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Enabling Private Investment in 5G Connectivity in Emerging Markets—An Assessment of Challenges and Policy Options

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This note proposes a high-level framework to assess challenges and policy options to enabling private sector-led investment in 5G connectivity in emerging markets. 5G is the latest mobile network technology and it has the potential to provide high-speed Internet connectivity and enable digital transformation across multiple sectors of an economy. The proposed framework leverages industry data to articulate the digital divide and benchmark the enabling environment for 5G connectivity in emerging markets. The note concludes with recommendations on policy options and business strategies, drawing from early experiences in advanced markets and major opportunities and challenges in emerging markets.

Key Findings

- 5G may take longer to reach maturity in emerging markets (EMs) than previous generations of mobile technologies under the current enabling environment.
- The negative impact of such a delay could be significant and includes a widening of the digital divide and limited efficiency gains across economic sectors such as infrastructure, agriculture, health, and education that could benefit from 5G solutions for growth.
- A number of challenges constrain 5G deployment in EMs, including (i) profitability for investors; (ii) a balance of benefits between the telecom sector and other sectors; and (iii) potential disruptions to the telecom sector due to technology advances such as network virtualization and digitalization, which risk a further erosion of profitability.
- Three key factors can enable investment in 5G: (i) improved service valuation, driven by the availability and relevance of use cases and the diffusion of 5G applications among business and the mass market; (ii) the degree of required capital intensity, depending on the availability of foundational digital infrastructure; and (iii) the institutional framework shaped by regulations and legislation.
- On the basis of these three enablers, the authors find that eight out of 10 EM countries, which together represent 60 percent of the population of emerging markets, today have limited 5G readiness; this is particularly the case in Africa and Central Asia. 5G readiness is highly correlated with a country's average income and openness to competition in the telecom sector.
- The biggest constraint to 5G readiness is the limited availability of use cases, suggesting the importance of developing a digital economy in parallel with network expansion to drive further digitalization. The second biggest constraint is limited availability of basic digital infrastructure.
- In Sub-Saharan Africa, limited availability of broadband and data infrastructure is the biggest barrier to 5G availability. Latin America lags South Asia in terms of 5G availability, due to limited availability of use cases.
- In advanced markets where 5G is developing rapidly, government interventions have focused on supporting targeted use cases, developing infrastructure-sharing regulations, and accelerating efficient spectrum allocation. Successful business models have generally involved a mix of competition and cooperation.
- In EMs, policy options to accelerate 5G deployment include (i) supporting pilot testing for use cases; (ii) making spectrum available early, especially in the "mid band"; (iii) opening the sector to non-telco operators to establish an environment favorable to partnerships; (iv) actively promoting a level playing field between holders of infrastructure assets and service providers; and (v) adjusting telecom regulatory frameworks to use cases enabled by 5G.
- A successful implementation of these policies depends on business strategies that include introducing value-added services in partnership with digital service providers, developing network-as-a-service offers to business customers, and business model innovation through outsourcing of infrastructure rollout, network virtualization, dynamic spectrum sharing, and blended use of licensed and unlicensed spectrum.

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In recent decades, emerging markets (EMs) have successfully managed to transition from one mobile network technology to the next, albeit at a slower pace than developed economies. 5G, the latest generation of mobile network technology, involves enhanced mobile broadband, massive machine-type communications, and ultrareliable and low-latency communications.[1] It offers numerous unique opportunities for EMs, but it also poses several challenges that need to be addressed with appropriate policies and business strategies.

5G in Emerging Markets—Opportunities and Challenges

Opportunities offered by 5G in EMs

The widespread adoption of 5G has the potential to generate numerous benefits for individuals and businesses and broader society,[2] depending on analog complements such as digital skills, device affordability,[3] access to electricity, and governance.[4] The economic literature finds that, on average, a 10 percent increase in mobile adoption increases GDP by 1 percent, and that rises to approximately 15 percent when connections are upgraded from one mobile network technology to another.[5] According to several industry forecasts, 5G is expected to add $1.5 to $1.9 trillion to the global economy by 2025,[6] and as much as $13.2 trillion by 2035.[7] The share of those benefits that accrue to EMs will depend on the contributions of all stakeholders to addressing challenges to 5G availability in these countries.

