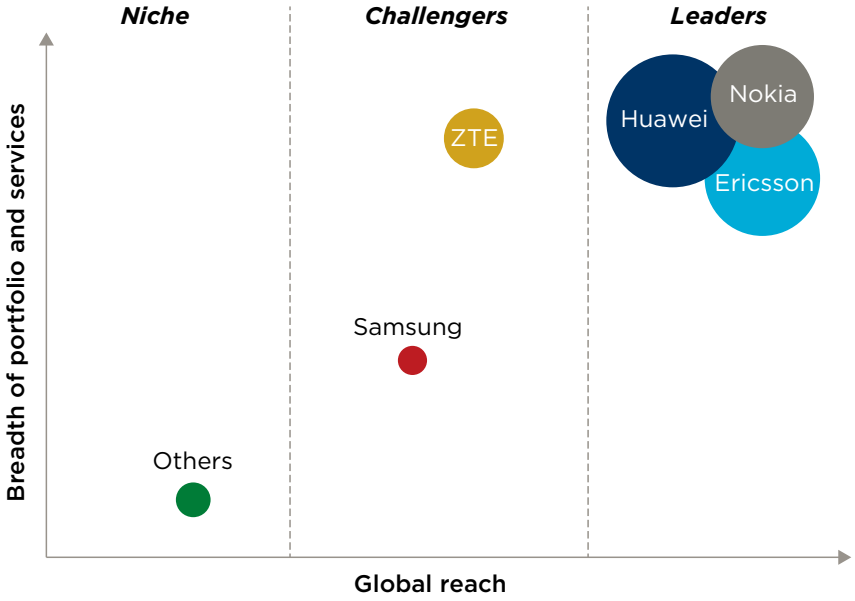
To understand the impact of restrictions on 5G equipment providers, it is important to understand the current market structure, and the nature of competition in this market.

The telecoms infrastructure underlying the 5G network consists predominantly of the Radio Access Network (RAN), which in turn consists mainly of mobile base stations that connect telecom networks wirelessly to mobile user devices.

2.1 WHO ARE THE KEY PLAYERS IN THE EUROPEAN MARKET?

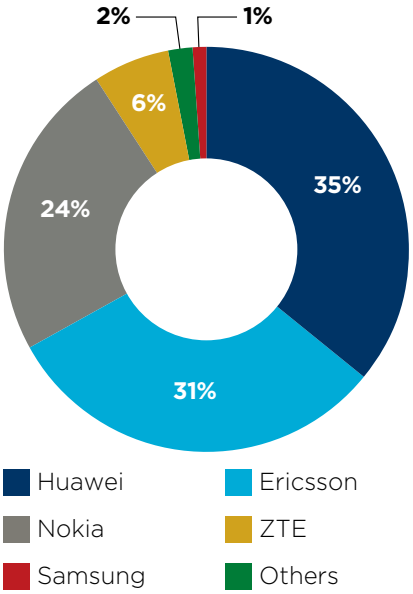
Ericsson (29% market share), Huawei (31%), and Nokia (23%) are the largest players in the global RAN market, across all generations of mobile technology. These three companies have the broadest product portfolios and widest global reach (see Fig. 6), as well as the strongest service support, and are expected to remain key global players as 5G becomes more prominent.

Fig. 6: Key players' European shares of RAN market and relative market positions, 2018



Source: Ovum, Oxford Economics

Fig. 7: Regional market shares in the RAN market, 2018



Source: Oxford Economics

While network providers are global players with a worldwide footprint, there are some differences in their regional market shares (see Fig. 7). Currently, Huawei has a small presence in North America, where Ericsson and Nokia dominate with a combined market share of close to 90%. On the other hand, ZTE has a small but significant presence in the Asia Pacific region, at the expense of Nokia and Ericsson. Despite these differences, responses to a 2015 EC review suggested that there are no obvious geographical barriers to the reach of the largest network providers.[16]

[16] *Nokia/Alcatel-Lucent Merger*. 2015. Case No COMP/M.7632 - REGULATION (EC) No 139/2004 Merger Procedure (European Commission, 24 July).

BOX 2: CROSS-COUNTRY DIFFERENCES IN THE 5G NETWORK MARKETS

In Europe, there are 45 network operators who provide mobile telecoms services across various national markets. Operators with cross-border presence must meet EU-wide regulatory requirements (if they operate in the EU) as well as those of the respective national markets.

The EU telecoms market is one of the most highly regulated in the world through the Framework Directive, Directive on Privacy and Electronic Communications, Directive on Network and Information Security (NIS), Cyber Security Act (CSA) certifications, European Electronic Communications Code (EECC), and Radio Equipment Directive (RED). National governments and telecoms authorities have taken steps to coordinate regulations. For example, EU member states set up the EU Toolbox for 5G Security to identify a coordinated European approach based on a common set of measures aimed at mitigating the main cybersecurity risks of 5G networks.

However, despite these measures, the differences in regulatory requirements across countries remains a major challenge for operators. For those that have cross-border interests, restrictions or additional regulatory requirements with respect to procurement of network equipment in one country may have an impact in all the countries they operate in. These cross-border effects could lead to the economic consequences of restricting competition in one market being felt more broadly outside its borders.

Given the uncertainty surrounding these effects, we have not included these in our estimates of the economic costs of competition restrictions in the 5G market.

2.2 THE 5G INFRASTRUCTURE TENDER PROCESS

Having declined over the last few years, the RAN market is expected to start growing again—driven by the rollout of 5G networks. In 2019, worldwide RAN sales was forecast at around US$31 billion, to which 5G equipment is expected to contribute roughly US$3.6 billion. The contribution of 5G is then expected to grow rapidly over the next decade as the contribution of 4G declines, resulting in total RAN sales exceeding US$35 billion by 2023.

Mobile network operators, such as EE and Vodafone in the UK, issue tenders to the network providers for building 5G networks. These tender processes are already under way in many countries, with the duration of such contract awards being around three years, on average.

Economic theory implies that a competitive tender will typically yield benefits for consumers, in terms of prices, quality of service, and technological innovation.

Across Europe, 5G services have been launched in 10 countries as of March 2020. However, the EU and the UK have introduced regulatory frameworks that could potentially exclude one of the vendors from participating the 5G network building process. The EU has not yet made any direct references to Huawei. The regulatory guidance indicates that these countries will have to balance the security implications against other economic and industrial priorities.

In the next chapter, we discuss the theoretical impact of restricting competition on the 5G network provision market, before going on to explain our three-stage modelling approach. Then in Chapter 4, we quantify the economic consequences of such a restriction across the 31 countries in our study, in terms of increased investment costs, delayed 5G rollout, and lost productivity.

3. HOW WE ASSESS THE IMPACT OF RESTRICTING 5G COMPETITION

The technological benefits of 5G are expected to be transformational, and potentially revolutionary. As the world prepares to roll out 5G, a healthy and competitive market will help to ensure that the network infrastructure is installed as efficiently, quickly, and cheaply as possible.

Economic theory suggests imposing restrictions on a major global provider such as Huawei would be expected to increase prices, which might in turn slow down 5G rollout. Furthermore, the quality of the infrastructure may be diminished, and productivity growth delayed and possibly lost.

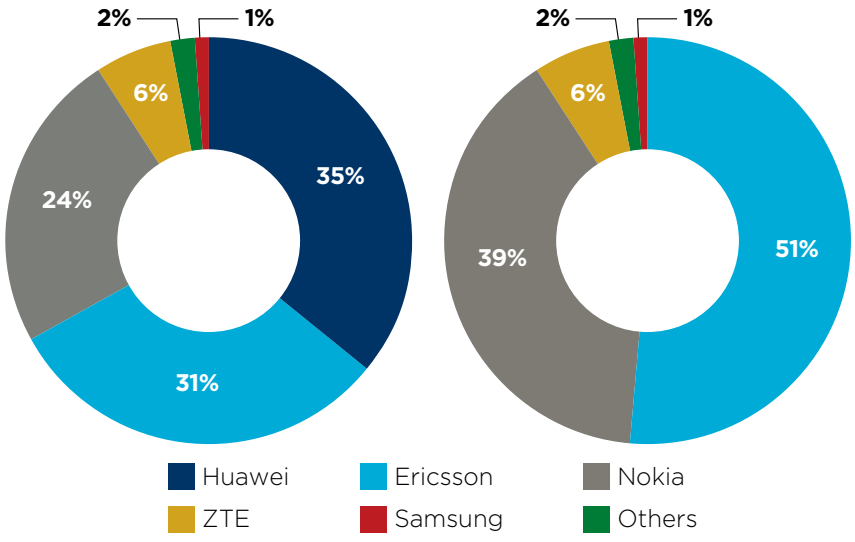
3.1 WHAT HAPPENS IF HUAWEI IS RESTRICTED FROM COMPETING?

For this study, we assume that if Huawei is restricted in each country's 5G infrastructure market, network operators in that market would switch to one of the two other large providers, Ericsson and Nokia, in proportion to their existing market shares. We believe that the other providers do not have the same global reach or breadth of products and services that would allow them to successfully compete for Huawei's customers, and therefore their market shares would remain unchanged.

We also assume that 5G network equipment market shares over the next decade in the baseline scenario (no restrictions on Huawei) will remain close to 4G market shares in 2018. In that year, Huawei had 29% of the global 4G market, while Ericsson and Nokia had 27% and 25% respectively of the global 4G market.

With Huawei blocked from the market, our assumption means that Ericsson and Nokia's market shares would increase to 42% and 39% respectively, while Samsung, ZTE, and the other operators would not see a change in their market shares (see Fig. 8).

Fig. 8: Worldwide market shares, with and without restrictions on Huawei (based on 2018 4G revenues)



Source: Oxford Economics

This results in an increase in concentration[17] in European markets. In our study, we focus on 31 technology markets in Europe.[18] Given the proximity and similarity of the markets, we use European market shares as the basis for our calculations.[19] Huawei has a significant market share in Europe and therefore, restrictions on Huawei in Europe will lead to a significant increase in concentration.

In this study, we only consider the economic impact due to increases in concentration and do not account for the loss of the technological know-how, experience and capabilities that are unique to Huawei or the potential additional transition costs related to moving from Huawei 4G equipment to a different vendor's 5G equipment. Huawei is among the leading spenders on R&D and is considered to have an advantage over its competitors due to its technological prowess.[20] Therefore, the rest of the modelling, described further in the following chapter, is more appropriately described as being based on the exclusion of a competitor of Huawei's size.

3.2 OUR THREE-STAGE MODELLING APPROACH

Reduced competition due to restrictions on Huawei can be expected to increase investment costs, slow down rollout and delay productivity improvements. Using Oxford Economics' world-leading Global Economic Model (GEM) and a host of other sophisticated industry and market structure models, we analysed the impact of a supplier of Huawei's size being restricted from each market's 5G network infrastructure, in terms of the projected increase in investment costs, delays in 5G rollout, and reduced national GDP levels. We used a three-stage modelling framework to assess the economic impact of restricting competition in the provision of 5G network equipment.

Stage 1: Impact on investment costs

To calculate the economic impact of restricting competition, we started by estimating the increase in mobile network operators' investment costs when a major infrastructure provider is restricted from the market. We did this using a range of techniques developed in collaboration with Dr Martin Pesendorfer from the London School of Economics.

The techniques used were:

- a **theoretical model of oligopoly** characterising the 5G network infrastructure market that simulates the change in price of network infrastructure associated with restrictions on competition;
- **merger simulation techniques** that are used by competition authorities to estimate the price impact following changes to the market structure e.g. following the completion of a merger; and
- **empirical evidence** from a range of studies across industries that estimated the change in price following a merger.

Given the worldwide nature of the network infrastructure market, we made some adjustments to standardise the price impacts across our 31 countries of interest.

[17] A concentrated market is one where a small number of firms account for large percentage of the total market. Concentration increases as the size of the market controlled by the small number of firms increases.
[18] In this study, we cover the following 31 countries: Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.
[19] Ideally, we would have used national market share data to tailor our analysis to the individual markets, but we had to use regional market shares as the corresponding national data was not available.
[20] Strategy Analytics. 2019. "Comparison and 2023 5G Global Market Potential for leading 5G RAN vendors - Ericsson, Huawei and Nokia."

Stage 2: Impact on rollout

We translated the increase in investment costs to delays in rollout using a network rollout model built in collaboration with Dr Edward Oughton (University of Oxford). This model translates an increase in investment costs to a reduction in the share of the population covered for each country and scenario by assuming that the overall operators' capex remains the same.

Our baseline—i.e. with no competition restrictions—forecasts for 5G rollout and capital expenditure were sourced from GSMA. Based on this, we calculated the average investment expenditure required to extend 5G coverage on a per person basis. The increase in investment costs due to restricted competition, as estimated in Stage 1, was used as an input into the rollout model. Assuming that nominal investment remains unchanged, the higher cost of rollout results in lower coverage.

Stage 3: Impact on productivity and macroeconomic growth

The increase in investment costs and delays in rollout were translated into lower productivity growth using estimates of the productivity benefits of 5G from various academic and industry studies. The lower productivity growth is partly due to the increase in the costs of building the 5G network and partly due to the reduced investment in 5G and related services due to delays in rollout.

These were then fed into the Oxford Economics Global Economic Model to estimate the impact on a range of macroeconomic indicators such as GDP and household consumer spending.

3.3 TRANSMISSION MECHANISM OF COMPETITION RESTRICTIONS

There are a large number of ways through which restrictions on competition in the network infrastructure market results in loss in productivity and GDP. Fig. 9 summarises the transmission mechanism, highlighting the channels that have not been included in our modelling.

In general, restricting competition in the 5G network infrastructure market leads to lower competitive pressures on the unrestricted network providers, who will be able to charge higher contract prices for 5G equipment.

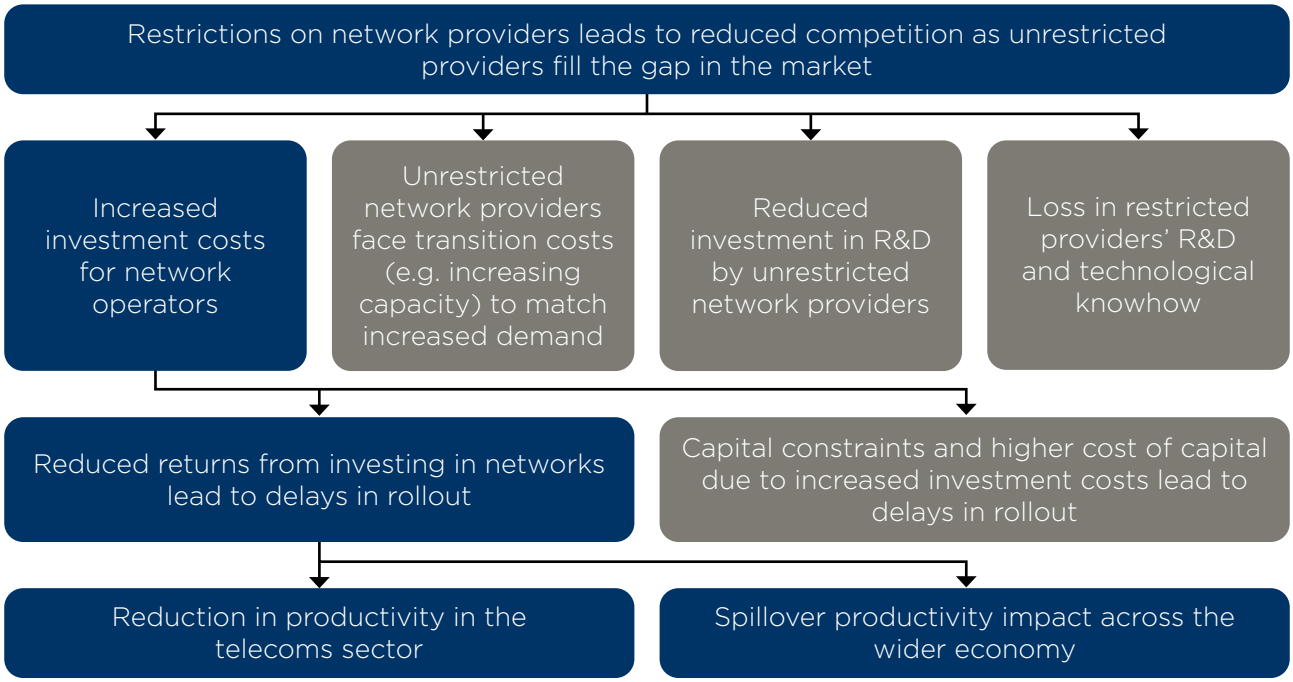
Our modelling approach does not account for a number of other potential costs of restricting competition. For example, in addition to the increase in prices, there may also be a reduction in quality and technological innovation in the 5G network equipment as the unrestricted firms do not face the same pressures to invest in R&D and innovation.

Further, network operators and providers may face some transition costs as they adapt their plans and existing infrastructure to adequately fill in the gap left by a large competitor such as Huawei.

The higher network equipment prices translate into higher investment costs, which translates into delays in rollout. We assume that network operators do not suffer from any capital constraints or increased costs of capital as they increase their investment expenditure.

The increase in investment costs and the consequent delays in rollout lead to productivity losses across the economy.

Fig. 9: Transmission mechanism of restrictions in competition



Note: The grey boxes indicate channels that are not considered in our modelling approach. Only the channels described in the blue boxes are modelled.

3.4 ACCOUNTING FOR UNCERTAINTY

The precise extent of this negative impact will depend on the potential future benefits of 5G, and the market reactions to competition restrictions. To capture the uncertainty around the future benefits of 5G and the different market responses to competition restrictions, we modelled three scenarios which are summarised in Fig. 10.

The modelling assumptions corresponding to these scenarios are shown in Fig. 11. To model the low cost scenario, we assumed that 5G leads to productivity benefits of 0.15% in GDP growth per year, which is based on the lower end of estimates from various studies. To account for limited increases in prices in the low cost scenario, we assumed that investment costs increase by the lower end of the range of estimates from our three price models.

For the high cost scenario, we assumed that 5G leads to productivity benefits of 0.30% in GDP growth per year, which is based on the higher end of the estimates from the various studies. Similarly, the increase in investment costs was based on the higher end of the range of estimates from our three price models in Stage 1. In the central cost scenario, we assumed that 5G leads to productivity benefits of 0.15% in GDP growth per year in the first year of 5G rollout, increasing to 0.30% in five years. The increase in investment costs was based on the median of estimates from the three price models in Stage 1.

Fig. 10: Definitions of scenarios modelled to reflect uncertainty

Source of uncertainty	LOW COST scenario	CENTRAL COST scenario	HIGH COST scenario
Potential future benefits of 5G	5G, characterised as Enhanced Mobile Broadband (eMBB), provides higher broadband speeds and supports high-bandwidth services such as Augmented Reality (AR) and Virtual Reality (VR) apps.	5G enables Massive Machine-type Communications (mMTC): i.e. the connection of a very large number of connected devices (one million per sq. km), supporting low-power, low-energy devices which enables large-scale IoT deployments across sectors.	5G is revolutionary, providing Ultra-reliable and Low Latency Communications (URLLC) that enables applications which are heavily dependent on low latency and high reliability, and supports critical applications in transport, healthcare and energy.
Market reaction to competition restrictions	We assume that the scope for other 5G infrastructure vendors to exercise their market power and increase prices is limited.	Other vendors are able to increase their prices to some extent but are not fully able to exercise their market power.	Given the revolutionary impact of 5G, infrastructure vendors can fully exercise their market power and increase prices to the maximum extent.

Fig. 11: Modelling assumptions to reflect uncertainty

Source of uncertainty	LOW COST scenario	CENTRAL COST scenario	HIGH COST scenario
Potential future benefits of 5G modelled using GDP growth per year in the baseline (no restrictions) scenario	0.15% per year from 2020-2035	0.15% in 2020; increasing to 0.30% in 2025 and constant at 0.30% per year after.	0.30% per year from 2020-2035
Market reaction to competition restrictions modelled using increase in investment costs (varies by country)	8%-9% increase per year	16%-19% increase per year	24%-29% increase per year

4. THE ECONOMIC IMPACT OF RESTRICTING 5G INFRASTRUCTURE COMPETITION IN EUROPE

Our analysis suggests that throughout Europe, there would be significant economic impacts from restricting a key supplier from participating in the development of 5G infrastructure. As explained in Section 3.4, our findings are based on modelling three different scenarios (low, central, and high cost) which capture both the potential future benefits of 5G, and the market reactions to competition restrictions, for each of the 31 European countries in our study.[21]

We begin this chapter by presenting Europe-wide results, which are the sum of all our country-specific results. In each case, the results are given relative to our (post-coronavirus) baseline scenario in which no competition restrictions are imposed on the 5G infrastructure market. All monetary figures are in 2020 prices.

4.1 TOTAL IMPACT OF RESTRICTING COMPETITION ACROSS EUROPE

Our modelling suggests restricting a major participant could increase the cost of building the 5G network in the 31 countries in our study by €3 billion per year over the next decade (19% of baseline costs) in our central cost scenario.

Due to these price increases, 56 million people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Europe over the next 15 years. We estimate this could reduce GDP in the 31 countries in 2035 by €40 billion in aggregate (see Fig. 12).

As highlighted, there is a large amount of uncertainty attached to these results, so we also present result ranges based on our low and high cost scenarios. Restricting a key supplier of 5G infrastructure in all 31 countries studied was found to increase the total 5G investment costs across Europe by between 9% and 29%. This equates to a total increase in investment costs of €1.4 billion to €4.5 billion per year over the next decade.

According to our low and high cost scenarios, between 29 million and 78 million fewer European residents would be covered by the 5G network in 2023 if all 31 countries faced restrictions.

Europe's economic growth would also be significantly reduced over the next decade and beyond, due to the delays in 5G rollout and associated slower technological growth. In 2035, we estimate a total (permanent) loss in GDP of between €12 billion and €85 billion.

[21] The results presented for Europe in this report do not cover all European countries. In particular, our study does not cover Russia, Ukraine, Belarus, Serbia, Moldova, Bosnia and Herzegovina, Albania, North Macedonia, Montenegro, Andorra, Monaco, Liechtenstein, San Marino, or the Vatican City.

Fig. 12: Total Europe-wide impacts of restricting a major participant in 31 countries, under our three modelling scenarios

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€1.4 billion (9%)	€3.0 billion (19%)	€4.5 billion (29%)
Absolute number of people who will have delayed access to 5G by 2023	29 million (6%)	56 million (11%)	78 million (15%)
Estimated permanent loss in Gross Domestic Product (GDP) due to delay in 5G rollout in 2035	€12 billion	€40 billion	€85 billion

4.2 IMPACT OF RESTRICTING COMPETITION IN EACH COUNTRY

Over the remainder of this chapter, we detail our results for each of the 31 countries in our study, according to all three scenarios. In each case, we include a chart showing projected 5G rollout rates for that country, with and without competition restrictions. In fact, these charts include two baseline rollout rates, reflecting the impact of the coronavirus pandemic on our short-term 5G forecasts. All of the country results are given relative to our "post-coronavirus" baseline scenario, in which no competition restrictions are imposed on the 5G infrastructure market.

BOX 3: ECONOMIC COSTS OF REPLACING EXISTING 4G/5G INFRASTRUCTURE

Our results for each country reflect the macroeconomic impact of network competition restriction for future 5G rollout. In other words, they capture the loss in productivity and increased investment costs resulting purely from restrictions in competition to build network infrastructure in the future.

However, if a large network vendor is restricted, then operators may also incur significant costs in replacing existing telecoms infrastructure built by the restricted vendor. Estimates of the replacement costs are not readily available on a consistent basis for the countries in our study and would involve a detailed review of the operators' network assets on a country-by-country basis. The replacement costs could be significant and consequently our estimates of the impact on rollout and productivity are potentially conservative.

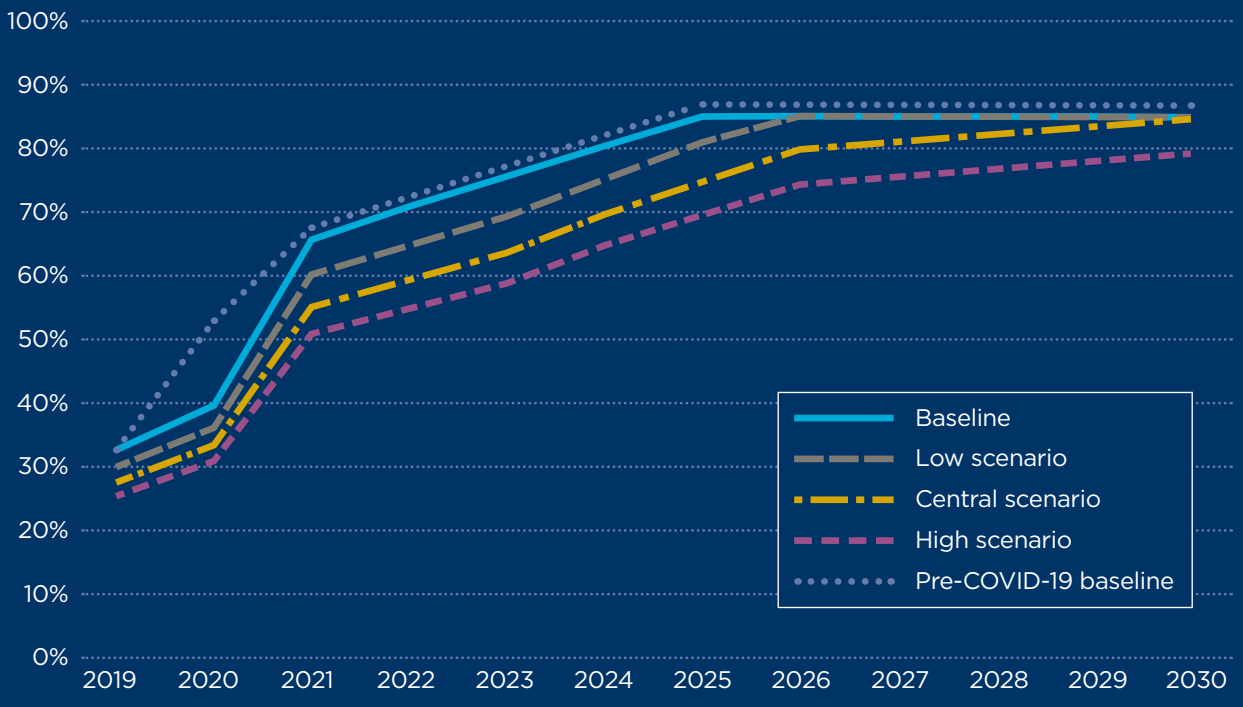
AUSTRIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€35 mn (9%)	€73 million (19%)	€111 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	600,000 (6%)	1.1 million (12%)	1.5 mn (17%)
Estimated permanent loss in Gross Domestic Product (GDP) due to delay in 5G rollout in 2035	€300 mn	€1.1 billion	€2.3 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Austrian economy is suffering from strict lockdown measures as the Coronavirus pandemic brings activity to an abrupt halt. We now see GDP falling 7.5% this year before rebounding next year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Austria. 5G services and associated activities will stimulate economic activity worth €2 billion in GDP and support around 25,200 jobs in Austria.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €73 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 1.1 million people (12% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Austria over the next 15 years. We estimate this could reduce GDP in 2035 by €1.1 billion. The potential future benefits of 5G are hard to predict.

While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €35 million (9%) and €111 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.5 million more people (17% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €300 million and €2.3 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

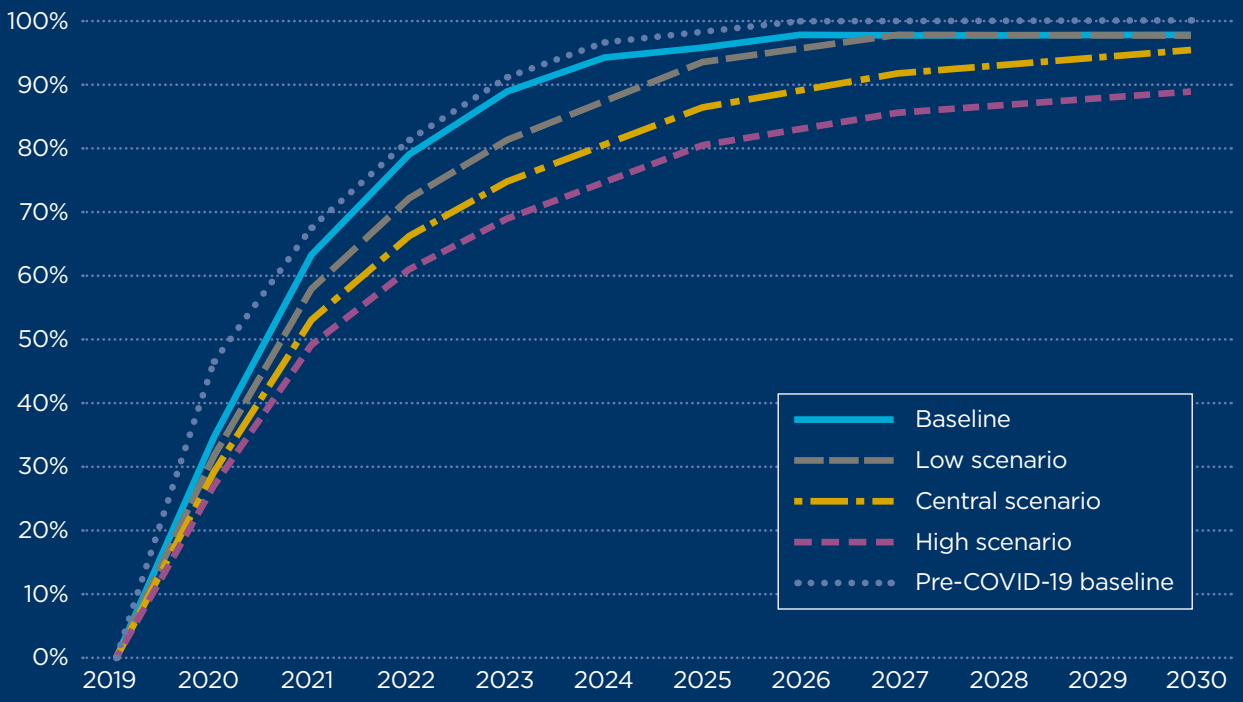
BELGIUM

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€31 mn (9%)	€65 million (19%)	€98 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	900,000 (8%)	1.7 million (14%)	2.3 mn (15%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€300 mn	€1.1 billion	€2.5 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Lockdowns to contain the Coronavirus pandemic are taking a massive toll on the Belgian economy. We now see GDP falling 8.9% this year before rebounding next year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Belgium. 5G services and associated activities will stimulate economic activity worth €3 billion in GDP and support around 36,300 jobs in Belgium.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €65 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 1.7 million people (14% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Belgium over the next 15 years. We estimate this could reduce GDP in 2035 by €1.1 billion. The potential future benefits of 5G are hard to predict.

While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €31 million (9%) and €98 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 2.3 million more people (20% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €300 million and €2.5 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

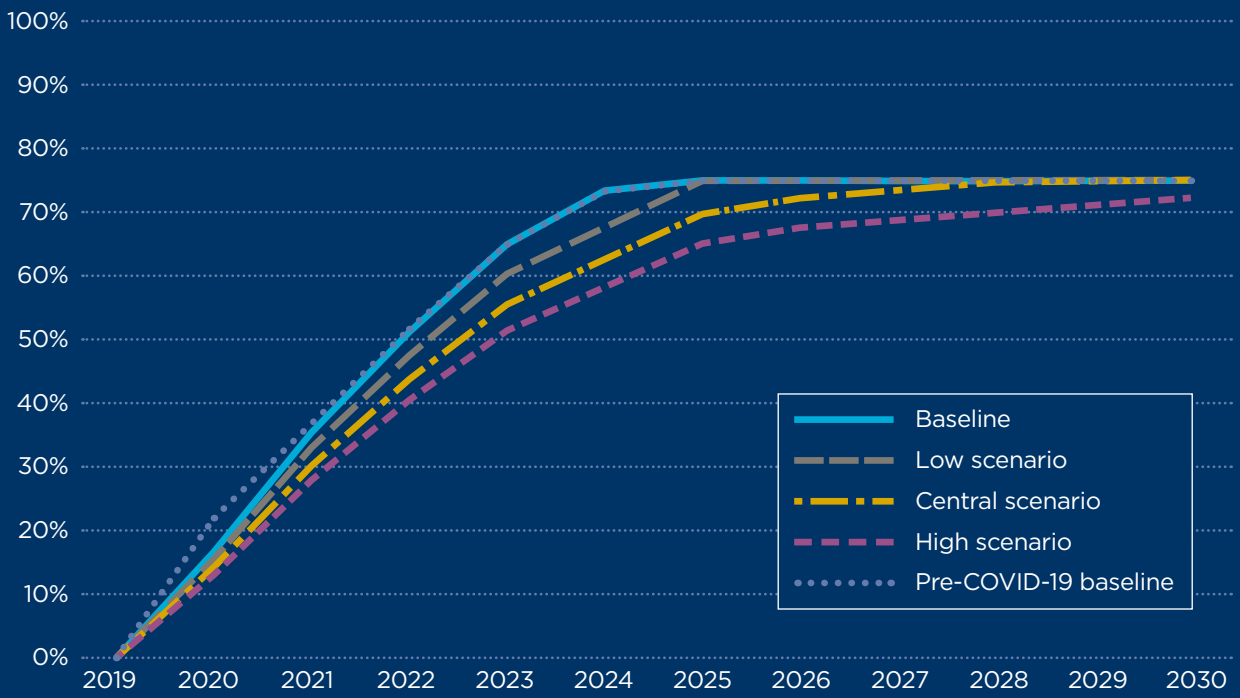
BULGARIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€9 mn (9%)	€20 million (19%)	€30 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	300,000 (5%)	700,000 (10%)	900,000 (14%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€30 mn	€100 million	€250 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The escalation of the coronavirus pandemic means that Bulgaria will see a massive contraction this year with our latest forecast predicting a 2.6% contraction in GDP this year before rebounding next year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Bulgaria. 5G services and associated activities will stimulate economic activity worth €2 billion in GDP and support around 128,900 jobs in Bulgaria.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €20 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 700,000 people (10% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Bulgaria over the next 15 years. We estimate this could reduce GDP in 2035 by €100 million. The potential future benefits of 5G are hard to predict.

While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €9 million (9%) and €30 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 900,000 more people (14% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €30 million and €250 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

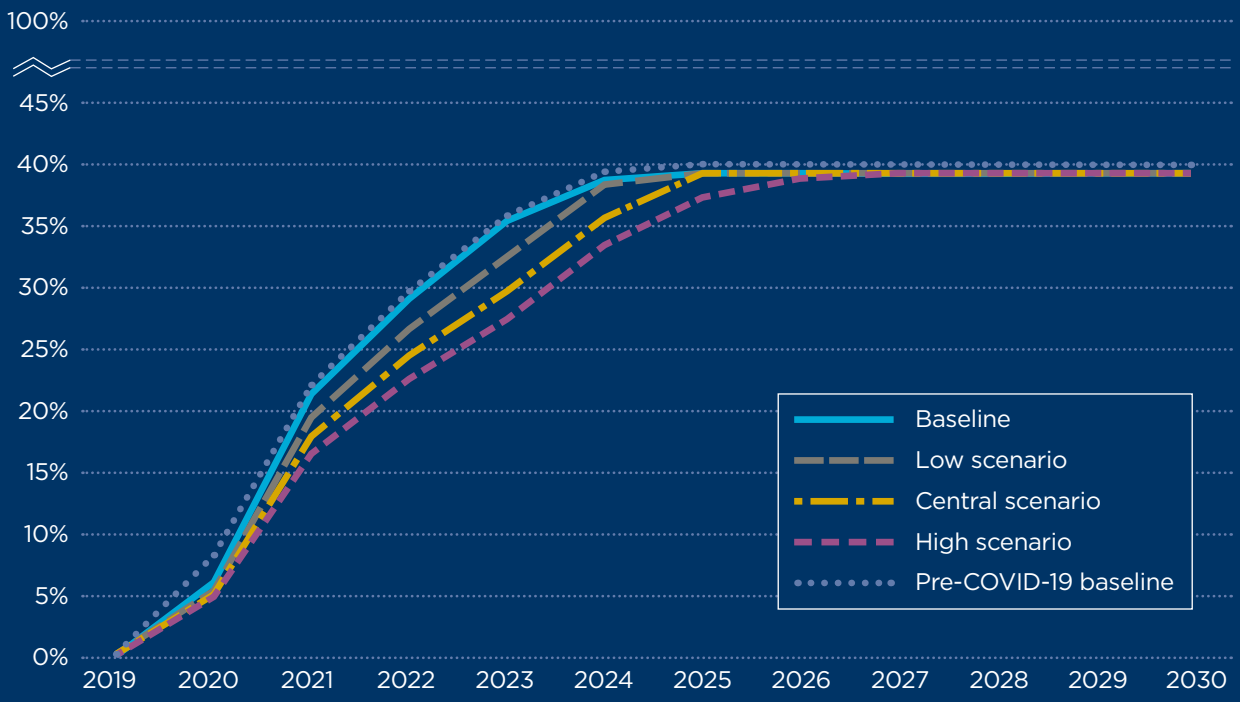
CROATIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€11 mn (9%)	€23 million (19%)	€35 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	100,000 (3%)	200,000 (6%)	300,000 (8%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€30 mn	€80 million	€200 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The coronavirus pandemic will lead to an immense contraction this year in Croatia. We expect GDP to contract by more than 9% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Croatia. 5G services and associated activities will stimulate economic activity worth €1.5 billion in GDP and support around 64,400 jobs in Croatia.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €23 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 200,000 people (6% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Croatia over the next 15 years. We estimate this could reduce GDP in 2035 by €80 million. The potential future benefits of 5G are hard to predict.

While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €11 million (9%) and €35 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 300,000 more people (8% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €30 million and €200 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

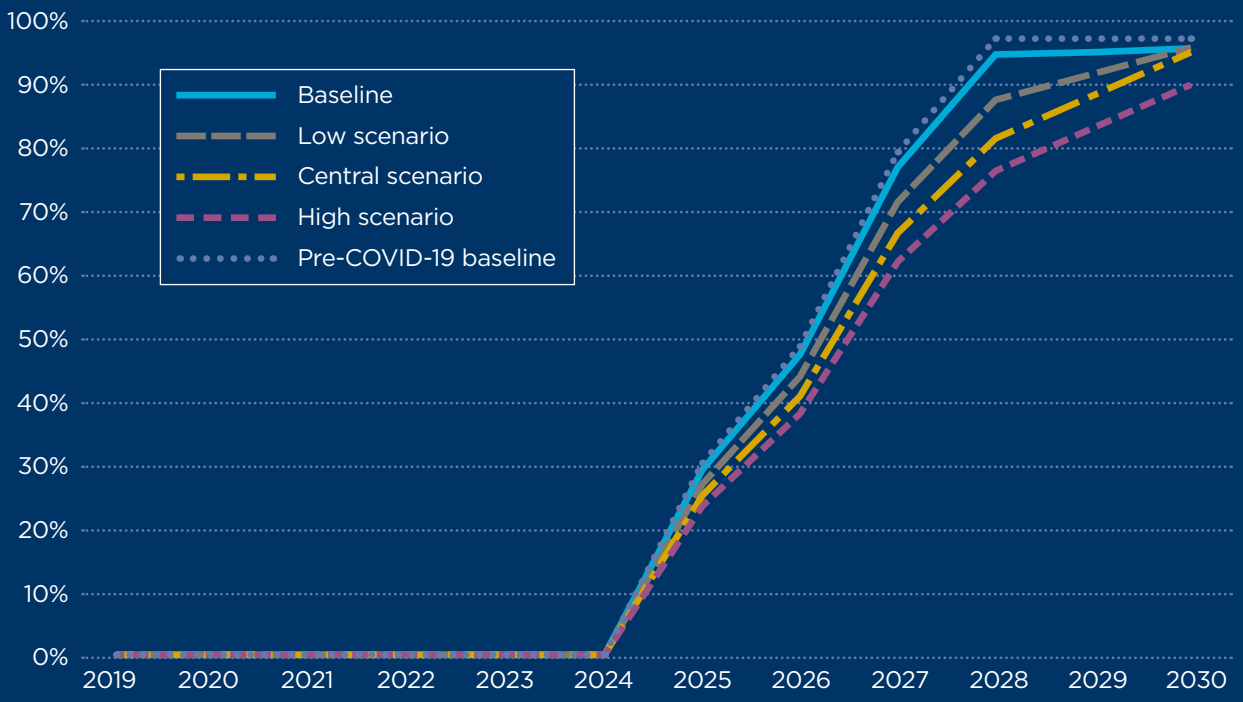
CYPRUS

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€3 mn (9%)	€7 million (19%)	€10 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	21,000 (2%)	38,000 (4%)	53,000 (6%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€10 mn	€40 million	€60 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The coronavirus pandemic will lead to a significant contraction this year in Cyprus. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Cyprus. 5G services and associated activities will stimulate economic activity worth €470 million in GDP and support around 20,800 jobs in Cyprus.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €7 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 38,000 people (4% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2025.[22]

Restricting competition in the network infrastructure market may significantly reduce economic growth in Cyprus over the next 15 years. We estimate this could reduce GDP in 2035 by €40 million. The potential future benefits of 5G are hard to predict.

While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €3 million (9%) and €10 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 53,000 more people (6% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €10 million and €60 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

[22] However, as 5G spectrum auction in Cyprus is expected to complete in 2020, rollout could be much quicker than estimated by the GSMA. This would mean that the economic impact, in terms of delays in rollout and GDP loss, could be much higher than estimated using the GSMA rollout estimates as the basis of our calculations.