In general, 5G is expected to support a deeper digitalization of various sectors of the economy, with the scaling up of technologies like artificial intelligence (AI), robotics, and augmented/virtual reality in sectors such as transport, manufacturing, and healthcare.[8] In addition, and similar to previous generations of mobile communications, the adoption of mass market applications and services cannot be predicted in advance,[9] and can also be a significant driver of the expansion of this technology. The following are several opportunities offered by 5G in emerging markets (Figure 1).

Improving the quality of digital connectivity by offering very high-speed mobile broadband or fixed wireless access to individuals in areas that are currently underserved by high-speed broadband Internet. Network operators can benefit from increased revenue as 5G supports the development of new value-added services beyond those supported by 4G networks, including virtual/augmented reality, online entertainment, and gaming, among others. Operators can also benefit from cost efficiencies as 5G, combined with AI and analytics, can optimize networks' operations. However, this opportunity remains challenging, as operators have yet to monetize 5G investment on the consumer front.[10]

Improving the efficiency of general infrastructure by enabling the optimization of transportation networks, and especially the automation of ports, tracking systems for transport companies, and optimization of long-haul and last-mile delivery absent formal addressing systems. 5G can also contribute to the optimization of waste management systems and power distribution networks through the use of Internet of Things (IoT) sensors as well as remote monitoring of decentralized power production centers in rural areas.

Improving agricultural productivity by supporting the use of IoT sensors to track farms' performance levels and predict production; enabling precision farming, especially in arid environments like the Sahel; or tracking cattle, a key asset in rural areas of emerging markets. Specific applications include remote inspection of fish farms and disease diagnoses of plants through the use of images captured by drones.

	1–2G	3–4G	5G
Major technological innovation	Calls, low-speed data	High-speed internet access (up to 10 Mbps)	Very-high speed internet access (up to 100 Mbps) and low latency (below 1 ms)
Major use cases (examples)	Telephony	Online contents and transactions	Virtual or Augmented Reality, Machine Remote control, Internet of Things
Economic opportunities	• Productivity growth stemming from reduced transactions cost • Entrepreneurship (resale of mobile handsets and offers)	• Innovation in established firms through digitalization of relationships with suppliers, workers and clients. • Entrepreneurship, stemming from reduced barriers to entry in services sector with entry of FinTech, e-commerce, EdTech and online media companies • Digitalization of government	• Innovation in established firms through digitalization of relationships with suppliers, workers and clients. • Entrepreneurship, stemming from reduced barriers to entry in manufacturing, agriculture and infrastructure sectors with entry of AgTech, HealthTech, InfraTech (smartgrid, smart cities, autonomous cars,
Main challenges	• Network externalities • Digitalization of communications	• Externalities, mainly in the service sectors • Entry of over-the-top players, online communication companies, specialized digital infrastructure companies	• Economy-wide externalities • Increased cost of network deployment • Network slicing, entry of non-telco providers

FIGURE 1 Mobile Technologies – Key Opportunities and Challenges

Source: IFC.

Improved productivity in manufacturing through greater automation of the production process and large-scale use of augmented and virtual reality technologies.

Supporting the expansion of telemedicine through remote diagnostics, especially for rural households, leveraging the capacity of 5G networks to handle high-volume data such as video and images.

Supporting large-scale rollouts of online education by enabling educational institutions, especially in the tertiary sector, to deliver online education in mobile-first settings, leveraging technologies such as augmented or virtual reality.

Main challenges to scaling up 5G in EMs

Compared to previous generations of mobile technologies, 5G carries a number of unique challenges that may delay its availability in emerging markets (Figure 1). These include traditional challenges such as spectrum availability, use of unlicensed spectrum, and cross-sector infrastructure sharing. However, 5G entails new challenges which include:

A potential delay in 5G deployment in emerging markets. On average, EMs took 15 years to reach 80 percent population coverage of 2G networks, compared to 10 years for 3G and eight years for 4G. Recognizing the remaining gaps in network quality across countries,[11] such an accelerated pace of technological transition occurred in environments marked by complex and sometimes challenging regulatory requirements, and it reflects economies of scope as new generations of mobile network technology take advantage of the sunk costs of infrastructure incurred to deploy previous generations. For instance, 4G antennas could be installed on tower sites built for 3G networks.