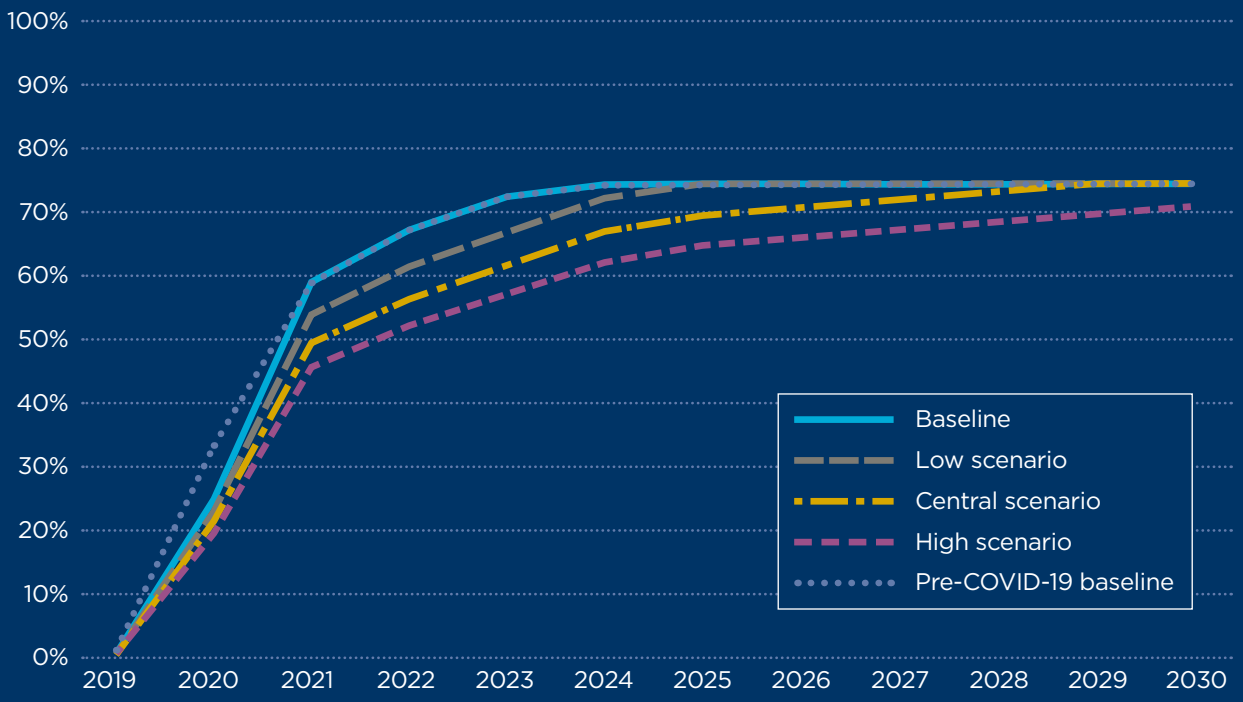
CZECH REPUBLIC

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€28 mn (9%)	€57 million (19%)	€87 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	600,000 (6%)	1.2 million (11%)	1.6 mn (15%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€100 mn	€400 million	€1.1 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

As the severe containment measures in the Czech Republic take their toll on the economy, we forecast GDP to fall by 1.7% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Czech Republic. 5G services and associated activities will stimulate economic activity worth €4.0 billion in GDP and support around 143,000 jobs in the Czech Republic.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €57 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 1.2 million people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in the Czech Republic over the next 15 years. We estimate this could reduce GDP in 2035 by €400 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €28 million (9%) and €87 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.6 million more people (15% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €100 million and €1.1 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

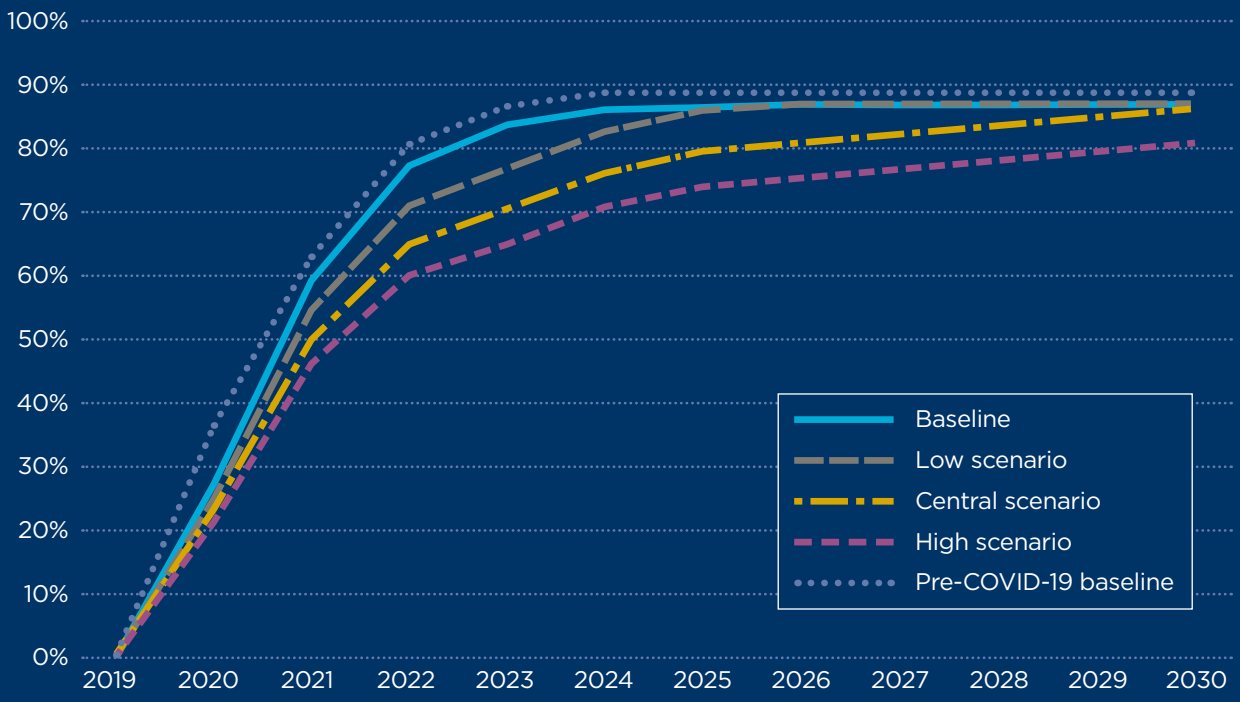
DENMARK

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€14 mn (9%)	€29 million (19%)	€43 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	400,000 (7%)	800,000 (13%)	1.1 mn (19%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€200 mn	€600 million	€1.4 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

While Denmark fared better than other European economies in the Q1 this year, we expect a slow recovery with GDP growth in 2020 forecast to be -3.9%. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Denmark. 5G services and associated activities will stimulate economic activity worth €1.5 billion in GDP and support around 14,800 jobs in Denmark.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €29 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 800,000 people (13% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Denmark over the next 15 years. We estimate this could reduce GDP in 2035 by €600 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €14 million (9%) and €43 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.1 million more people (19% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €200 million and €1.4 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

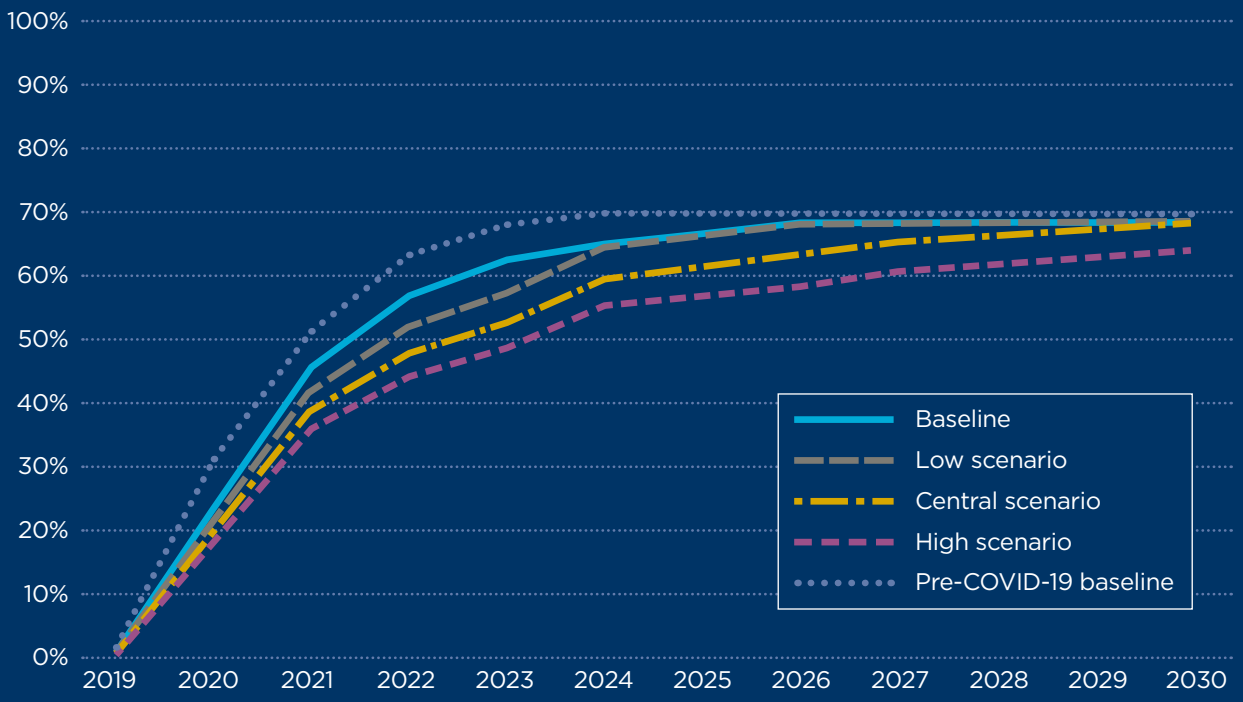
ESTONIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€5 mn (9%)	€10 million (19%)	€15 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	70,000 (5%)	130,000 (10%)	190,000 (14%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€15 mn	€60 million	€150 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The spread of coronavirus and the ensuing lockdown in Estonia are hitting activity severely and we now see GDP contracting 2.2% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Estonia. 5G services and associated activities will stimulate economic activity worth €560 million in GDP and support around 13,600 jobs in Estonia.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €10 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 130,000 people (10% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Estonia over the next 15 years. We estimate this could reduce GDP in 2035 by €60 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €5 million (9%) and €15 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 190,000 more people (14% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €15 million and €150 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

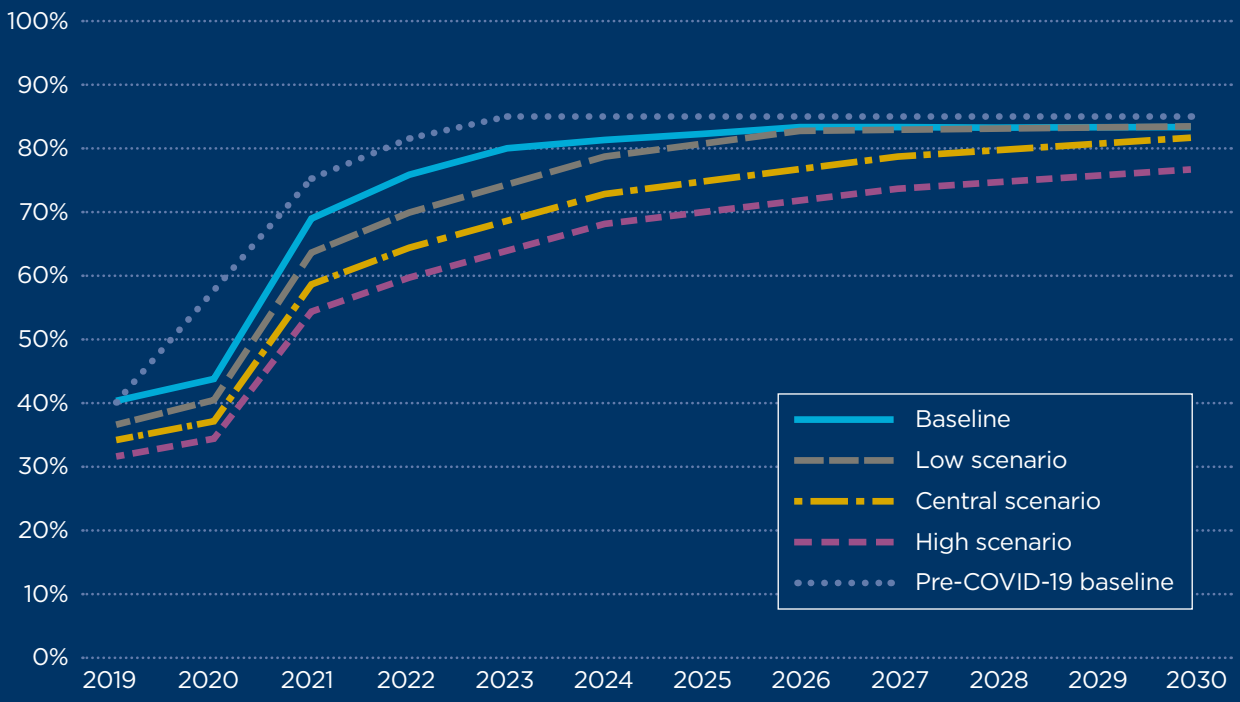
FINLAND

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€38 mn (9%)	€79 million (19%)	€120 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	300,000 (6%)	600,000 (11%)	900,000 (16%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€100 mn	€400 million	€800 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The longer-lasting lockdowns to contain the pandemic in Finland is expected to see GDP to fall by 6.3% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Finland. 5G services and associated activities will stimulate economic activity worth €1.5 billion in GDP and support around 19,900 jobs in Finland.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €79 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 600,000 people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Finland over the next 15 years. We estimate this could reduce GDP in 2035 by €400 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €38 million (9%) and €120 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 900,000 more people (16% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €100 million and €800 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

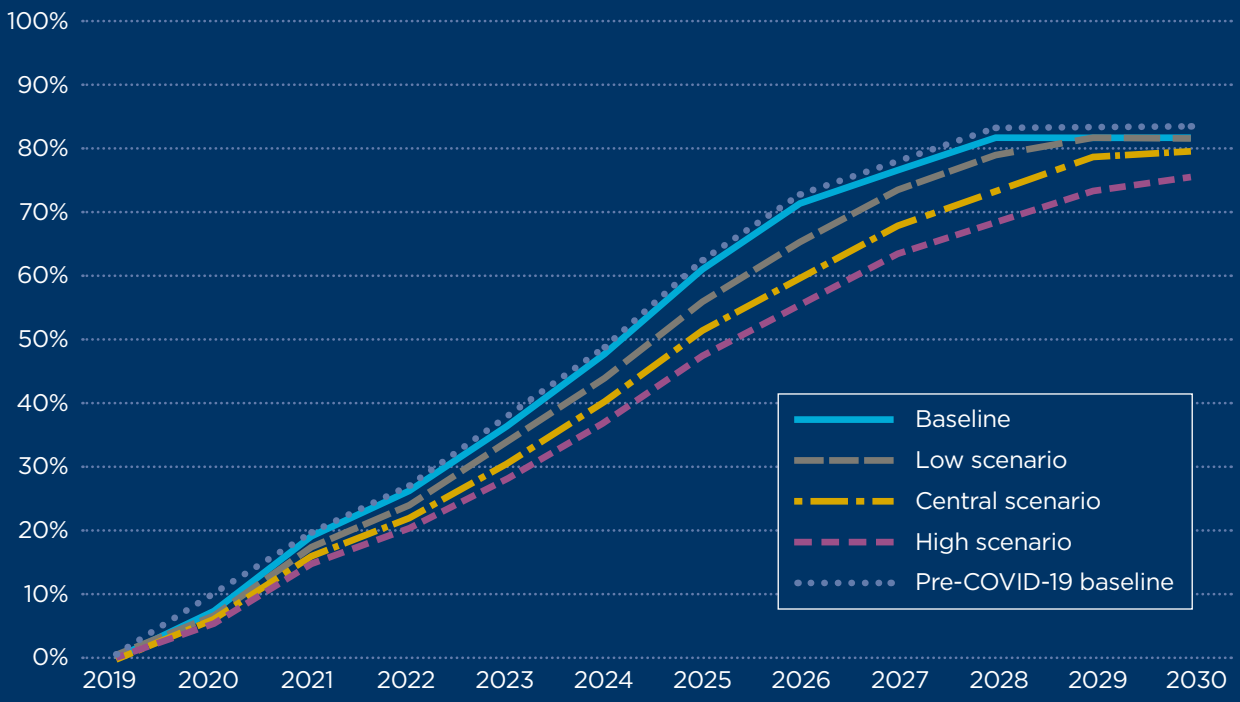
FRANCE

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€217 mn (9%)	€447 million (19%)	€678 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	2.1 mn (3%)	4.0 million (6%)	5.6 mn (8%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€2.3 bn	€7.3 billion	€14.4 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The coronavirus crisis will deliver a big shock to the French economy with GDP expected to fall by almost 10% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in France. 5G services and associated activities will stimulate economic activity worth €17 billion in GDP and support around 224,700 jobs in France.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €447 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 4 million people (6% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in France over the next 15 years. We estimate this could reduce GDP in 2035 by €7.3 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €217 million (9%) and €678 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 5.6 million more people (8% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €2.3 billion and €14.4 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

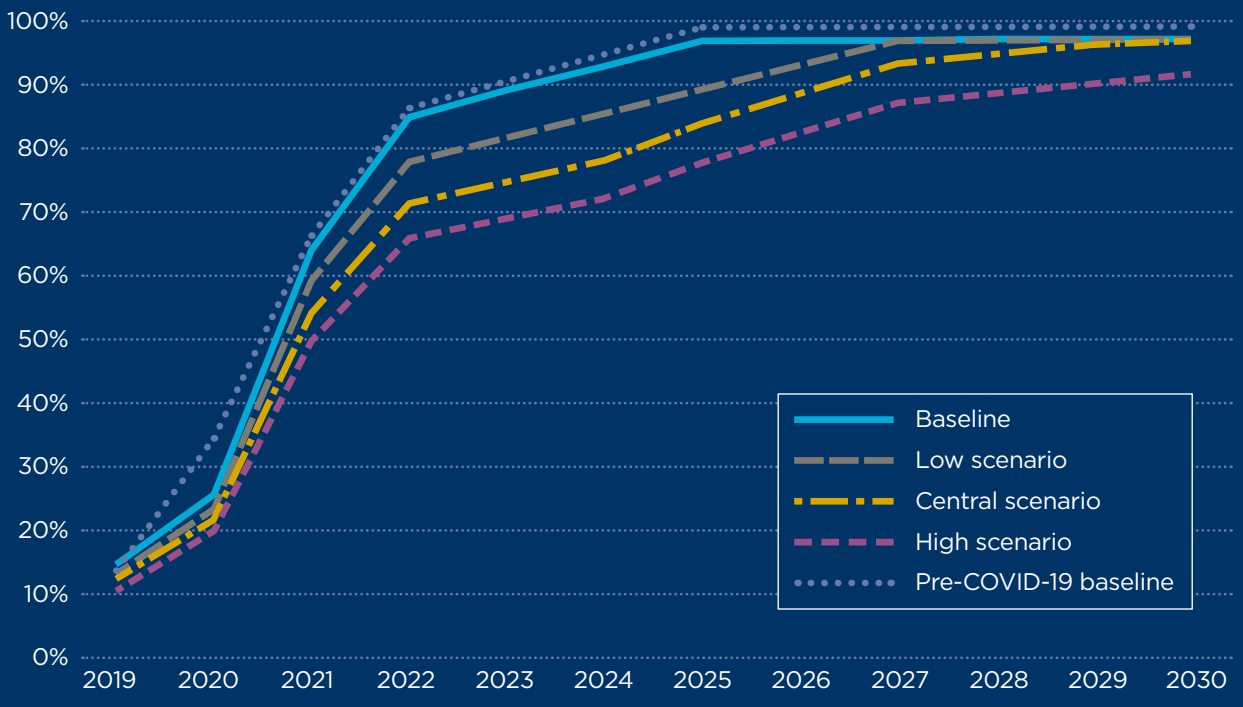
GERMANY

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€232 mn (9%)	€479 million (19%)	€726 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	6.3 mn (8%)	11.9 million (14%)	16.7 mn (20%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€2.3 bn	€6.9 billion	€15.3 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The German economy may have already begun its recovery from the Coronavirus crisis as restrictions have been lifted with the backdrop of declines in new Coronavirus cases. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Germany. 5G services and associated activities will stimulate economic activity worth €21 billion in GDP and support around 211,100 jobs in Germany.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €479 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 12 million people (14% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Germany over the next 15 years. We estimate this could reduce GDP in 2035 by €6.9 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €232 million (9%) and €726 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 16.7 million more people (20% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €2.3 billion and €15.3 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

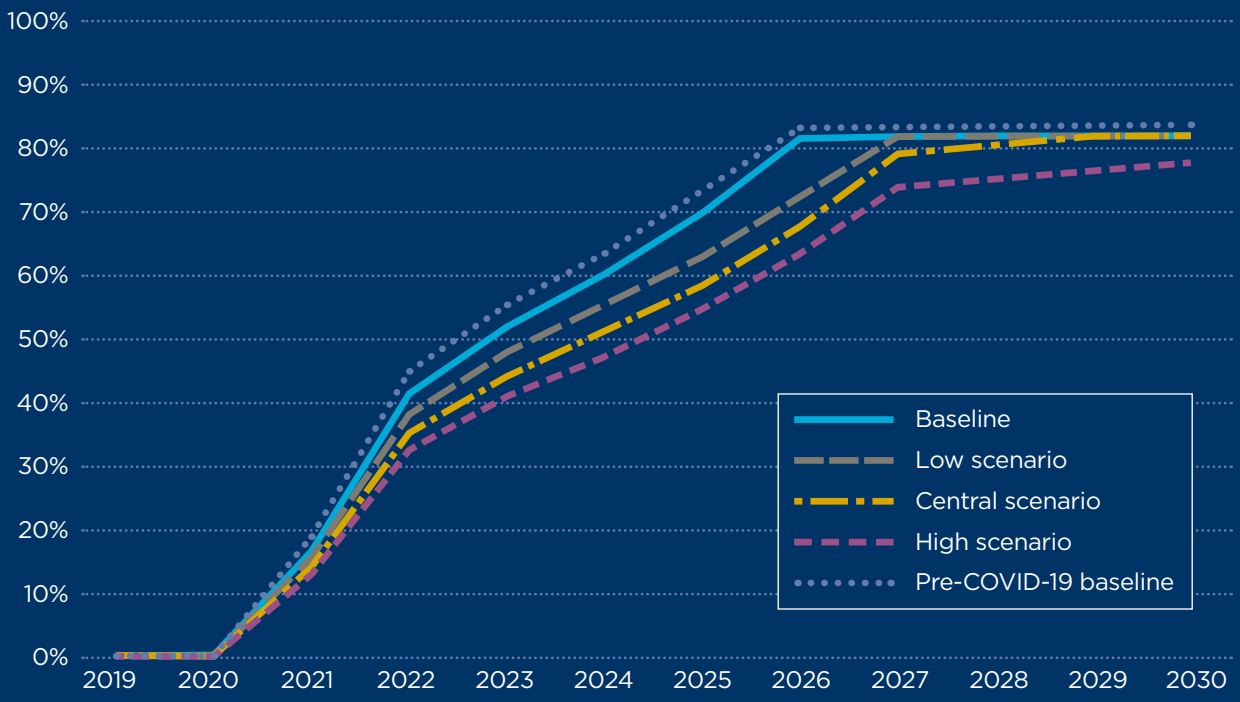
GREECE

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€18 mn (9%)	€37 million (19%)	€57 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	400,000 (4%)	800,000 (8%)	1.2 mn (11%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€200 mn	€600 million	€1.2 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Still dealing with the fallout from the last economic crisis, Greece's response to contain the coronavirus outbreak means the economy is plunging into another recession. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Greece. 5G services and associated activities will stimulate economic activity worth €2.2 billion in GDP and support around 101,300 jobs in Greece.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €37 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 800,000 people (8% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Greece over the next 15 years. We estimate this could reduce GDP in 2035 by €600 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €18 million (9%) and €57 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.2 million more people (11% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €200 million and €1.2 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

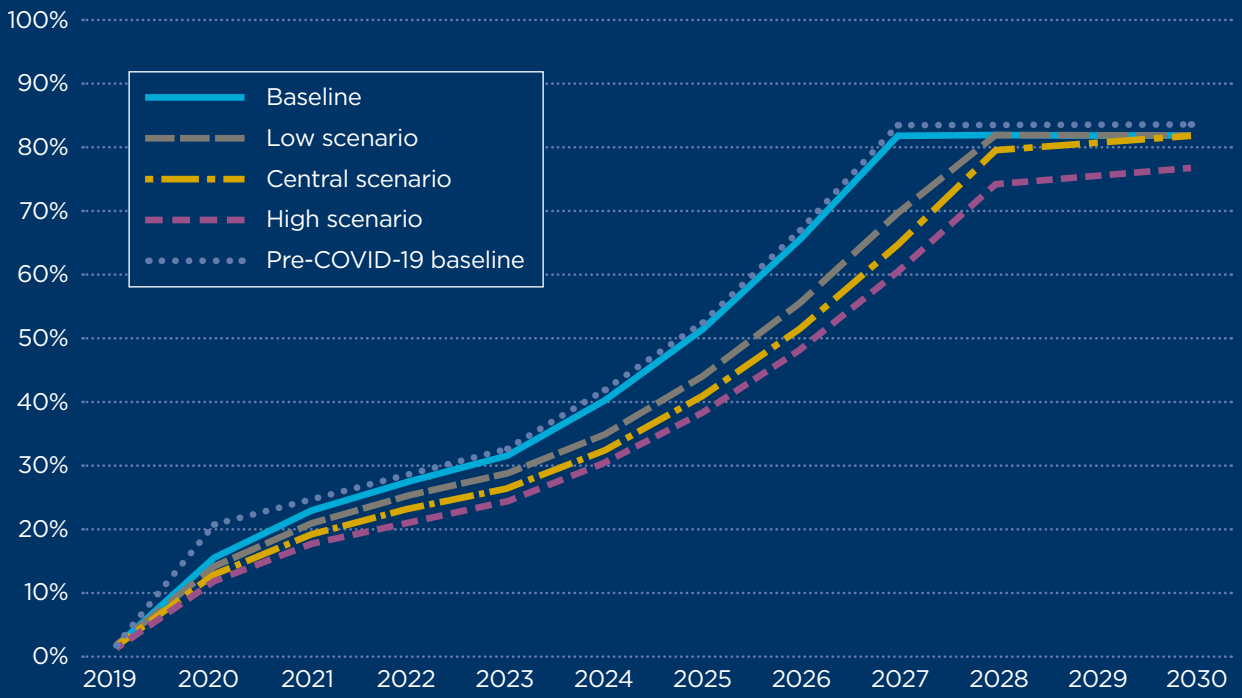
HUNGARY

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€27 mn (9%)	€55 million (19%)	€83 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	300,000 (3%)	500,000 (5%)	700,000 (7%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€100 mn	€300 million	€600 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

While the Hungary has not suffered directly from the number of national Coronavirus cases, its central role in international supply chains means a significant downturn in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Hungary. 5G services and associated activities will stimulate economic activity worth €3.5 billion in GDP and support around 134,600 jobs in Hungary.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €55 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 500,000 people (5% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Hungary over the next 15 years. We estimate this could reduce GDP in 2035 by €300 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €27 million (9%) and €83 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 700,000 more people (7% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €100 million and €600 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

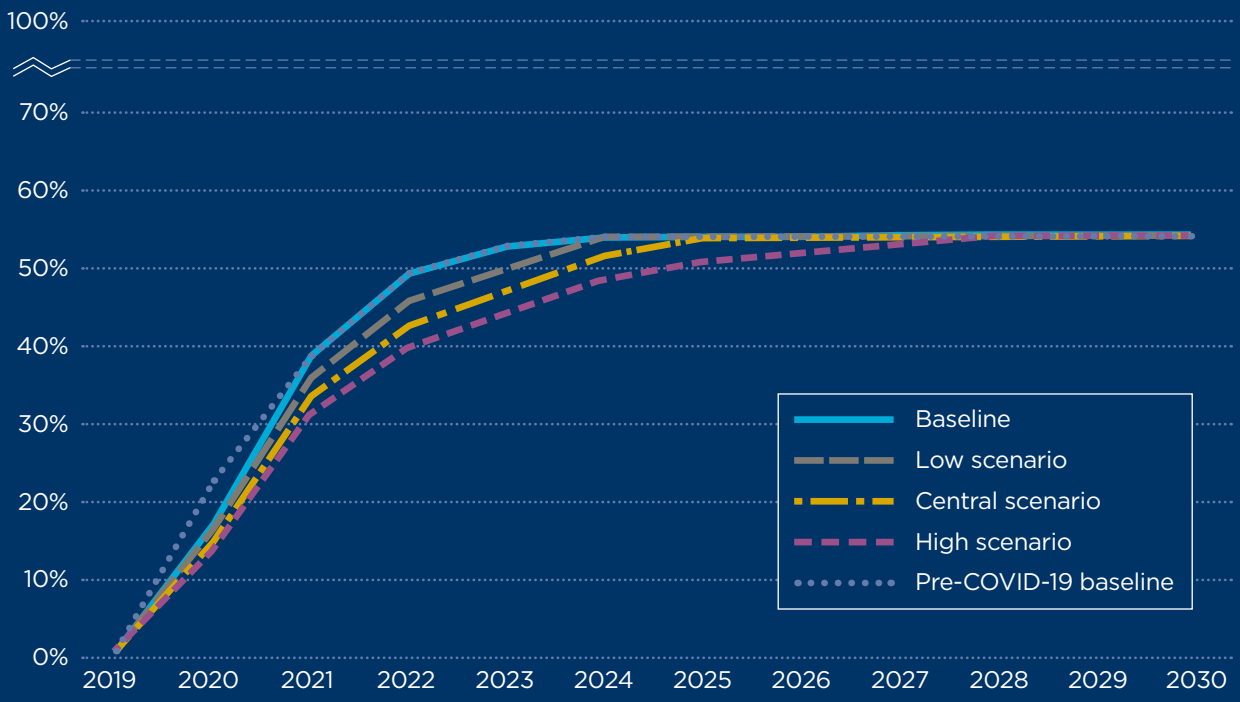
ICELAND

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€1 mn (9%)	€3 million (19%)	€5 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	11,000 (3%)	20,000 (6%)	30,000 (9%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€5 mn	€13 million	€33 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

GDP, exports, and employment in Iceland are set to fall sharply in 2020, despite success in containing the spread of coronavirus, due to much weaker tourism and export demand from main European markets. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Iceland.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €3 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 20,000 people (6% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Iceland over the next 15 years. We estimate this could reduce GDP in 2035 by €13 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €1 million (9%) and €5 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 30,000 more people (9% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €5 million and €33 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

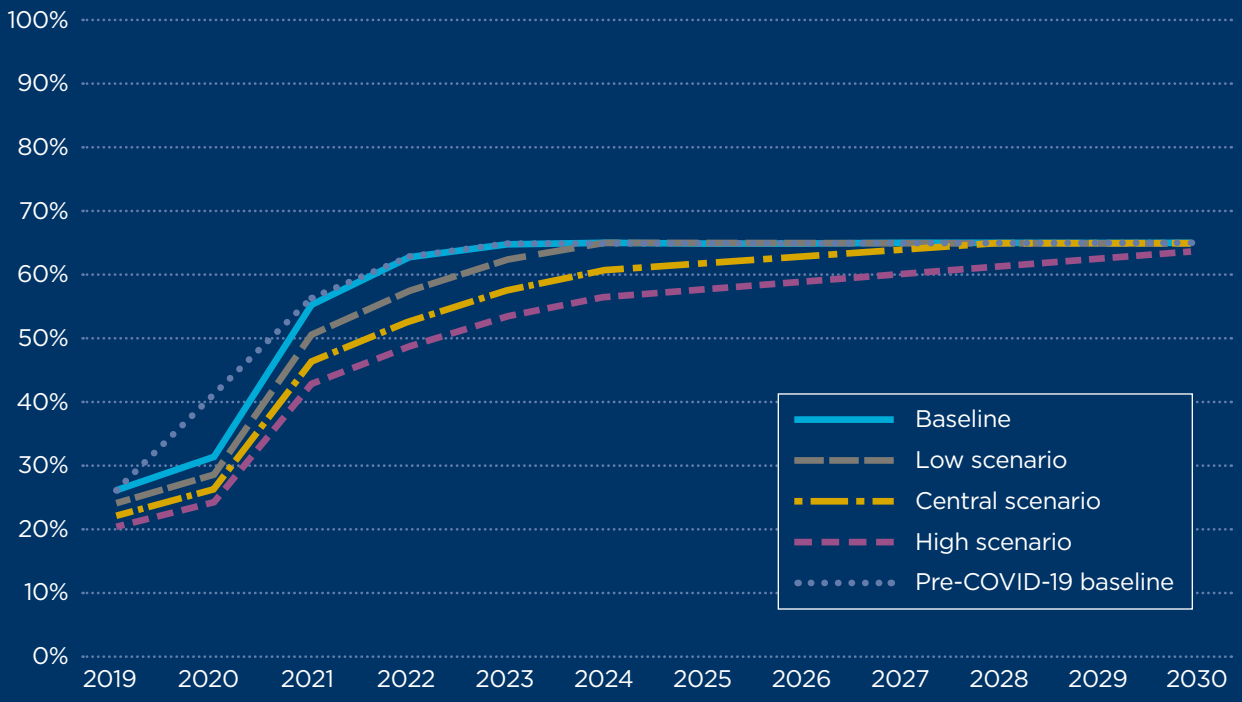
IRELAND

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€13 mn (9%)	€27 million (19%)	€41 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	150,000 (3%)	345,000 (7%)	540,000 (11%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€200 mn	€700 million	€1.7 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Ireland's coronavirus lockdown is now being relaxed. The government's decision to accelerate the exit from lockdown should aid the speed of recovery, but GDP is expected to fall by 4.8% in 2020.. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Ireland. 5G services and associated activities will stimulate economic activity worth €1.2 billion in GDP and support around 10,700 jobs in Ireland.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €27 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 345,000 people (7% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Ireland over the next 15 years. We estimate this could reduce GDP in 2035 by €700 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €13 million (9%) and €41 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 540,000 more people (11% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €200 million and €1.7 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

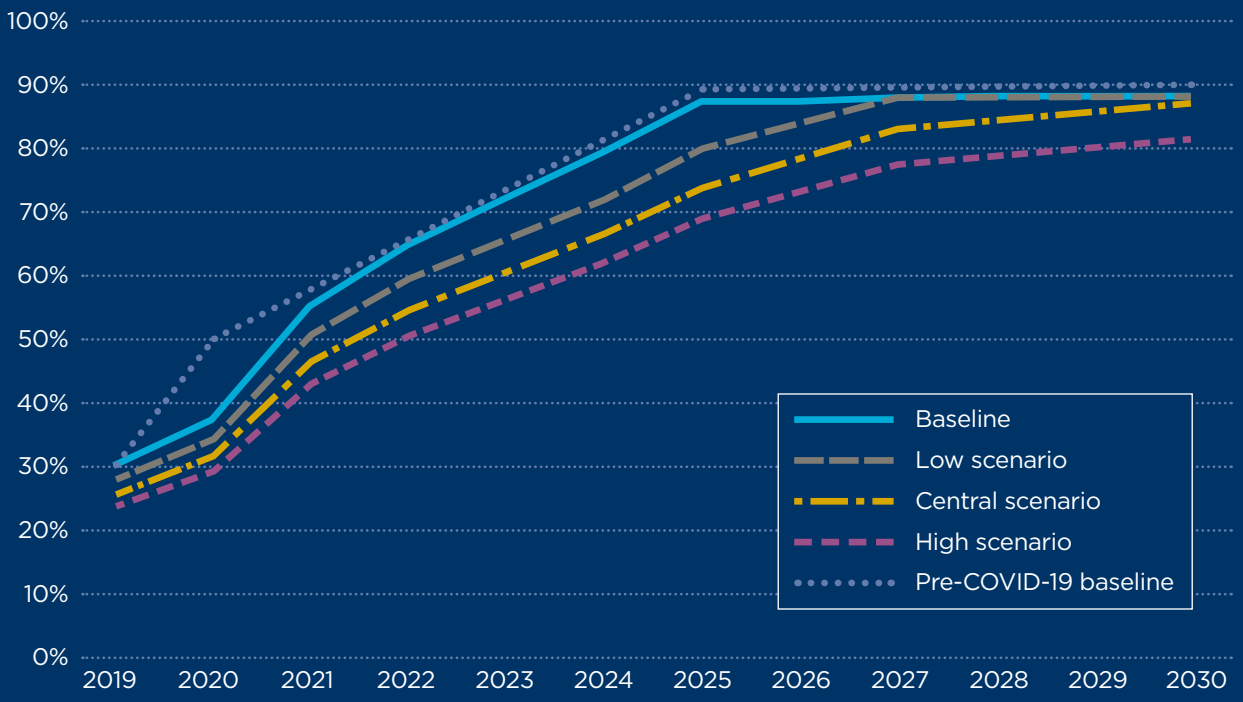
ITALY

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€137 mn (9%)	€282 million (19%)	€428 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	3.7 mn (6%)	6.9 million (12%)	9.7 mn (16%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€1.5 bn	€4.7 billion	€10.2 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Global Coronavirus Recession will leave a painful scar on Italy with the economy shrinking by 9% in 2020. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Italy. 5G services and associated activities will stimulate economic activity worth €15.7 billion in GDP and support around 186,830 jobs in Italy.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €282 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 6.9 million people (12% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Italy over the next 15 years. We estimate this could reduce GDP in 2035 by €4.7 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €137 million (9%) and €428 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 9.7 million more people (16% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €1.5 billion and €10.2 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

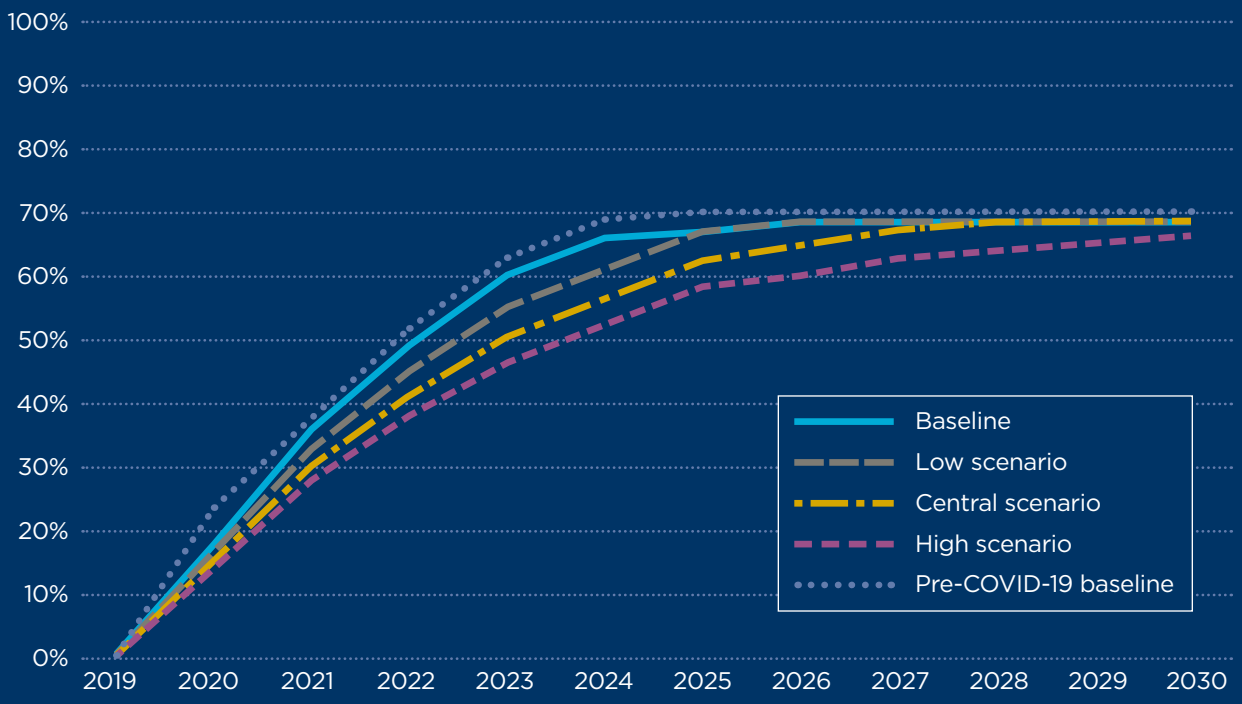
LATVIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€4 mn (9%)	€8 million (19%)	€12 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	90,000 (5%)	180,000 (10%)	250,000 (13%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€20 mn	€70 million	€160 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The impact of coronavirus and other EU countries in lockdown will cause a short recession in Latvia, with GDP seen falling 1.4% in 2020 despite prompt fiscal action to offset the drop in demand. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Latvia. 5G services and associated activities will stimulate economic activity worth €570 million in GDP and support around 16,800 jobs in Latvia.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €8 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 180,000 people (10% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Latvia over the next 15 years. We estimate this could reduce GDP in 2035 by €70 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €4 million (9%) and €12 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 250,000 more people (13% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €20 million and €160 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

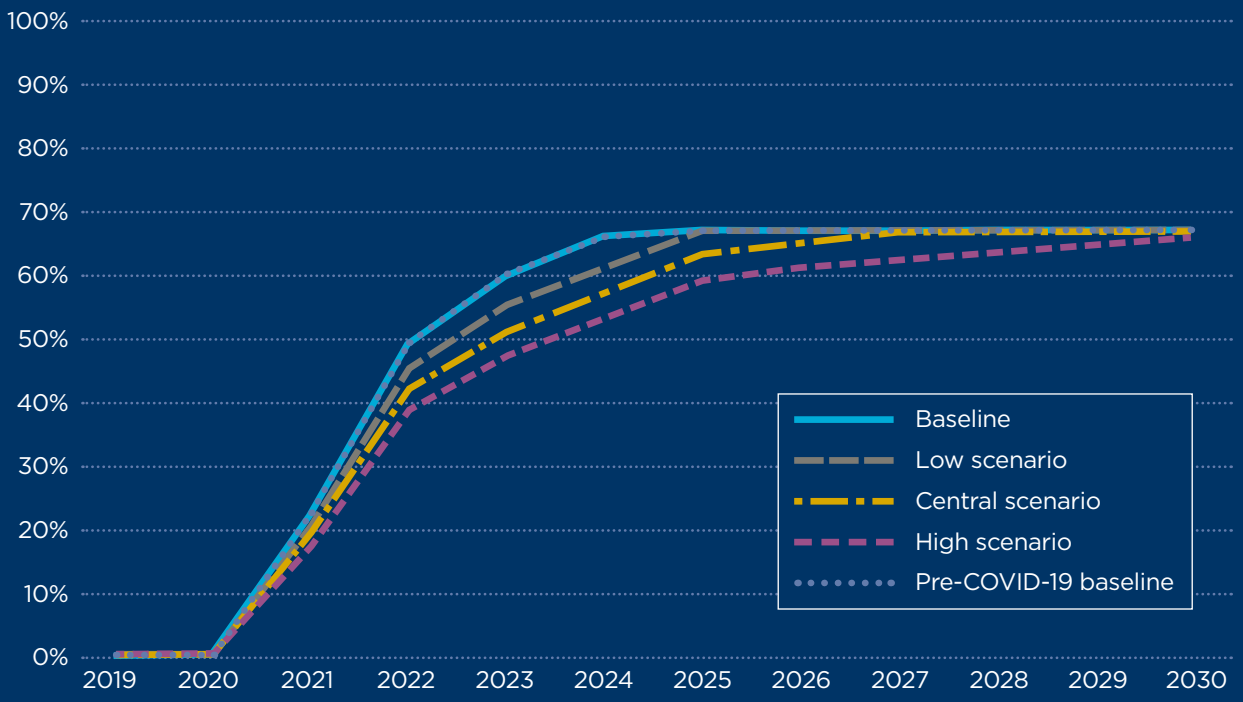
LITHUANIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€4 mn (9%)	€8 million (19%)	€13 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	100,000 (5%)	200,000 (9%)	300,000 (13%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€20 mn	€60 million	€130 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Economic growth is expected to slowdown in Lithuania due to weak external demand and the Coronavirus outbreak. In the context of the slowdown and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Lithuania. 5G services and associated activities will stimulate economic activity worth €700 million in GDP and support around 28,200 jobs in Lithuania.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €8 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 200,000 people (9% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Lithuania over the next 15 years. We estimate this could reduce GDP in 2035 by €60 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €4 million (9%) and €13 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 300,000 more people (13% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €20 million and €130 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

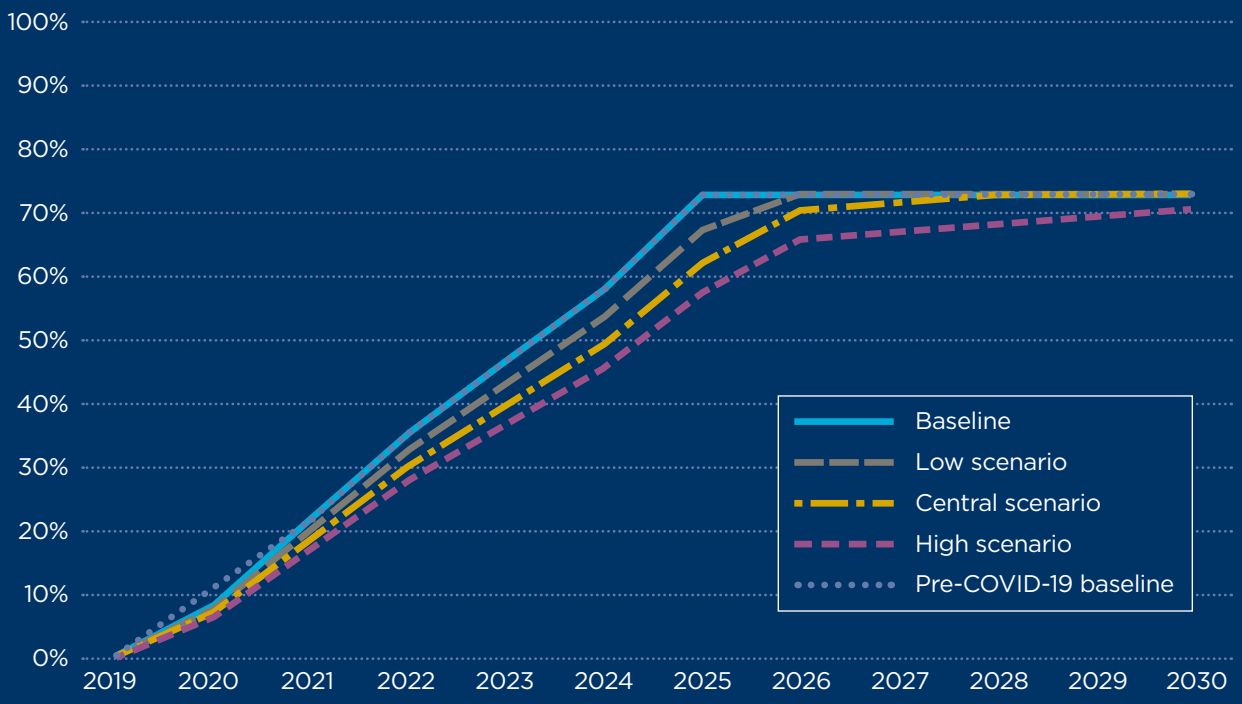
LUXEMBOURG

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€3 mn (9%)	€5 million (19%)	€8 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	20,000 (3%)	50,000 (7%)	70,000 (10%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€40 mn	€130 million	€310 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Luxembourg economy is expected to be hit hard by the pandemic with GDP expected to contract by 6.2% in 2020. In the context of the slowdown and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Luxembourg. 5G services and associated activities will stimulate economic activity worth €122 million in GDP and support around 600 jobs in Luxembourg.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €5 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 50,000 people (7% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Luxembourg over the next 15 years. We estimate this could reduce GDP in 2035 by €13 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €3 million (9%) and €8 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 70,000 more people (10% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €40 million and €310 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