However, with the exception of a few cases such as China, the speed of the transition to 5G in EMs may be slower than for previous generations, and slower than that of developed economies.[12] While 5G uptake should not be assessed on the same metrics as previous generations of technologies because of its unique properties, certain comparisons remain useful. For instance, 5G population coverage, a measure of the availability of enhanced mobile broadband, a particular type of 5G use case, is projected to reach 39 percent by 2025, growing at an annual rate of 6 percent.[13] At that speed, it could take up to 15 years to reach 80 percent 5G coverage in EMs, similar to the diffusion speed of 2G, and nearly half the speed of the transition to 4G, recognizing that as the equipment becomes cheaper and more integrated, upgrades will be simpler and may well accelerate. In advanced markets, 5G population coverage is projected to reach 85 percent by 2025, more than twice the projected coverage in emerging markets and a perpetuation of the digital divide.[14]

Likewise, penetration of IoT devices, a proxy for preparedness to 5G business use cases such as low-latency and massive machine-type applications, is lagging in most EMs: it was on average 45 IoT devices per thousand inhabitants in 2019, nearly five times below the ratio in high-income countries.[15] Due to affordability issues, 5G in emerging markets will rely more on industrial applications, with large companies deploying their own 5G network infrastructure. However, enterprise uses will require advanced 5G applications such as massive machine-type communications and low-latency communications.

Retaining appropriate levels of profitability, due to the high costs of network deployment in low-income environments. In most EMs, the average revenue per user of mobile connectivity is below $5 per month, compared to $20 in advanced markets;[16] and most businesses still operate in the informal sector. However, the transition to 5G will require considerable investment in network densification through the addition of towers, base stations, and spectrum, as well as energy resources. Under previous generations of mobile technologies, network operators typically invested 10 to 15 percent of their annual revenues in network upgrades.[17] 5G may require a higher level of investment, depending on capital intensity, network sharing, and rural deployment strategies,[18] as it relies on specialized towers, consumes more energy, and requires access to infrastructure beyond the telecom sector to deploy small cell sites. In India, a nationwide rollout of 5G is projected to cost up to $30 billion over 5 years.[19] In China, 5G capex is expected to amount to $411 billion between 2020-2030, with two to three times more 5G base stations than that of 4G.[20]

The balance of benefits between the telecom sector and other sectors. Previous generations of mobile technologies (2G-4G) enabled Internet services, innovation, and digital platforms, especially in the service sectors.[21] A portion of those benefits was captured by the telecom sector through digital connectivity services. With 5G, an increasing share of the benefits of connectivity will accrue to industries beyond the telecom sector, especially in transport and manufacturing.[22] These externalities can result in underinvestment in 5G by telecom network operators, especially in EMs with large inefficiencies in infrastructure sectors such as ports, energy, and water distribution. However, the increasing interest of non-telco companies to invest in 5G may create opportunities for telecom operators to share the investment burden with other parties.

Disruptions to traditional telecom business models. By enabling digital transformation and network virtualization, 5G is expected to change the horizontal and vertical structure of the mobile sector, potentially resulting in increased concentration of radio access networks.[23] Such disruptions also have the potential to affect telecom operators' revenues from legacy technologies.[24] 5G could disrupt the structure of mobile network operators (MNOs) by inducing business model innovations such as the entry of platform operators offering various slices of the mobile network, similar to the disruption of voice and text message revenue by Over-The-Top

players (OTT)[25] with the introduction of mobile data. This could provide additional sources of revenue to MNOs, but it also constitutes a threat to their core businesses through further cannibalization of voice and captive data revenues. Non-telco spectrum licenses, private 5G networks under various business models, and specialized operators, could all further disrupt the mobile telecom sector. 5G might also accelerate the convergence of fixed and mobile networks, for instance through fixed wireless access.