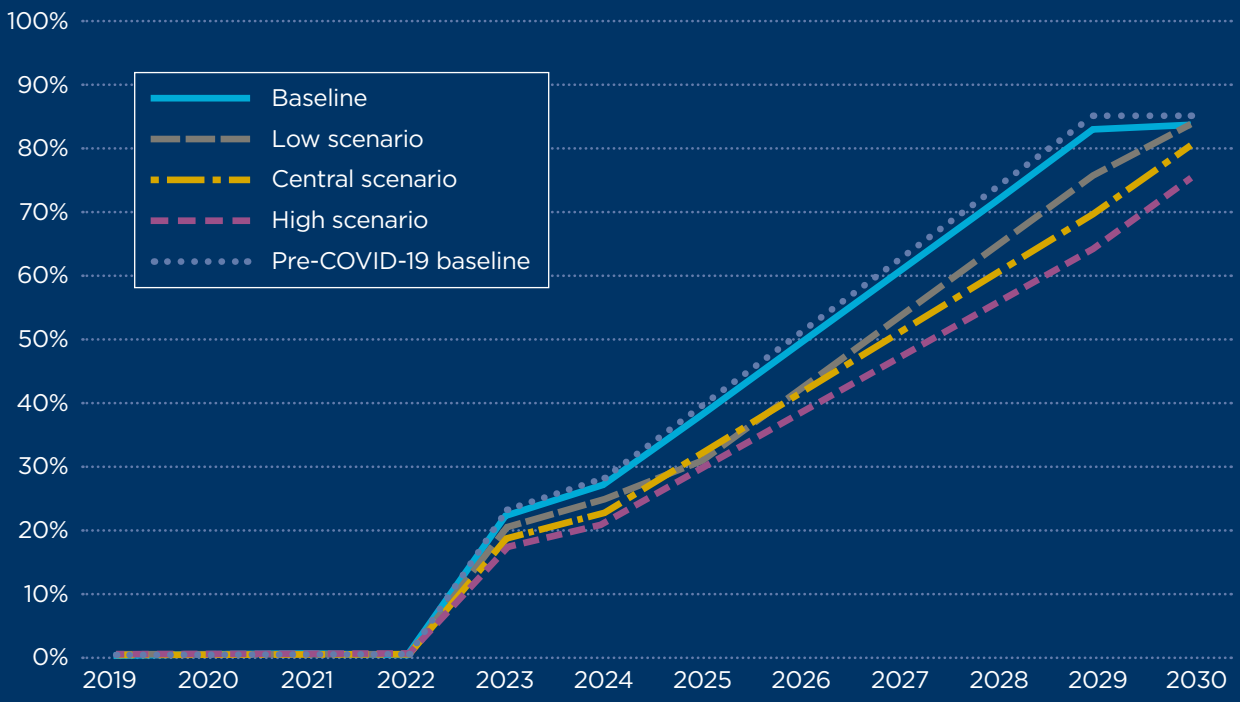
MALTA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€2 mn (9%)	€4 million (19%)	€5 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	10,000 (2%)	20,000 (4%)	30,000 (5%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€20 mn	€40 million	€60 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The outbreak of coronavirus has led to a significant downturn in Malta's economy as tourist numbers will collapse, exacerbating the impact on consumption through strict social distancing measures implemented. In the context of the slowdown and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Malta. 5G services and associated activities will stimulate economic activity worth €190 million in GDP and support around 3,900 jobs in Malta.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €4 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 20,000 people (4% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Malta over the next 15 years. We estimate this could reduce GDP in 2035 by €40 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €2 million (9%) and €5 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 30,000 more people (5% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €20 million and €60 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

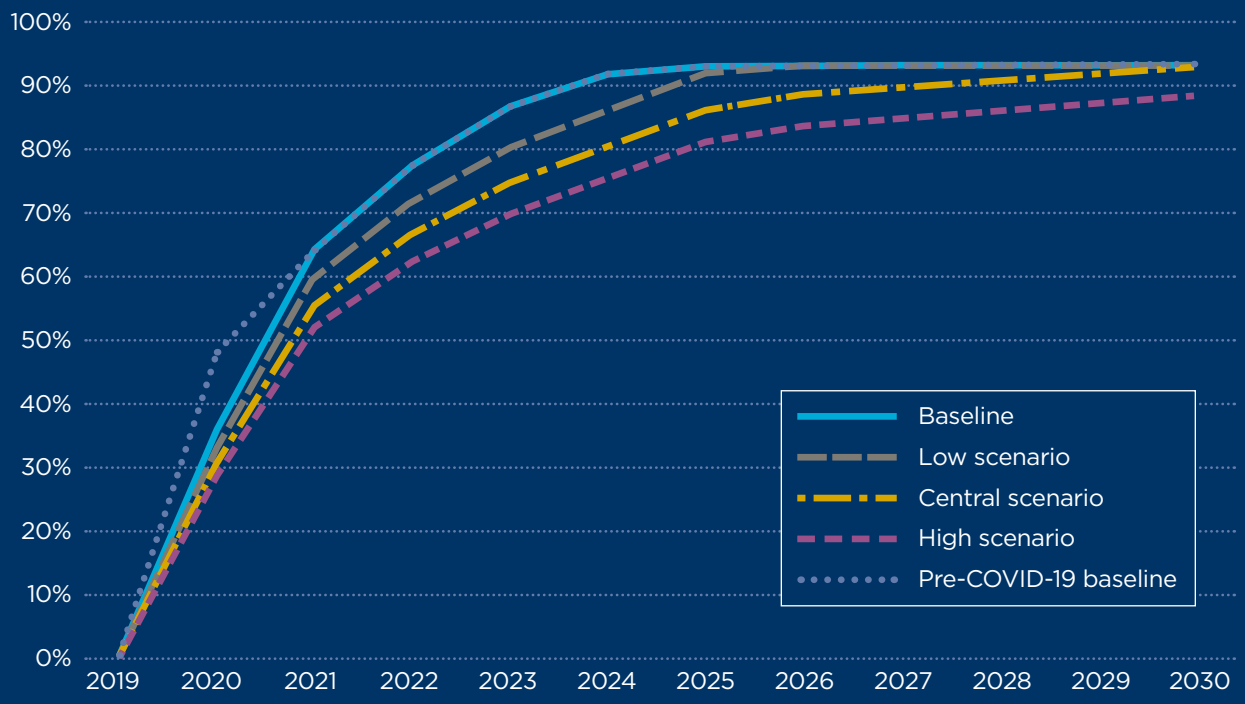
NETHERLANDS

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€25 mn (9%)	€52 million (19%)	€79 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	1.1 mn (6%)	2.1 million (12%)	2.9 mn (17%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€500 mn	€1.6 billion	€3.5 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The outbreak of coronavirus and cuts to global trade translate into a severe contraction in the Dutch economy, with GDP expected to contract by 4.4%. In the context of the slowdown and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in the Netherlands. 5G services and associated activities will stimulate economic activity worth €5 billion in GDP and support around 68,300 jobs in the Netherlands.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €52 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 2.1 million people (12% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in the Netherlands over the next 15 years. We estimate this could reduce GDP in 2035 by €1.6 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €25 million (9%) and €79 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 2.9 million more people (17% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €500 million and €3.5 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

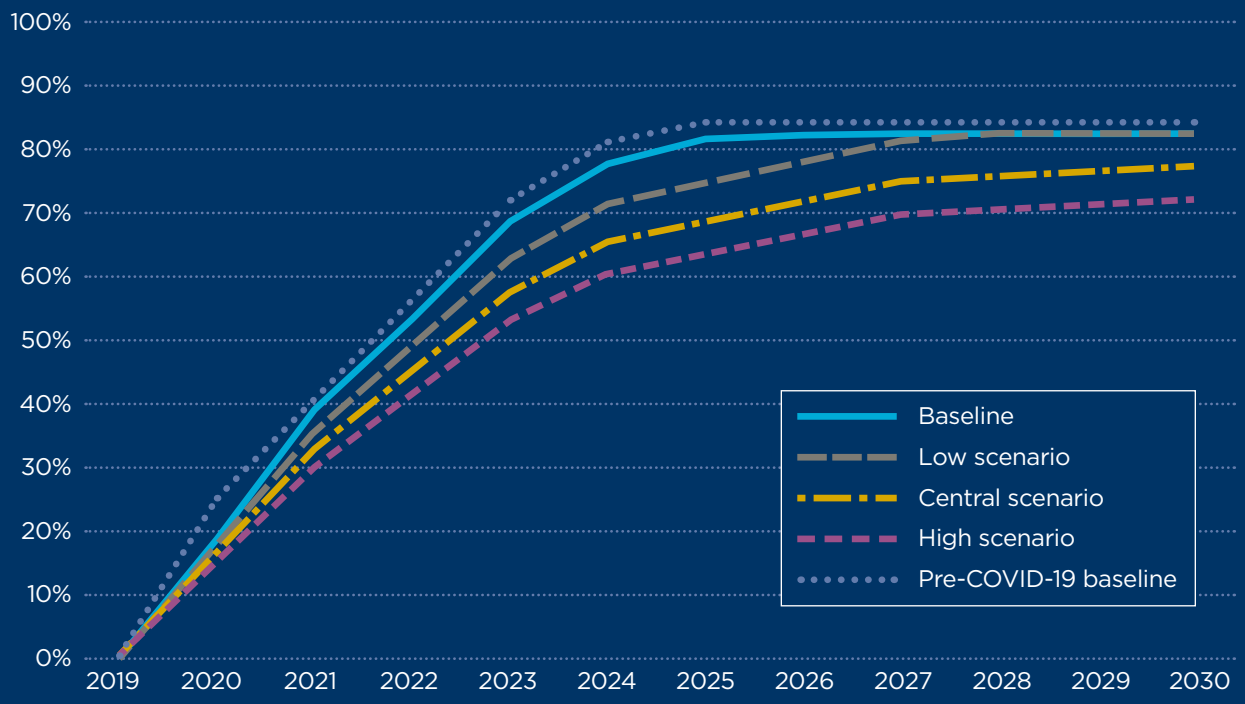
NORWAY

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€48 mn (9%)	€98 million (19%)	€149 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	300,000 (6%)	600,000 (11%)	900,000 (15%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€300 mn	€1.1 billion	€2.3 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The unprecedented measures set in place to battle the spread of coronavirus in Norway are likely to cause a sharp economic downturn this year. We still expect the nature of the recession to be sharp but short, with a strong recovery in the second half of the year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Norway.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €98 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 600,000 people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Norway over the next 15 years. We estimate this could reduce GDP in 2035 by €1.1 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €48 million (9%) and €149 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 900,000 more people (15% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €300 million and €2.3 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

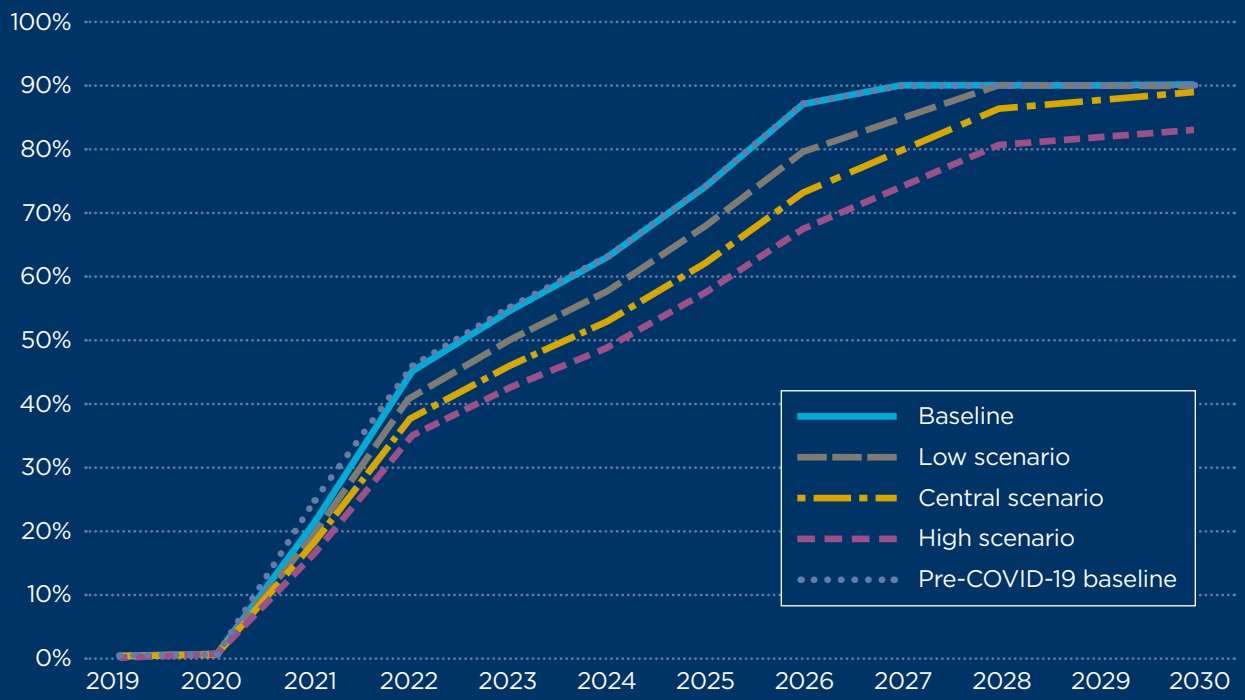
POLAND

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€58 mn (9%)	€120 million (19%)	€181 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	1.7 mn (5%)	3.3 million (9%)	4.6 mn (12%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€200 mn	€1.0 billion	€2.2 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Polish economy is expected to see a sharp downturn in economic activity as severe lockdown measures are put in place to contain the spread of the Coronavirus pandemic. Contingent on containment measures being lifted, we still expect the nature of the recession to be sharp but short, with a strong recovery in the second half of the year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Poland. 5G services and associated activities will stimulate economic activity worth €13 billion in GDP and support around 569,553 jobs in Poland.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €120 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 3.3 million people (9% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Poland over the next 15 years. We estimate this could reduce GDP in 2035 by €1 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €58 million (9%) and €181 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 4.6 million more people (12% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €200 million and €2.2 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

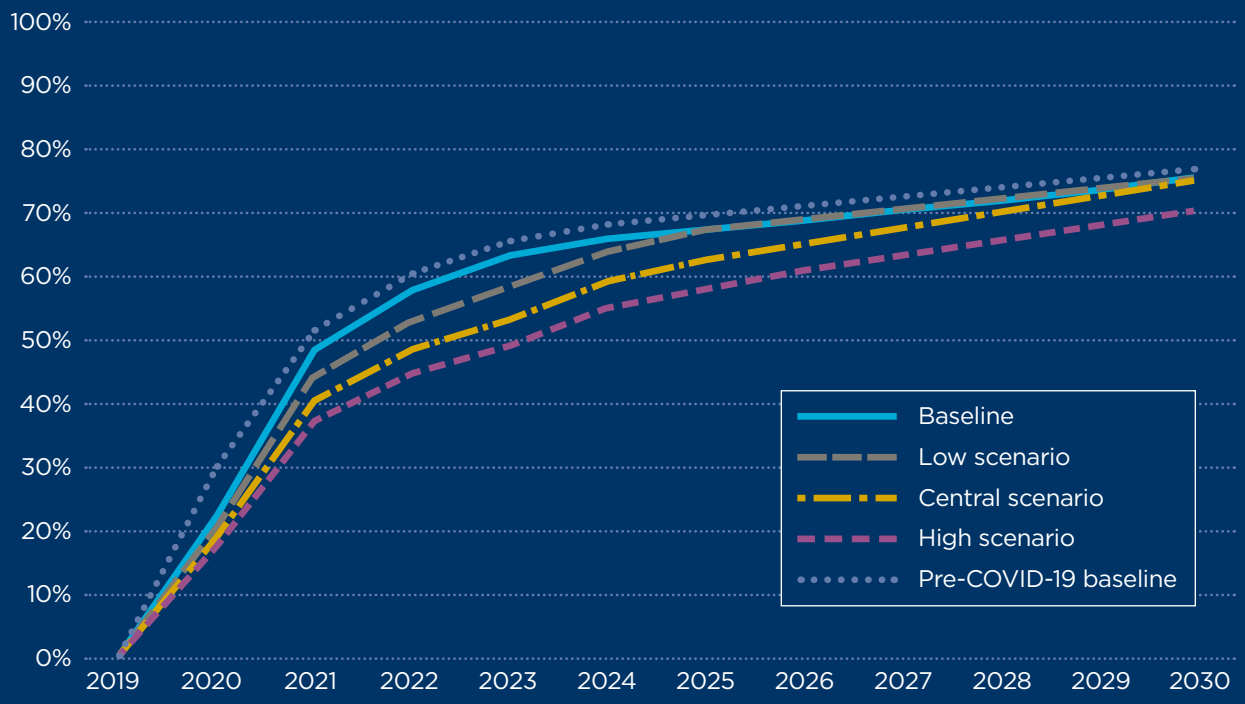
PORTUGAL

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€30 mn (9%)	€63 million (19%)	€95 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	500,000 (5%)	1.0 million (10%)	1.4 mn (14%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€100 mn	€500 million	€1.1 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Portuguese economy is expected to contract very sharply in 2020 due to the escalation of the coronavirus outbreak and the economic impact of the lockdowns, both domestically and all across Europe. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Portugal. 5G services and associated activities will stimulate economic activity worth €3.7 billion in GDP and support around 127,300 jobs in Portugal.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €63 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 1.0 million people (10% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Portugal over the next 15 years. We estimate this could reduce GDP in 2035 by €500 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €30 million (9%) and €95 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.4 million more people (14% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €100 million and €1.1 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

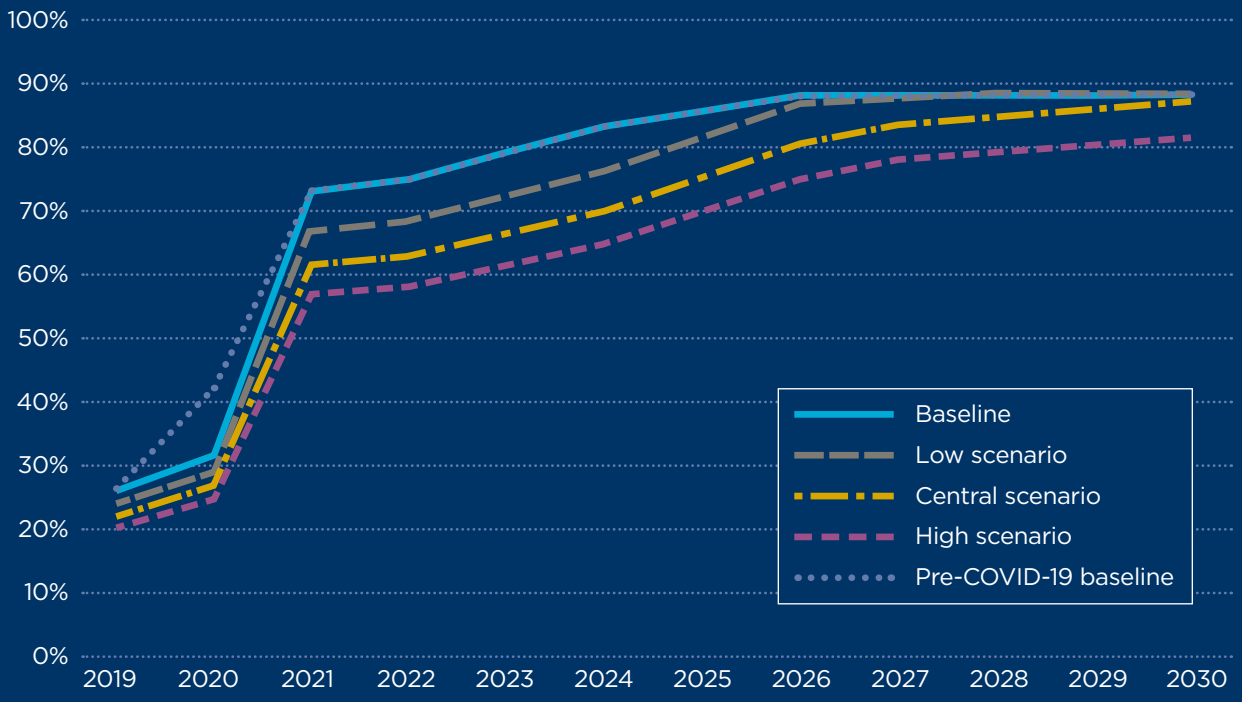
ROMANIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€28 mn (9%)	€59 million (19%)	€89 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	1.3 mn (7%)	2.4 million (13%)	3.3 mn (18%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€20 mn	€80 million	€200 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Romanian economy is expected to shrink sharply in 2020 given the fairly sizeable coronavirus outbreak in Romania and the massive economic impact of the lockdowns across Europe. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Romania. 5G services and associated activities will stimulate economic activity worth €4.6 billion in GDP and support around 252,300 jobs in Romania.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €59 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 2.4 million people (13% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Romania over the next 15 years. We estimate this could reduce GDP in 2035 by €80 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €28 million (9%) and €89 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 3.3 million more people (18% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €20 million and €200 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

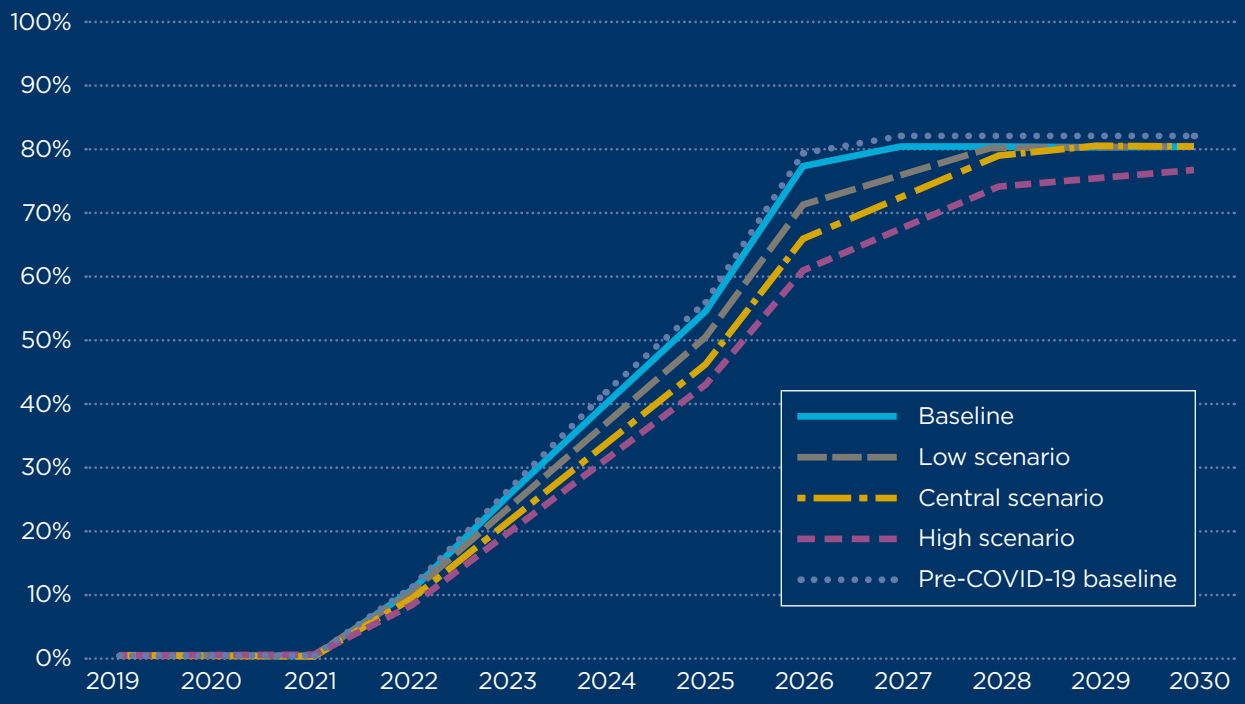
SLOVAKIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€15 mn (9%)	€31 million (19%)	€47 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	100,000 (2%)	200,000 (4%)	300,000 (5%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€100 mn	€200 million	€400 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The Slovak economy is expected to shrink sharply in 2020 as severe containment measures are put in place to stop the Coronavirus outbreak. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Slovakia. 5G services and associated activities will stimulate economic activity worth €2.0 billion in GDP and support around 71,500 jobs in Slovakia.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €31 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 200,000 people (4% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Slovakia over the next 15 years. We estimate this could reduce GDP in 2035 by €200 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €15 million (9%) and €47 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 300 million more people (5% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €100 million and €200 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

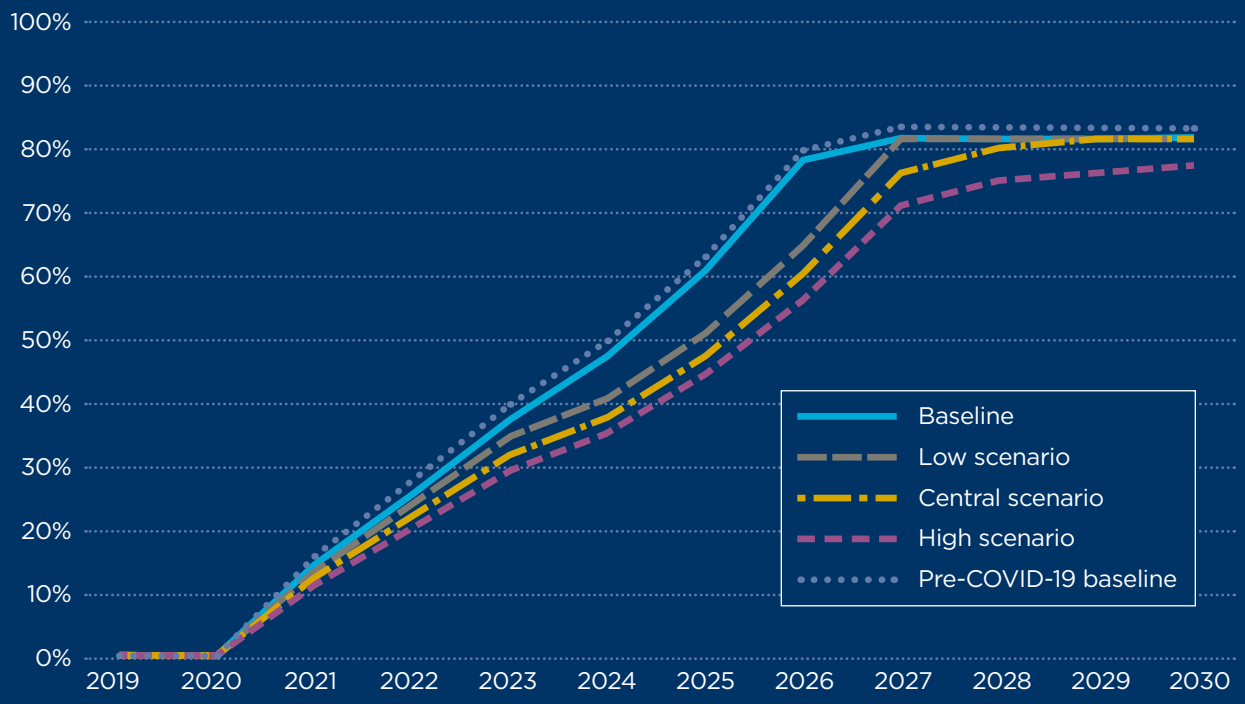
SLOVENIA

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€7 mn (9%)	€15 million (19%)	€23 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	60,000 (3%)	120,000 (6%)	160,000 (8%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€50 mn	€150 million	€280 mn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

GDP growth in Slovenia had already slowed down in 2019 and is expected to take a severe hit in 2020 as domestic and international demand drop sharply. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Slovenia. 5G services and associated activities will stimulate economic activity worth €610 million in GDP and support around 14,700 jobs in Slovenia.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €15 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 120,000 people (6% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Slovenia over the next 15 years. We estimate this could reduce GDP in 2035 by €150 million.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €7 million (9%) and €23 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 160 million more people (8% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €50 million and €280 million in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

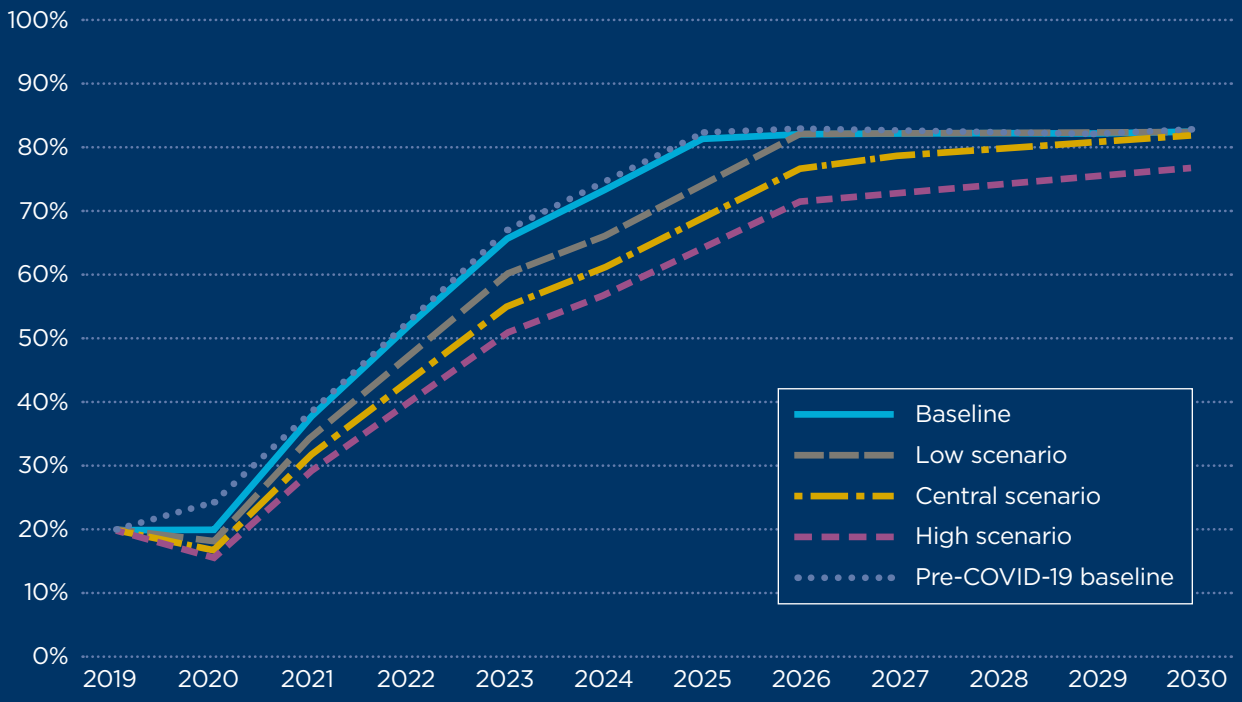
SPAIN

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€141 mn (9%)	€292 million (19%)	€442 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	2.7 mn (6%)	5.0 million (11%)	7.0 mn (15%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€1.2 bn	€3.7 billion	€8.1 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Lockdowns in Spain are taking a severe toll on the Spanish economy which saw the worst lost in GDP in decades in Q1 2020. However, the economy is expected to rebound strongly once the threat of the pandemic recedes. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Spain. 5G services and associated activities will stimulate economic activity worth €14.6 billion in GDP and support around 329,400 jobs in Spain.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €292 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 5 million people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Spain over the next 15 years. We estimate this could reduce GDP in 2035 by €3.7 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €141 million (9%) and €442 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 7 billion more people (15% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €1.2 billion and €8.1 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

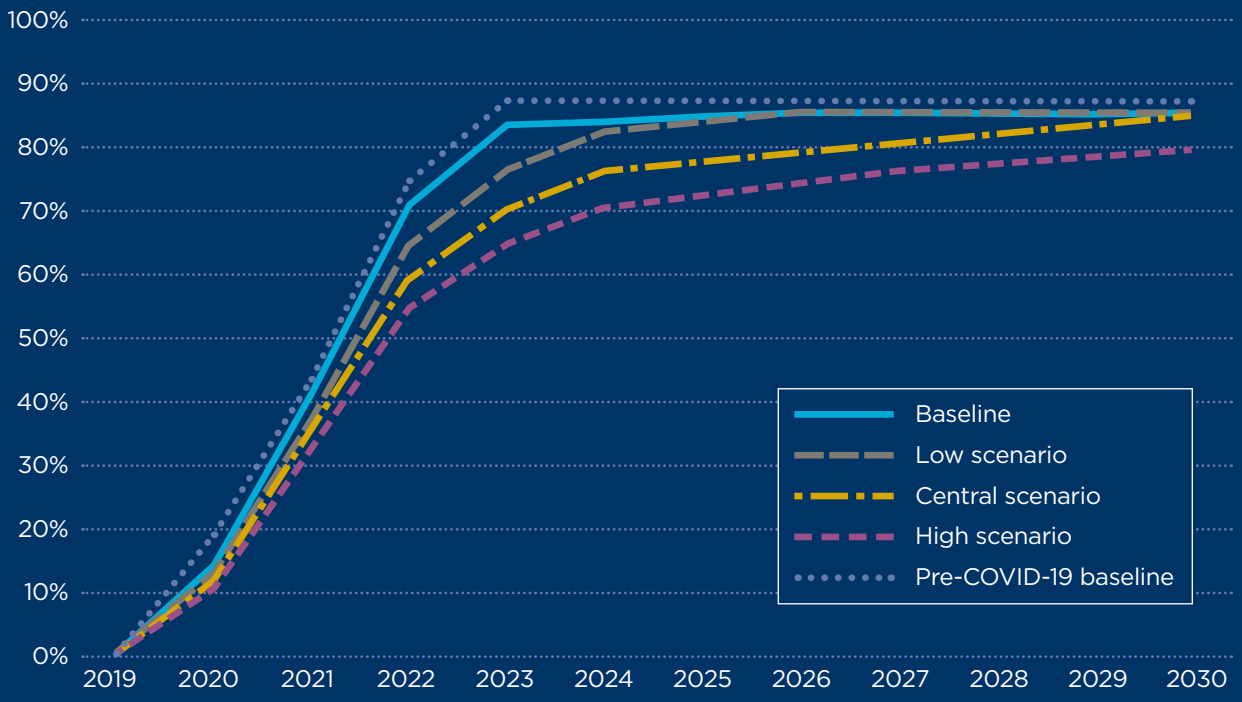
SWEDEN

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€31 mn (9%)	€64 million (19%)	€97 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	700,000 (7%)	1.4 million (13%)	2.0 mn (19%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€300 mn	€1.1 billion	€2.5 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The worsening impact of the coronavirus pandemic in Sweden has had a severe impact on Swedish GDP but the economy is well placed to recover in the following years. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Sweden. 5G services and associated activities will stimulate economic activity worth €2.5 billion in GDP and support around 25,300 jobs in Sweden.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €64 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 1.4 million people (13% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Sweden over the next 15 years. We estimate this could reduce GDP in 2035 by €1.1 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €31 million (9%) and €97 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 2 billion more people (19% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €300 million and €2.5 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

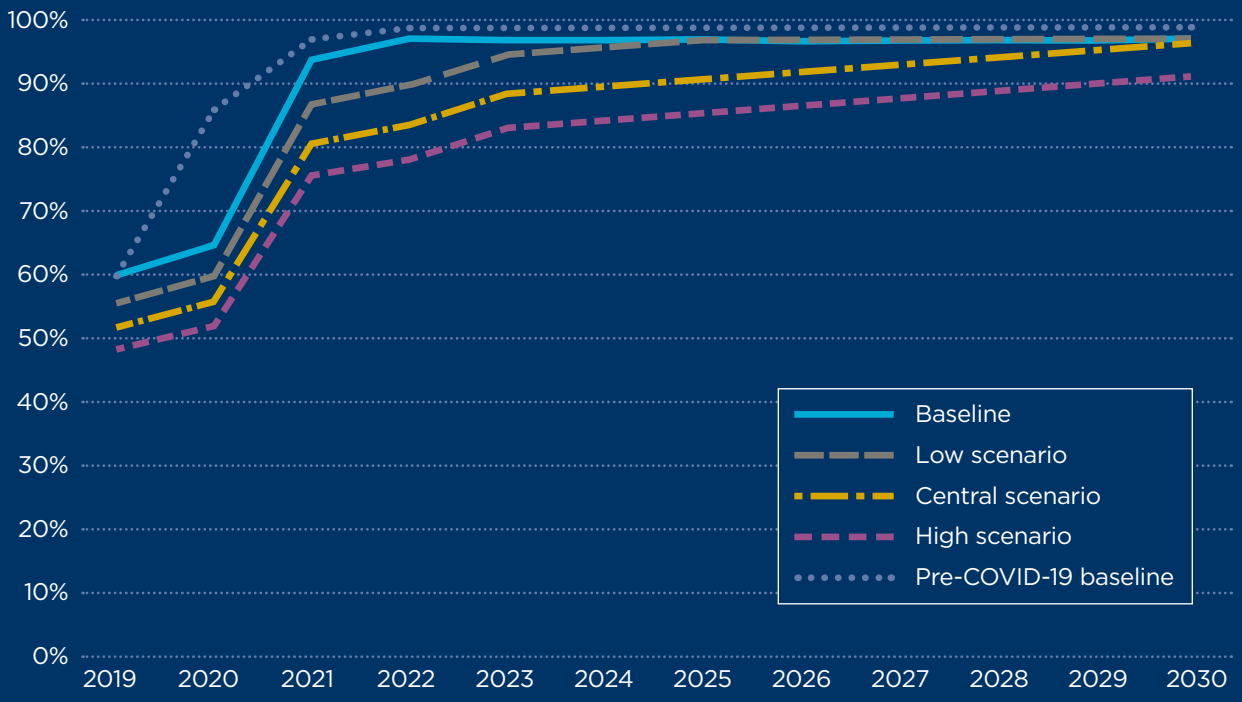
SWITZERLAND

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€45 mn (9%)	€94 million (19%)	€142 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	200,000 (2%)	800,000 (9%)	1.2 mn (14%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€400 mn	€1.7 billion	€4.3 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

Switzerland has seen its sharpest contraction in GDP in decades in Q1 2020 but is expected to recover gradually as the impact of the pandemic lessens. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in Switzerland.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €94 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 800,000 people (9% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in Switzerland over the next 15 years. We estimate this could reduce GDP in 2035 by €1.7 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €45 million (9%) and €142 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 1.2 million more people (14% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €400 million and €4.3 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

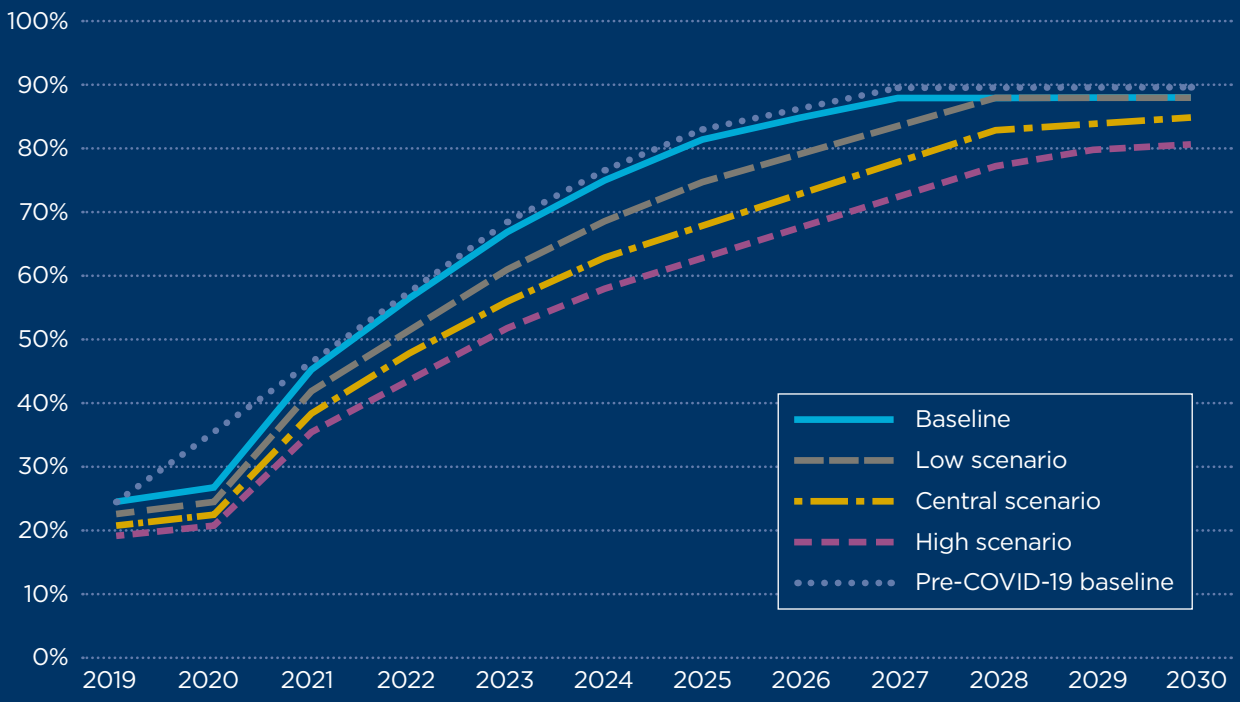
UNITED KINGDOM

IMPACTS OF RESTRICTING A MAJOR PARTICIPANT

	Low cost scenario	Central cost scenario	High cost scenario
Increase in average annual investment costs for 5G infrastructure over the next decade	€181 mn (9%)	€374 million (19%)	€567 mn (29%)
Absolute number of people who will have delayed access to 5G by 2023	3.9 mn (6%)	7.3 million (11%)	10.2 mn (15%)
Estimated permanent loss in GDP due to delay in 5G rollout in 2035	€1.3 bn	€4.4 billion	€8.6 bn

5G ROLLOUT RATES, WITH AND WITHOUT COMPETITION RESTRICTIONS

Percentage of population covered



Source: Oxford Economics

MARKET ANALYSIS

The extension of lockdown measures in the UK will translate into a sharp contraction in the UK economy in 2020. However, growth is expected to rebound strongly next year. In the context of the recession and the subsequent recovery, a competitive market for 5G infrastructure would help maximise the gains from technological innovation and growth in the UK.

On the other hand, restricting competition can have significant adverse economic impacts. Our modelling suggests restricting a major participant could increase the cost of building the 5G network by €374 million per year over the next decade (19% of baseline costs) in our central cost scenario. Due to these price increases, 7.3 million people (11% of the population) who would have otherwise had access to the 5G network could be left without access to a 5G network in 2023.

Restricting competition in the network infrastructure market may significantly reduce economic growth in the UK over the next 15 years. We estimate this could reduce GDP in 2035 by €4.4 billion.

The potential future benefits of 5G are hard to predict. While most industry players expect 5G to transform the economy, 5G may end up being merely an enhancement to the existing 4G technology. Or it could be revolutionary in the way the steam engine or electricity was. The uncertainty about the nature of benefits will also be reflected in the economic consequences of restricting competition in the network infrastructure market.

To account for this, we have modelled two additional scenarios that capture the lower and higher end of the range of potential future outcomes from competition restrictions in the 5G network market.

Across our scenarios, we expect the increase in average annual investment costs over the next 10 years due to competition restrictions to vary between €181 million (9%) and €567 million (29%). The wide range in these estimates is due to the uncertainty around the reaction of other vendors of network infrastructure.

This increase in prices would translate into delays in rollout. We estimate that these delays would leave up to 10.2 billion more people (15% of the population) without access to 5G by 2023.

The resulting loss in productivity has significant economic consequences. Lower economic growth due to delays in 5G rollout and the associated slower technological growth reduces GDP by between €1.3 billion and €8.6 billion in 2035.

Operators may also have to incur additional investment expenditure replacing existing network equipment built by the restricted operator. This could further delay rollout and technological innovation which could result in larger GDP losses.