Creating an Enabling Environment for 5G in EMs

Potential drivers of investment in 5G connectivity

The incentives for private sector-led operators to invest in a new technology such as 5G can be driven by three key factors:[26]

(a) **Service value**, or how many additional end-users are willing to pay for 5G-enabled connectivity services compared to 4G connectivity. The magnitude of such a valuation depends on the scope of use cases, as well as end-users' purchasing power and their ability to effectively take advantage of the technology. 5G is expected to enable three broad sets of use cases:[27] (i) enhanced mobile broadband, providing higher-speed Internet access compared to 4G; (ii) ultra-low latency communications; and (iii) massive machine-type communications. Given the potentially large externalities generated by 5G, the valuations from these use cases are likely to generate benefits beyond the scope of digital connectivity. For instance, some individuals may value 5G connectivity only if they have access to media content with augmented or virtual reality. A manufacturing or agribusiness company may value 5G connectivity only when it comes with AI applications or data analytics that improve productivity. An enabling framework is needed to ensure that the overall value created is fairly shared among various stakeholders, e.g., mobile network operators and media companies.

(b) **The degree of capital intensity**, or the upfront and non-recoverable costs to be incurred before operators can provide 5G services. These costs typically stem from investment in complementary digital infrastructure such as submarine cables, satellites, terrestrial fiber optic cables, small cell sites, and data centers. However, these infrastructure assets are not specifically dedicated to 5G networks and, as such, could derail the total cost of investment if they are not sufficiently available. Building such foundational infrastructure is therefore critical to enabling 5G deployment in a cost-effective manner. In addition, 5G will require network upgrades that go beyond the radio portion of the network (core, transport, distributed edge computing, devices, etc.). Bottlenecks to high-speed and low-latency can happen in any of these areas, with the potential to erode the value of 5G connectivity.

(c) **Institutional framework**, or the regulatory framework needed to ensure the availability of public resources like radio spectrum to provide a degree of certainty to investors, and to arbitrate the sharing of value across various stakeholders. 5G radio spectrum ranges from the low-band (below 1GHz) to the high-band (above 24GHz), with a mid-band between 1GHz and 6GHz, each tailored to specific use cases. Potential disruptions to traditional telecom businesses require a degree of regulatory certainty with respect to the level of competition and the scope of regulatory remedies. Likewise, the broader scope of externalities requires regulations across sectors such as media, telecom, financial services, health, and transportation. Such institutional frameworks are also necessary to clearly delineate the scope for public and private interventions, separately or in partnership. Several academics also point out that the dense network of small antennas has natural monopoly features, which will require greater regulation of fewer radio access networks (RANs).[28]

These three factors played a critical role in the transition from 3G to 4G. As suggested by Figure 2 below, emerging markets with high levels of incremental valuation (proxied by their level of average revenue per user), high availability of foundational infrastructure (proxied by the penetration of 3G), and an effective regulatory environment that promotes competition and the entry of new providers, transitioned more quickly to 4G than the laggards.

An Assessment of 5G Readiness

To assess countries' readiness for scaling up 5G, IFC has prepared a high-level composite index that combines the potential valuation and capital intensity of 5G deployment with the institutional framework to quantify the enabling

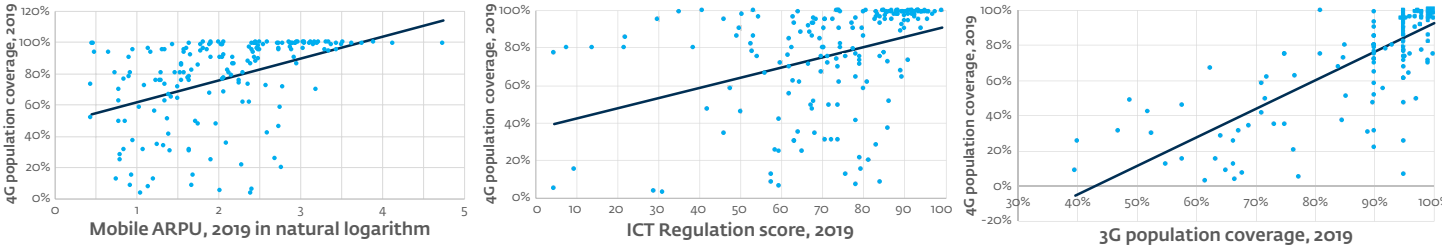

FIGURE 2 Drivers of the transition from 3G to 4G

Source: IFC, using data from GSMA Intelligence, 2019.