APPENDIX 1: GLOSSARY OF TERMS

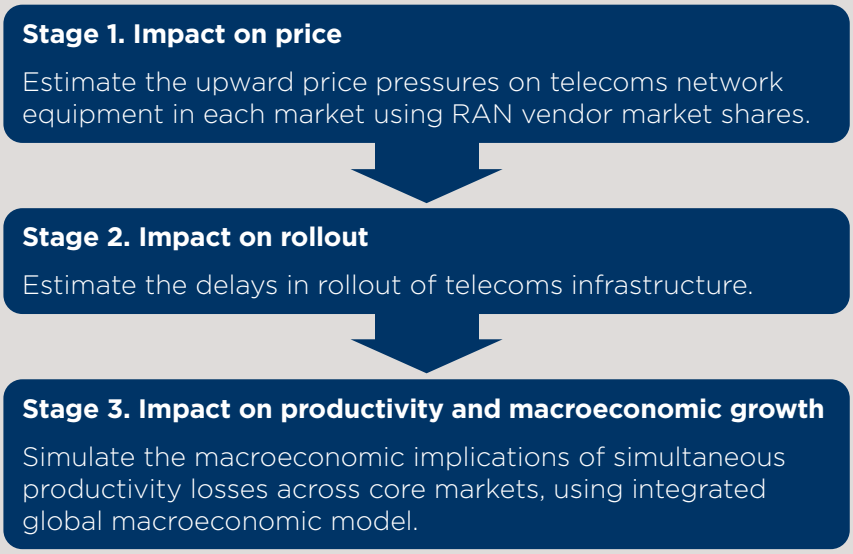
TERM	DESCRIPTION
1G	The first generation of mobile networks used analogue radio systems that allowed users to make phone calls but not send text messages.
2G	The second generation of mobile networks relied on digital signals, not analogue, which improved its capacity and allowed users to send text and multimedia messages.
3G	The third generation of mobile networks could transmit greater amounts of data that allowed users to video call, share files and surf the internet.
4G	4G, or the fourth generation of mobile networks, allowed for five-times faster data transmission compared to 3G networks, which allowed users to experience less buffering, higher voice quality, easy access to messaging services and social media, higher quality streaming and faster downloads.
5G	The fifth generation of mobile networks is expected to significantly improve speeds and capacity of mobile networks, which could lead to new trends such as connected cars, smart cities and smart homes and offices.
Augmented Reality	Augmented Reality combines virtual pictures or sounds with the real, or physical, world to enhance the environment. AR is being used in gaming, medicine, education, archaeology and architecture. For example, AR is used to support surgeries by providing virtual overlays to guide medical practitioners.
Average Revenue Per User (ARPU)	ARPU is the total revenue divided by the number of subscribers, a commonly used measure in communications, digital media and subscription services.
Compound Annual Growth Rate (CAGR)	CAGR is the annual rate of return required for a variable, say investment, to grow from its beginning value to its ending value assuming that the variable has been compounding over the time period.
Enhanced Mobile Broadband (eMBB)	Enhanced mobile broadband is one of the three possible use scenarios defined by the ITU (see below) for 5G. Under the eMBB use case, 5G will enable data-driven services that will require high speeds across a wide coverage area such as 360-degree video streaming, immersive virtual reality and augmented reality.
Global Economic Model (GEM)	We simulated the macroeconomic implications of restrictions in competition across the 31 economies using our Global Economic Model (GEM). See Appendix 3 for further details.
Internet of Things (IoT)	Internet of Things is a system of connected computing, mechanical and digital devices that can transfer data over a network without the need for human interaction. This will enable services such as remote health monitoring and automatic emergency notification systems.

TERM	DESCRIPTION
International Telecommunications Union (ITU)	The ITU facilitates international cooperation to enable standardisation of global communications networks so that networks and technologies seamlessly interconnect.
Latency	Latency is the amount of time between a command and its corresponding action over the internet.
Long Term Evolution (LTE)	Long Term Evolution, a 4G mobile communications standard
mMTC	Massive Machine Type Communications (mMTC) is one of the three possible use scenarios defined by the ITU (see above) for 5G. Under the mMTC use case, 5G will enable fully automatic generation, exchange and processing by devices, which would enable widespread adoption of the Internet of Things (IoT).
Mobile network operators (MNO)	Mobile Network Operators are providers of wireless communications services that own or control all the infrastructure necessary to deliver mobile network services to consumers (end users).
Network slicing	Network slicing allows the physical infrastructure to be split into several virtual networks that can be tailored to different end-users, thereby facilitating dedicated disruption-free networks for critical users such as health and transport services that are free from disruption from other consumer and business uses
Radio Access Network (RAN)	Radio Access Network (RAN) is a component of 5G network infrastructure. RAN consists mainly of mobile base stations that connect telecom networks wirelessly to mobile devices.
Ultra-Reliable Low-Latency Communication (URLLC)	Ultra-Reliable Low-Latency Communication (URLLC) is one of the three possible use scenarios defined by the ITU (see above) for 5G. Under this use scenario, 5G will cater to multiple advanced services that rely on quick response times such as autonomous driving, factory automation, smart grids and robotic surgeries.
Virtual Reality (VR)	Virtual Reality creates a simulated environment that is completely different from the real, or physical world. A person using VR equipment can look around the artificial world, move around in it and interact with features or items.

APPENDIX 2: MODELLING APPROACH AND METHODOLOGY

Economic theory dictates that restricting competition in any market will lead to upward prices pressures as well as negative implications for innovation. We have assessed the economic impact of banning Huawei from competing in the market for telecommunications network equipment, through a three stage modelling framework as illustrated in Fig. 13. We describe each step in more detail below.

Fig. 13: Three-stage modelling framework for assessing the economic costs of excluding Huawei from the telecoms network equipment market



STAGE 1: PRICE OF NETWORK EQUIPMENT

In the first stage of our assessment, we start by exploring the implications for the price of network equipment in each of our 31 target markets. We applied three alternate approaches, developed in collaboration with Dr Martin Pesendorfer (LSE), to establish an estimated range of impacts, to add credibility and depth to the findings:

The techniques used are:

- a **theoretical model of oligopoly** characterising the 5G network infrastructure market that simulates the change in price of network infrastructure associated with restrictions on competition;
- **merger simulation techniques** that are used by competition authorities to estimate the price impact following changes to the market such as a merger; and
- **empirical evidence** from a range of studies across industries that estimated the change in price following a merger.

For this study, we assume that if Huawei is restricted in each country's 5G infrastructure market, network operators in that market would switch to one of the two other large providers, Ericsson and Nokia, in proportion to their existing market shares. We believe that the other providers do not have the same global reach or breadth of products and services that would allow them to successfully compete for Huawei's potential customers, and therefore their market shares would remain unchanged.

We assume that 5G network equipment market shares over the next decade in the baseline (no restrictions on Huawei) will be closest to 4G (LTE) market shares in 2018. All our methods rely on the change in the Herfindahl-Hirschman Index (HHI) due to restrictions on Huawei. The HHI, which is a measure of concentration, increases by 1291 based on European 4G market shares.

Theoretical models of oligopoly

There are two standard models of oligopoly used in economic theory:

- **Cournot:** where firms compete by choosing quantity supplied and let market forces set prices;
- **Bertrand:** where firms compete by choosing prices and let market forces set quantities.

However, we do not believe that either of these standard models characterises the 5G network infrastructure market. Vendors, when participating in a tender, make decisions on prices, and therefore the Bertrand model may appear the most appropriate for our study. However, we understand that firms compete in prices as well as capacities and the decision to participate in tenders by network operators. Kreps and Scheinkman (1983) show that outcomes in the Bertrand market where firms make additional decisions on tender participation and capacities is similar to the outcomes from a Cournot setting.

We have built two variations of the Cournot model: with linear demand curves (Motta 2007) and with constant elasticity of substitution (CES)[23] demand curves (Pindyck and Rubinfeld 2017). The price impact in the linear demand curve model relies on the number of existing credible competitors (which we define as the number of competitors with more than 5% market share in the 4G LTE network market). Based on 4G LTE network equipment market shares in 2018, we expect the number of credible competitors to decline from 4 to 3 in Europe. This implies an increase in price of RAN equipment of 16%.

The price impact in the CES model depends on the change in HHI[24]. Again, using 4G LTE network market shares in 2018 as the basis for our calculations, we estimate that HHI in Europe would change by 0.13% which implies a median increase in price of 24%.

Merger simulation techniques

We have also adapted the merger simulation tool (used by economists to quantify the impact of mergers) to estimate the price impact of restrictions on Huawei. The price impact depends on the diversion ratio[25] and the profit margin. Using the 4G LTE network market shares, we estimate the diversion ratio would be 52.4% and 47.6% for Ericsson and Nokia respectively. We then combine these diversion ratios with an assumption of 34% profit margin, based on Gross Margins for the Telecom Equipment sector from the NYU Stern dataset (Damodaran, 2019). The implied increase in price is approximately 9% across Europe.

Empirical evidence

We have also estimated the price increase by adapting the findings from a EC retrospective review of mergers. The EC (2015) reviewed 27 papers that used different econometric techniques to estimate the price effects following a merger. Of these, 11 studies included information on HHI that allowed us to adapt the findings to our study. Fig. 14 shows the change in price corresponding to the 11 mergers. The change in price is adjusted by the change in HHI to enable comparison across studies. The median price increase is 2.43% per 100 unit change in HHI.

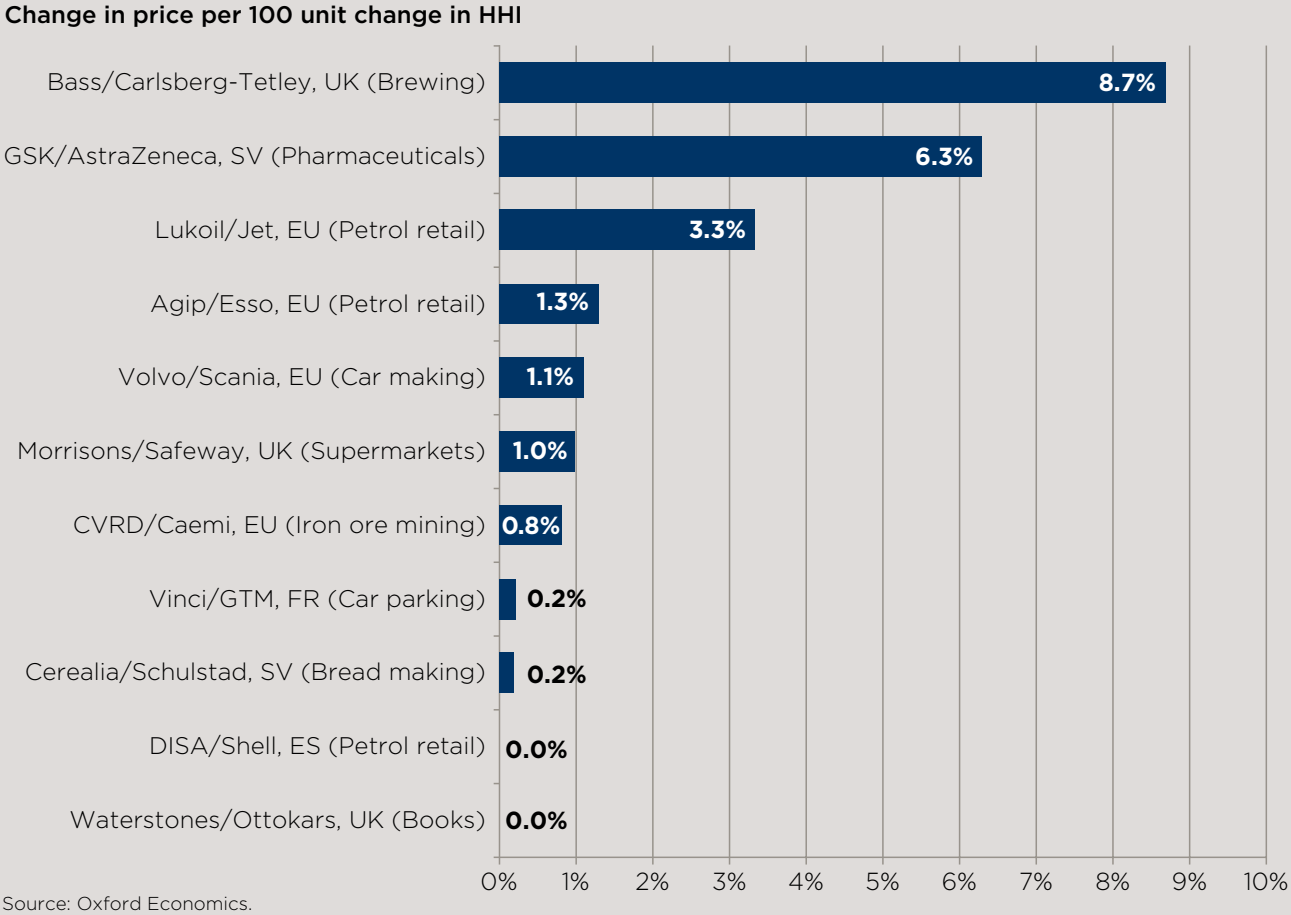
We then combine the median price increase per 100 unit change in HHI along with our estimated increase in HHI, of 0.13% in Europe, to estimate a price impact of 31%.

[23] Constant Elasticity of Substitution (CES) implies that the percentage change in demand for a 1% change in price remains constant at all levels of RAN equipment. We use estimates of the elasticity of digital infrastructure estimates from the literature (UK National Infrastructure Commission 2017) – between -0.4 to -0.8 – as proxies for RAN elasticities.

[24] HHI is an indicator of market concentration, calculated as the sum of squared market shares. We assume that when Huawei is restricted, Huawei's market share is distributed between Nokia and Ericsson proportionate to their market shares in the counterfactual (with Huawei). We use market shares in the 4G network equipment market as the basis for our calculations.

[25] A diversion ratio measures "where product goes" from Firm A (Huawei, in this instance) when there is a price rise or other event (restrictions on Huawei, in this instance). For example, if 20% of sales would go to Firm B when Firm A raises its price, then the diversion ratio of A to B would be 20%.

Fig. 14: Estimated change in price following a merger, percentage change per 100 unit change in HHI



Source: Oxford Economics.

Combining results from various price models

The results from the three approaches above are combined to provide a range of estimates for the price impact: from 9% to 31%. The wide range of estimates for each country presented on the previous slide reflect the competitive nature of the regional markets.

However, the market for RAN equipment is global – vendors compete internationally. To reflect the global nature of the market, we adjust the range for each country. We limit the minimum and maximum estimates on either side by two percentage points over the worldwide ranges (10% to 27%).

Therefore, the lower range of estimates for Europe is within the bounds suggested by the rule above, but the upper bound is higher than that implied by the rule and therefore is adjusted down to 29%.

To capture the range of potential reactions following the imposition of restrictions on Huawei, we define three scenarios—low, central and high—based on the lower end, median and higher end of the range of estimates for each country.

STAGE 2: IMPACT ON ROLLOUT

An increase in the price of network reduce the commercial incentive to build the network, thereby delaying the rollout of 5G. This is more likely in areas with lower population densities or more remote areas. Further, if the costs of 5G network are high, then operators are likely to charge higher prices for 5G services.

This could affect the potential take up of the technology and focus 5G activity on the most profitable business uses. With slower adoption rates, businesses are less likely to invest in technologies that use 5G such as IoT. We used the price impacts (i.e., investment costs for network operators) from Stage 1 to estimate the delay in rollout in each of the 31 countries.

We translated the increase in investment costs to delays in rollout using a network rollout model built in collaboration with Dr Edward Oughton (University of Oxford). This model translates an increase in investment costs to a reduction in the share of the population covered for each country and scenario by assuming that the overall operators' capex remains the same.

Baseline rollout and required capex per person

To define the baseline, we start with the GSMA network coverage forecasts, which provides the share of population covered by 5G for each year until 2025. The pandemic seems set to significantly slow the near-term rate of 5G rollout across the various countries in our study. GSMA has predicted that the pandemic will reduce global 5G coverage by around 25% this year.

However, 5G rollout is expected to start returning to levels planned pre-pandemic but some long-term impacts are likely. For the 2021-2025 period, we adjust the GSMA projections for 5G rollout in line with our forecasts of the impact of coronavirus on private sector business investment.

We extend these forecasts for subsequent years until 2030 using our judgement and relying on the 4G forecasts in comparable years. The share of population covered is translated into the number of people covered using population forecasts from WDI.

To estimate the associated capex required per person covered, we use:

- GSMA yearly capex forecasts (kept constant at the 2025 level for years beyond 2025); and
- the number of people covered (from the previous step).

The impact on rollout is estimated by re-drawing the rollout curves with the same level of capex as in the baseline but with increased required capex per capita.

Translating the price impact into a capex impact

For each country and scenario, the increase in prices translates into an increase in the capex required per capita. For example, if restrictions on Huawei lead to a 10% increase in prices, then the per capita capex required to extend 5G coverage increases by 10%.

Re-drawing rollout curves with increased prices

Assuming the operators maintain their capex budgets, they are now able to cover fewer people due to the increase in required per capita capex. For each country and scenario, we calculate the number of people who would be covered by 5G using:

- the increased per capita required capex; but
- with the same levels of capex as in the baseline.

The new rollout curve is derived by translating the absolute number of people into a share of the population for each year.

STAGE 3: IMPACT ON PRODUCTIVITY AND MACROECONOMIC GROWTH

Next, we estimated the productivity implications of such price changes across each economy. The associated loss of productivity will be derived from two channels as follows:

- The higher cost of rolling out the 5G network will represent a direct loss of productivity reflecting a reduced level of allocative efficiency.
- The delays and reduced scale of 5G rollout will diminish the future productivity gains that will be yielded by 5G.

The former is based on the results of the price model and estimates of 5G expenditure based on the GSMA capex forecasts and our judgement. We will then assess how this increase in investment costs raises the costs to businesses resulting in a loss of productivity across the economy.

There are a wide range of estimates of how 5G will improve productivity in the future. Fig. 15 shows the range of estimates for a variety of different technologies (both ICT and non-ICT) from various studies.[26] We use the estimates from these studies to define the baseline (i.e., no restrictions on Huawei) productivity impact from 5G. Restrictions on Huawei lead to slower rollout and therefore slower productivity growth. The productivity gains from 5G with restrictions is therefore calculated as the baseline productivity growth scaled down to reflect the slower rollout estimated in Stage 2. The productivity impact is the difference between the productivity growth in the no-restrictions and restrictions scenarios.

The impact on productivity due to slower rollout depends on the baseline (i.e., no restrictions) productivity growth assumptions. To capture the uncertainty in the productivity growth assumptions, again, we use three different scenarios:

- Low cost scenario to reflect only an increase in speed: 0.15% based on the estimates of productivity growth from 2G to 3G;
- Central cost scenario to reflect a transformative change in technology: 0.15% per year in the first year of rollout and increasing to 0.30% per year over a five-year period; and
- High cost scenario to reflect a revolutionary change in technology: 0.30% per year.

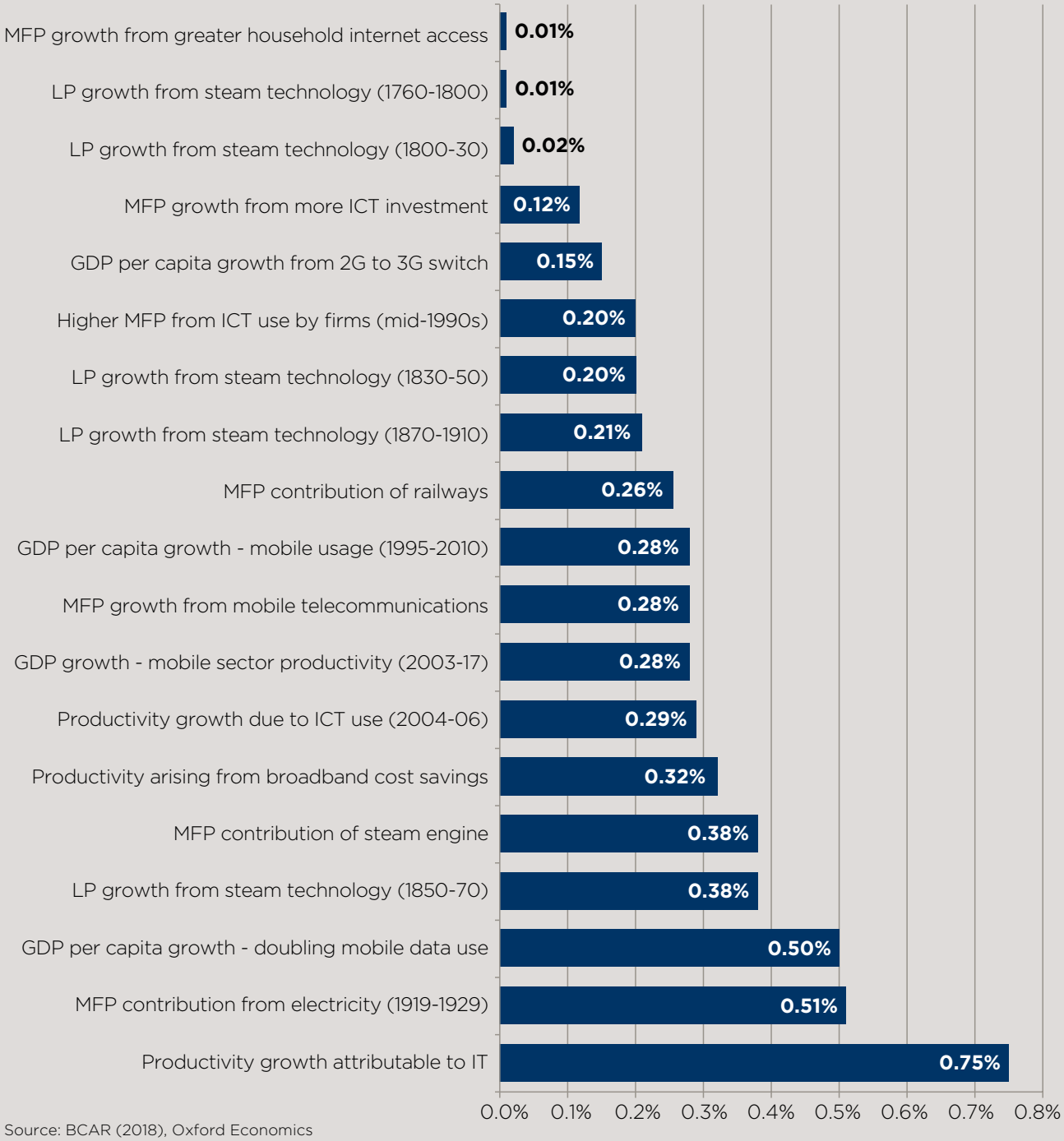
The 0.15% per year assumption is based on the estimated productivity growth associated with the transition from 2G to 3G, whereas the 0.30% per year growth assumption is based on the median values from Fig. 15, excluding the top- and bottom-four outlying estimates. The low cost, central cost, and high cost scenarios are paired with the low cost, central cost, and high cost scenarios for prices respectively, to limit the number of scenarios in our study to three. Finally, we simulated the macroeconomic implications of this simultaneous slowdown in productivity growth across the 31 economies using our Global Economic Model (GEM).[27]

The inputs from the previous stages are used as inputs to the GEM which we can use to quantify the macroeconomic implications of these changes. The slowdown in productivity growth will reduce the respective economy's capacity to supply goods and services. The equation structure of each economy works to ensure that in the long-term such a slowdown in trend growth is matched by a commensurate drop in the actual level of GDP so that demand equals supply, a state that economists refer to as 'equilibrium'. For this type of scenario, it is appropriate to focus on the long-term structural implications of these changes as opposed to any short-term cyclical effects. Therefore, we have used a reference year—2035—to report the results.

[26] Bureau of Communications and Arts Research (BCAR). 2018. Impacts of 5G on productivity and economic growth, Working paper. https://www.communications.gov.au/publications/impacts-5g-productivity-and-economic-growth
[27] See Appendix 3 for a detailed description of the GEM

Fig. 15: Comparison of estimated productivity impacts of historical technological advances

Change in productivity due to technology (average annual growth rate)



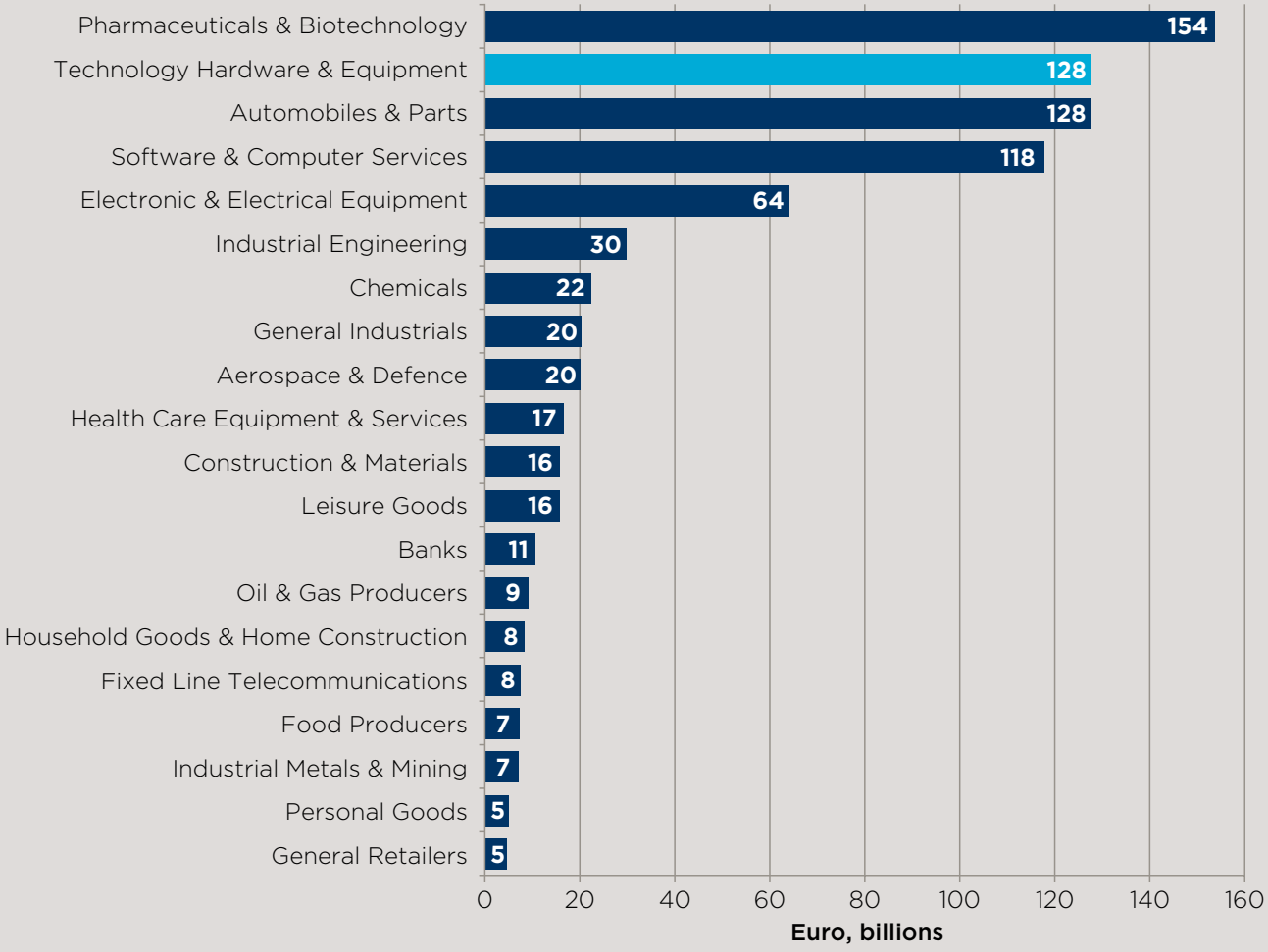
Source: BCAR (2018), Oxford Economics

MODELLING ASSUMPTION: REDUCED INVESTMENT IN R&D AND LOSS IN INNOVATION

Our modelling methodology only models the economic impact of a reduction in competition when a vendor of Huawei's size is excluded from the market. We do not estimate the impact due to the reduction innovation due to the loss in Huawei's technological and operational capabilities.

Equipment vendors have engaged in continuous innovation in new generations of radio access technology and core system products. Telecom network equipment vendors are among the largest spenders on R&D globally. As shown in Fig. 16 and Fig. 17, the technology, hardware and equipment industry is the second-largest spender on R&D and also has the third-highest R&D intensity (share of revenues spent on R&D)[28]. As shown in Fig. 18, Huawei is the largest spender on R&D in the Technology, Hardware and Equipment industry—spending more than €12 billion—more than Intel and Apple as well as other competitors in the RAN market such as Ericsson and Nokia.

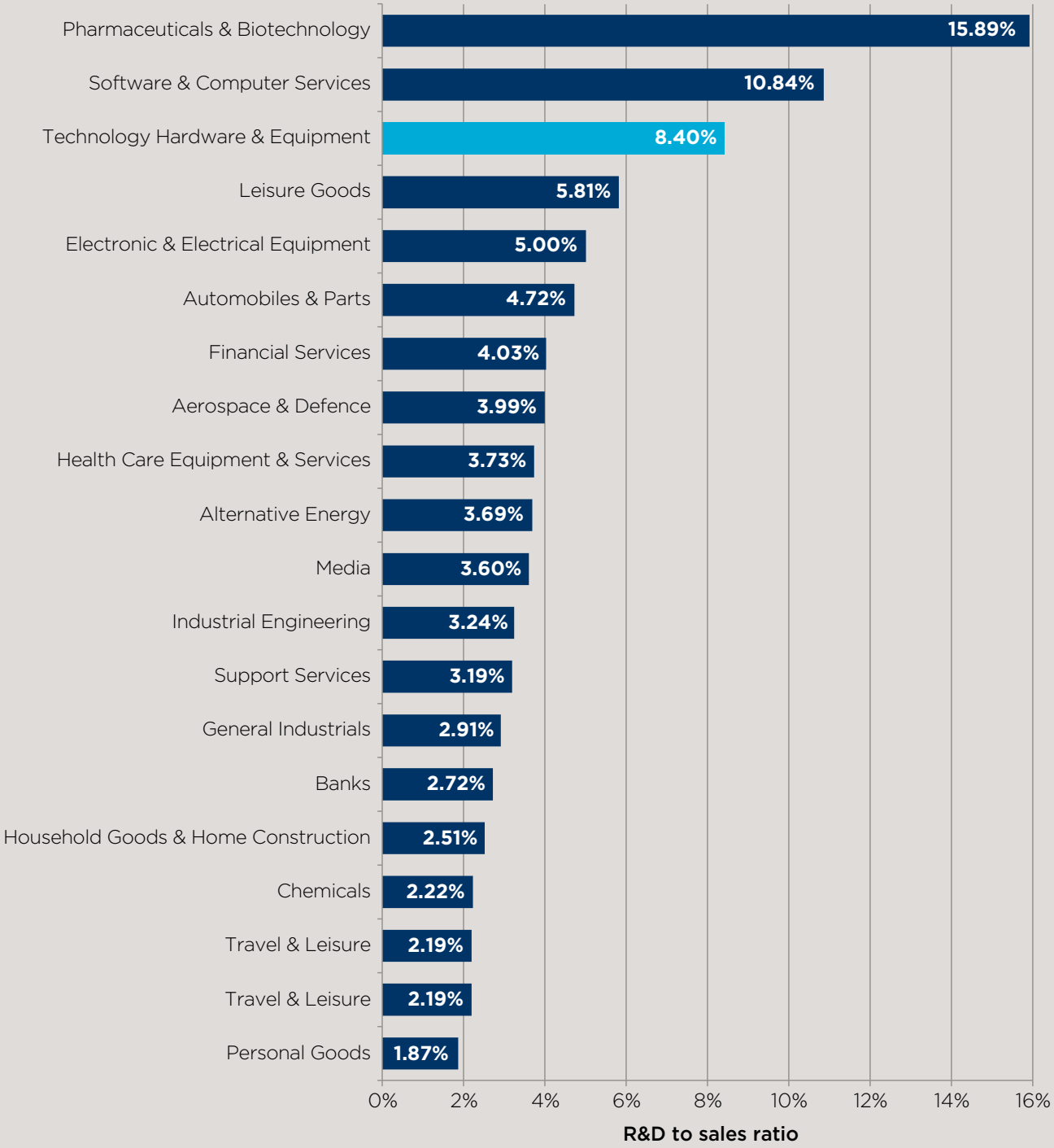
Fig. 16: R&D expenditure by the top 2,500 companies globally, categorised by their main industrial sector of activity, 2018/19



Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD, Oxford Economics

[28] The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

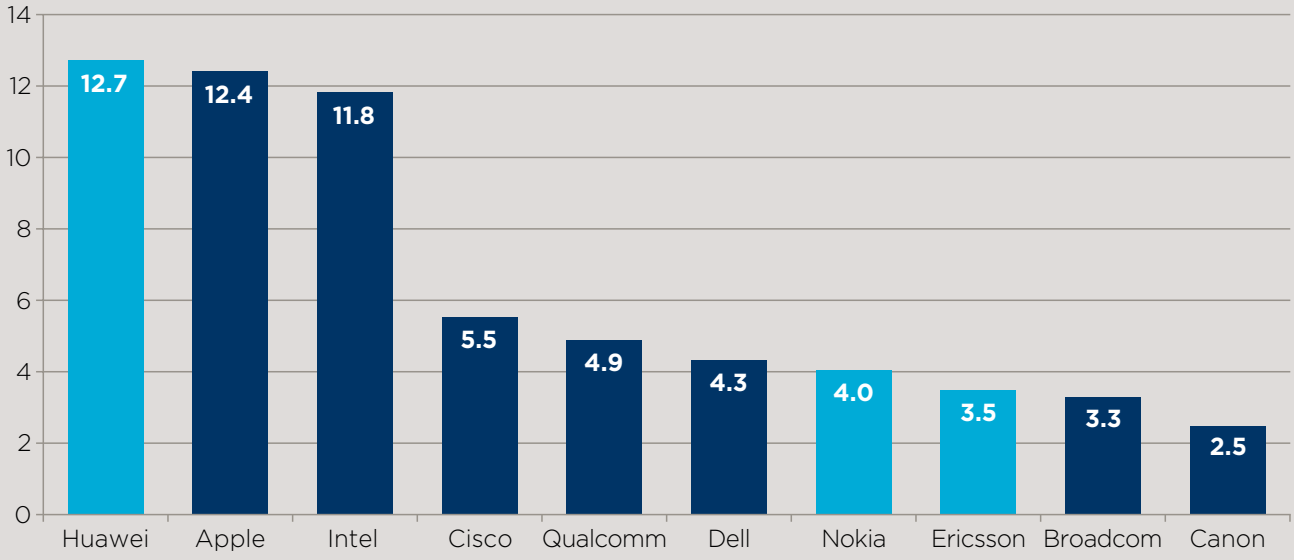
Fig. 17: R&D intensity by the top 2,500 companies globally, categorised by their main industrial sector of activity, 2018/19



Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD, Oxford Economics

Fig. 18: R&D by top 10 companies in the technology, hardware and equipment industry, 2018/19

Euro, billions



Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD, Oxford Economics

ACCOUNTING FOR UNCERTAINTY

While we have used a wide range of industry and academic estimates to inform our modelling, it is not possible to predict the potential benefits of 5G, or the market reaction to excluding a company the size of Huawei, with any certainty. Hence our inclusion of scenarios to capture the higher and lower end of the range of potential productivity benefits from 5G, as well as the central cost scenario.

LIMITATIONS OF THIS STUDY

In addition, it should be noted that this report focuses on the quantifiable economic impacts of an increase in the concentration of the 5G infrastructure market, due to restrictions on a vendor of Huawei's size. We do not account for the loss of technological knowhow and capabilities that are unique to Huawei—which is among the world's leading spenders on R&D and is considered to have an advantage over its competitors due to its technological prowess.

We assume that Huawei's customers are serviced by the two other competitors which have the global reach and breadth of services and products comparable to Huawei's, i.e., Nokia and Ericsson. The price impacts would be higher if these network providers do not have the capacity to take on Huawei's customers.

Conversely, the price impacts would be lower if another competitor could scale up its global reach and range of products to successfully take up Huawei's place in the market. When modelling the delays in rollout due to increases in investment costs, we assume that the operators do not face additional constraints in the capital markets. For example, an increase in investment costs would increase capital requirements which in turn could increase the cost of capital and therefore, would further increase the adverse productivity impacts. While our scenarios aim to capture a wide range of uncertainty, the factors listed above, while unlikely in our opinion, could result in impacts beyond the range suggested by our scenarios.

APPENDIX 3: THE GLOBAL ECONOMIC MODEL

The GEM is the most widely used commercial macroeconomic model in the world. 46 of the largest economies (which together account for over 90% of global GDP) are covered in depth by individual country models, with the remainder accounted for by regional blocs. Most of the core behavioural equations are specified in an Error Correction Mechanism (ECM) format.

We simulated the macroeconomic implications of restrictions in competition across the 31 economies using our Global Economic Model (GEM). Below, the key theoretical features of the model are discussed in more detail.

SUPPLY SIDE

The structure of each of the country models is based on the income-expenditure accounting framework. However, the models have a coherent treatment of aggregate supply. In the long run, each of the economies behaves like the classic one sector economy under Cobb-Douglas technology. Countries have a natural growth rate, which is determined by its capital stock, labour supply adjusted for human capital, and TFP. Output cycles around a deterministic trend, so the level of potential output at any point in time can be defined, along with a corresponding natural rate of unemployment.

Firms are assumed to set prices given output and the capital stock, but the labour market is characterised by imperfect competition. Firms bargain with workers over wages but choose the optimal level of employment. Under this construct, countries with higher real wages demonstrate higher long run unemployment, while countries with more rigid real wages demonstrate higher unemployment relative to the natural rate.

INFLATION AND MONETARY POLICY

Inflation is a monetary phenomenon in the long run. All of the models assume a vertical Phillips curve, so expansionary demand policies place upward pressure on inflation. Unchecked, these pressures cause an unbounded acceleration of the price level. Given the negative economic consequences of this (as seen in the 1970s in developed economies and more recently in some emerging markets), most countries have adopted a monetary policy framework which keeps inflation in check. The model mirrors this, by incorporating endogenous monetary policy.

For the main advanced economies, monetary policy is underpinned by the Taylor rule, captured using an inflation target, such that interest rates are assumed to rise when inflation is above the target rate, and/or output is above potential. The coefficients in the interest rate reaction function, as well as the inflation target itself, reflect assumptions about the hawkishness of different country's monetary policymakers.

Quantitative easing, whereby the central bank prints money and uses it to purchase assets in order to stimulate the economy, has played an important role as a policy tool in the aftermath of the Great Recession. The model introduces this policy using an exogenous variable for the US, Japan, the Eurozone, and the UK. All else equal, QE lowers government bond yields and boosts share prices through portfolio effects.

In addition, a number of central banks have begun using Forward Guidance in an attempt to influence the yield curve using verbal descriptions of their expectations about future monetary policy. The GEM also introduces this policy as an exogenous variable for the US, Japan, and UK. This variable affects exchange rates, long-term government bond yields, and share indices. US Forward Guidance also affects confidence levels and exchange rates in some other countries, which in turn alter consumption, investment, and impose additional amplification on share price effects. The relative effects of changes in Forward Guidance were calibrated after the Fed's May 18, 2009 policy announcement.

AGGREGATE DEMAND

Private consumption is modelled as a function of real incomes, real financial wealth, real interest rates and inflation. Investment equations are underpinned by Tobin's Q Ratio, such that the investment rate is determined by the return relative to the opportunity cost, adjusted for taxes and allowances. Countries are assumed to be "infinitely small", in the sense that exports are determined by aggregate demand and a country cannot ultimately determine its own terms of trade. Consequently, exports are a function of world demand and the real exchange rate, and the world trade matrix ensures adding-up consistency across countries. Imports are determined by real domestic demand and competitiveness.

GDP AND EMPLOYMENT BY SECTOR

In addition to the income-expenditure approach, the Global Economic Model includes a break-down of value added and employment by sector. Consistency between the income-expenditure and value added approaches to output is ensured by scaling value added in each sector up or down to obtain expenditure based value added as the sum of value added in the sectors.

The sector breakdown reflects the input-output structure of each economy. For each sector total demand is calculated as a weighted average of value added in other sectors and final expenditure, with the weights taken from input-output tables. We then use total demand to estimate the value added for that respective sector since in the long run (everything else equal) value added and demand must grow in line with each other. Value added is also affected by competitiveness (measured by relative unit labour costs) to a degree that reflects the international openness of each sector.

Employment by sector is derived from value added in that sector and sector-specific productivity trends. As in the case of value added, consistency between the total employment forecast and employment in all sectors is achieved by scaling the sector employment variables up or down.

The breakdown of value added and employment by sector depends on data availability and varies by country. For instance, for the European Union it consists of 14 sectors– agriculture and forestry, extraction, manufacturing, utilities, construction, distribution services, hotels and catering, transport and communications, financial services, business services, public administration, education, health and other services. Several additional sectors such as entertainment, arts and recreation and real estate are also included for the United States. The breakdown for Asia is less detailed.

TREATMENT OF EXPECTATIONS

Finally, the Oxford Global Economic Model assumes adaptive rather than forward-looking expectations because we believe that introducing expectations on the basis of economic theory is more advantageous than using the forward-looking assumption ubiquitously.

There is disagreement among economists about whether forward-looking expectations are consistent with observed data, which has become even more acute in light of the difficulties with obtaining accurate data on expectations for model-building purposes. Instead, we adopt adaptive expectations, which are introduced using a framework in which expectations are formed using the actual predicted values from the model. Exogenous variables are assumed to be known a priori. Where appropriate, the model does introduce expectations implicitly and explicitly, therefore accounting for how and the extent to which agents respond to information about changes in fundamentals. An example of this includes our derivation of exchange rate forecasts which implicitly capture expectations: in the short run, the exchange rate is driven by movements in domestic interest rates relative to the US, therefore accounting for uncovered interest rate parity. Another example is our use of a variable for forward guidance to capture expected movements in interest rates.

APPENDIX 4: FULL RESULTS

Country	Increase in investment costs (€ millions)	Reduction in number of people with access to 5G by 2023*	Reduction in GDP in 2035 (€, 2020 prices)
Austria	35 to 111	600,000 to 1.5 million	300 million to 2.3 bn
Belgium	31 to 98	900,000 to 2.3 million	300 million to 2.5 bn
Bulgaria	9 to 30	300,000 to 900,000	30 million to 250 million
Croatia	11 to 35	100,000 to 300,000	30 million to 200 million
Cyprus	3 to 10	21,000 to 53,000	10 million to 60 million
Czech Rep.	28 to 87	600,000 to 1.6 million	100 million to 1.1 bn
Denmark	14 to 43	400,000 to 1.1 million	200 million to 1.4 bn
Estonia	5 to 15	70,000 to 190,000	15 million to 150 million
Finland	38 to 120	300,000 to 900,000	100 million to 800 million
France	217 to 678	2.1 million to 5.6 million	2.3 bn to 14.4 bn
Germany	232 to 726	6.3 million to 16.7 million	2.3 bn to 15.3 bn
Greece	18 to 57	400,000 to 1.2 million	200 million to 1.2 bn
Hungary	27 to 83	300,000 to 700,000	100 million to 600 million
Iceland	1 to 5	11,000 to 30,000	5 million to 33 million
Ireland	13 to 41	150,000 to 540,000	200 million to 1.7 bn
Italy	137 to 428	3.7 million to 9.7 million	1.5 bn to 10.2 bn
Latvia	4 to 12	90,000 to 250,000	20 million to 160 million
Lithuania	4 to 13	100,000 to 300,000	20 million to 130 million
Luxembourg	3 to 8	20,000 to 70,000	40 million to 310 million
Malta	2 to 5	10,000 to 30,000	20 million to 60 million
Netherlands	25 to 79	1.1 million to 2.9 million	500 million to 3.5 bn
Norway	48 to 149	300,000 to 900,000	300 million to 2.3 bn
Poland	58 to 181	1.7 million to 4.6 million	100 million to 1.1 bn
Portugal	30 to 95	500,000 to 1.4 million	100 million to 1.1 bn
Romania	28 to 89	1.3 million to 3.3 million	20 million to 200 million
Slovakia	15 to 47	100,000 to 300,000	100 million to 400 million
Slovenia	7 to 23	60,000 to 160,000	50 million to 280 million
Spain	141 to 442	2.7 million to 7.0 million	1.2 bn to 8.1 bn
Sweden	31 to 97	700,000 to 2.0 million	300 million to 2.5 bn
Switzerland	45 to 142	200,000 to 1.2 million	400 million to 4.3 bn
UK	181 to 567	3.9 million to 10.2 million	1.3 bn to 8.6 bn
EU-27	1,168 to 3,564	24.7 million to 65.7 million	10.3 bn to 70 bn
Total 31 European countries[29]	**1,400 to 4,500**	**29 million to 78 million**	**12.3 bn to 85.3 bn**

Note: 5G rollout in Cyprus is expected to begin in 2024, and therefore the figures presented for Cyprus alone are with respect to 2025 and not 2023. Source: Oxford Economics.

[29] The results presented for Europe in this report do not cover all European countries. In particular, our study does not cover Russia, Ukraine, Belarus, Serbia, Moldova, Bosnia and Herzegovina, Albania, North Macedonia, Montenegro, Andorra, Monaco, Liechtenstein, San Marino, or the Vatican City.

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June 2020

The modelling and results presented here are based on information provided by third parties, upon which Oxford Economics has relied in producing its report and forecasts in good faith. Any subsequent revision or update of those data will affect the assessments and projections shown.

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