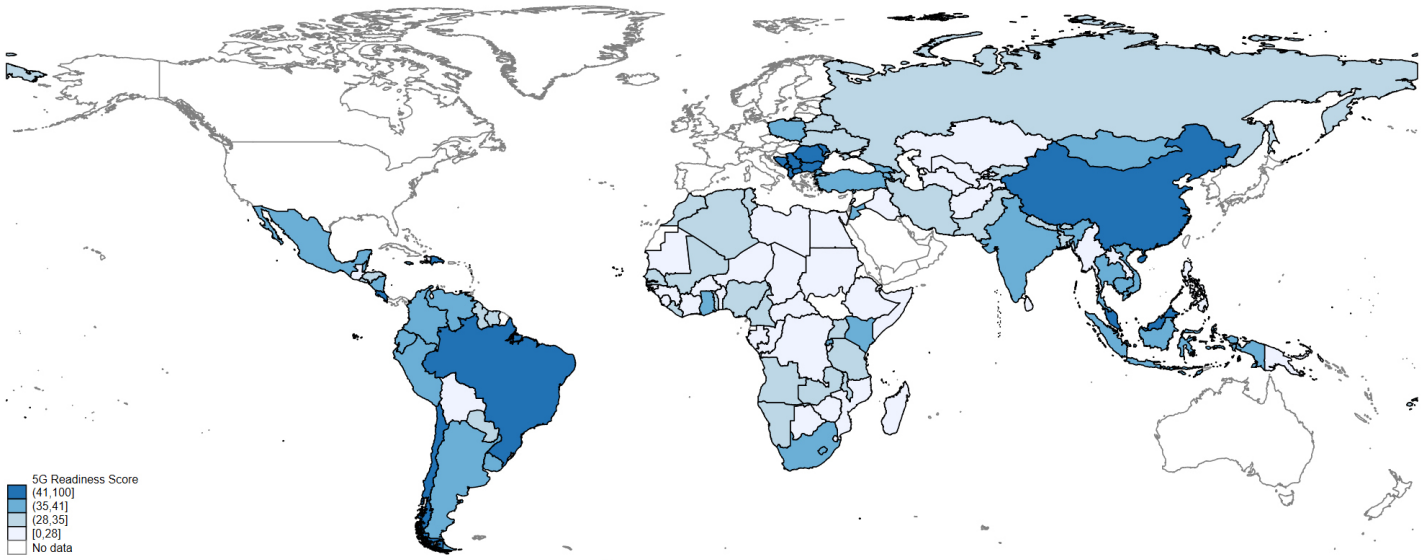

FIGURE 3 5G Readiness in 2020

Source: IFC.

environment in a country.[29] Given the role of use cases in driving valuation for 5G, that component of the index is labelled as "use cases." Likewise, the capital intensity component is labelled "digital infrastructure," whereas the institutional framework component is labelled "regulation." Each component represents an area of interventions for stakeholders seeking to create an enabling environment for 5G.

Each component receives a score between 0 and 33 on the basis of indicators collected from industry data sources (Table 1). The use cases component captures the potential demand for 5G connectivity from businesses and individuals, proxied respectively by the number of IoT connections and average revenue per user (ARPU). Other important aspects of demand such as income, digital literacy, and device affordability are expected to be correlated with the ARPU. The digital infrastructure component captures the supply side of 5G connectivity, especially the potential cost of network deployment, proxied by indicators of the availability of broadband, mobile, and data infrastructure. The regulation component captures the regulatory framework, especially spectrum management, infrastructure sharing, and competition, as well as the independence and effectiveness of regulation. Other dimensions of regulation such as online trust and consumer protection (including environmental considerations) are expected to be correlated to these sub-components.

The 5G readiness score is the sum of use cases, digital infrastructure, and regulation scores, and ranges from 0 to 100. The outcome is presented in Figure 3. The framework indicates that:

- In 8 out of 10 emerging markets, representing 60 percent of total EM population, 5G readiness is limited, with a score below 40. China, Brazil, Malaysia, and few Central European countries like Moldova and Romania exhibit the highest 5G readiness, with scores above 40.
- Africa and Central Asia concentrate the largest number of countries with limited 5G readiness.
- As expected, 5G readiness is highly correlated with countries' average incomes: Low-income countries are less ready than lower middle-income countries, followed by upper middle-income and high-income countries.

A closer examination of the index by subcomponent and a comparison with actual network rollout can help assess barriers to 5G availability:

- The biggest constraint to 5G readiness is the limited availability of use cases, followed by limited availability of digital infrastructure.
- Regulation remains a differentiating factor between high-income countries and emerging markets (low-income to middle-income countries), but plays only a minor role in explaining the gap among EMs. Digital infrastructure is the major differentiating factor between EMs.
- Sub-Saharan Africa trails in 5G readiness and availability. It is held back primarily by limited availability of foundational digital infrastructure; the region has the lowest infrastructure score and the lowest 5G coverage, despite a relatively high use cases score, comparable to that of South Asia.
- Latin America is lagging in terms of 5G rollout: the region is in a better position than South Asia in terms of use cases, digital infrastructure, and regulation, but has a slower pace of deployment.

TABLE 1 5G Readiness—Components and Data Sources

Component	Sub-component	Description	Data sources
Use cases (valuation)	Potential demand from businesses	Number of IoT connections, normalized by the size of the economy	GSMA Intelligence (GSMAi) and World Bank
	Potential demand from individuals	Mobile ARPU	GSMAi
Digital infrastructure (capital intensity)	International connectivity	International Internet bandwidth per user	Telegeography and GSMAi
	National broadband network capacity	Penetration rate of fixed broadband	Telegeography
		Share of high-speed (cable and fiber) last-mile broadband connections	Telegeography
	Mobile network capacity	4G population coverage	GSMAi
		Number of towers per subscribers	TowerXchange and GSMAi
	Data infrastructure	Number of data centers, normalized by the size of the economy	Datacentermap
Regulation (institutional framework)	Regulatory framework	ICT regulatory tracker	ITU
	Effectiveness of regulation	Share of towers managed by carrier-neutral operators	TowerXchange

Source: IFC.

Enabling Private Sector-led Investment in 5G

Policy and business strategy: a summary of the main lessons learned from advanced markets

Consistent with their 5G Readiness scores, high-income countries and China have initiated 5G rollouts, starting with the Republic of Korea in 2018. These early rollouts provide some evidence about how regulations can support private sector investment in 5G. Overall, government interventions involve stimulating demand through supporting use cases, lowering the cost of network deployment through infrastructure-sharing regulations, and improving the regulatory framework, especially on spectrum allocation, to promote effective competition and mitigate risks to private sector investments.[30] Successful business strategies involve "coopetition," a mix of competition and cooperation whereby network operators increasingly cooperate on infrastructure deployment while competing to provide connectivity services.

Policy Options and Business Strategy for Emerging Markets

To the extent that use cases and digital infrastructure are the biggest obstacles to 5G in emerging markets, a prerequisite involves public support to pilot the testing of use cases. Identifying relevant use cases remains critical (and a key challenge) to rolling out 5G in EMs, but the outcome of such processes is uncertain and the benefits can span beyond the telecom sector due to externalities. When justified, government funding and upstream interventions from development finance institutions or other donors can help mitigate such risks and contribute to spreading use cases beyond the telecom sector. Given the rapid urbanization in most EMs, smart cities applications could serve as 5G pilots.

Overall policy options include (Table 2):

Policy option 1 – Accelerate the availability of efficient and reliable spectrum, especially in the mid-band, to both telecom and non-telco companies. A revenue maximization approach to spectrum allocation could delay 5G availability by inflating the overall cost of network deployment. An early commitment on the expected timeline to release 5G spectrum, especially in the mid-band, can support investment in foundational digital infrastructure to prepare for 5G investment; 5G deployed in low-band spectrum can support little more than 4G speeds or latency. Allocations of spectrum in the low-band could be tied with 5G network deployment outside densely populated areas to limit any widening of the digital divide by the new technology. Making spectrum available to non-telco operators would also enable investment, given their potentially prominent role in 5G adoption.

Policy option 2 – Open the telecom sector to non-telco operators to enable the sharing of value from 5G connectivity among various stakeholders, and support competition and innovation and thereby enable the development of relevant use cases. The opening of the sector could be supported by leveling the playing field between operators through interoperability between networks, especially between private and public 5G networks.

Policy option 3 – Adjust telecom regulatory frameworks to the use cases enabled by 5G. Examples include regulations on small cells, heterogeneous networks, and IoT devices. Small cells and heterogeneous networks will be critical to providing low-latency applications, whereas IoT devices will support the deployment of massive machine-type communications services. Fixed wireless and wholesale open access networks that are upgradable for 5G can help mitigate the risks of a

TABLE 2 Policy Options and Business Strategy to Enable 5G in Emerging Markets

	1–2G	3–4G	5G
Key Policy Options	• Liberalization • Spectrum • Regulation and competition • Universal service obligations	• Liberalization of upstream segments of the broadband value chain • Infrastructure sharing	• Supporting 5G pilots • Making spectrum available, especially in the mid-band, at reasonable price • Opening the telecom sector to non-telco companies to promote competition and innovation • Adjusting telecom regulatory frameworks to the use cases enabled by 5G
Operators' key strategy	• Vertical integration with ownership of towers, national backbone and backhaul network • Prepaid pricing and financing options for devices	• Divestiture of physical assets, with a focus on core business • Innovation in media contents • Mobile financial services to the underserved	• Value added services (e.g. Virtual/Augmented Reality) using enhanced mobile broadband for residential consumers • Network-as-a-service offers for businesses • Business model innovation through outsourcing of network rollout, network virtualization, dynamic spectrum sharing, and blending the use of licensed and unlicensed spectrum

Source: IFC.

digital divide. Open Radio Access Network is an opportunity to share the costs of 5G but needs to be balanced with geopolitical concerns. In addition, regulations around the use of data will be critical to accommodating the expected massive growth in data fueled by 5G.

To be effective, these interventions have to be supported by a continuation of reforms triggered by previous generations of mobile technologies (Table 2). These include the liberalization of all segments of the broadband value chain, infrastructure sharing, and universal service obligations, as well as enabling private sector investment in data infrastructure. Key challenges raised by 5G may support increased government interventions in the telecom sector, but those interventions ought to be limited in most cases to the enabling factors.

Given the many challenges that 5G poses, the approaches of telecom network operators and their business strategies will be essential for successful implementation of policy interventions. Potential strategies include:

Business strategy 1 – New value-added services in partnership with digital service providers. With the disruptions introduced by 5G, most mobile network operators would derive additional revenue primarily from the introduction of value-added products. In emerging markets, especially low-income countries, specific product innovations will depend on the development challenges faced by each country; this was the case for mobile financial services with the arrival of 3G. For telecom operators, product innovations from 4G have remained limited so far. With the arrival of 5G, some telecom operators may have to partner with digital services providers to develop more use cases and share the economic benefits.

Business strategy 2 – Network-as-a-service offers to business customers through network slicing. In anticipation of the entry of non-telco operators, telecom operators could introduce network slicing services or enter into the market segment of private networks for businesses. Such an approach would limit disruptions to the telecom sector and enable investment in foundational digital infrastructure, especially 4G.

Business strategy 3 – Business model innovation through: (i) outsourcing of infrastructure rollout to specialized neutral entities; (ii) network virtualization to become more flexible in serving clients' needs in more economical ways (e.g., cloud-RAN, edge computing); (iii) dynamic spectrum sharing to lower costs; and (iv) blending use of licensed and unlicensed spectrum.

The Road Forward

Overall, accelerating the availability of 5G in emerging markets will require concerted efforts between the public and private sectors, including private businesses beyond the telecom sector. Those efforts should not, however, supersede ongoing reforms to improve the competitiveness of the digital infrastructure sector.

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Please see the following additional reports and EM Compass Notes about responses to COVID-19 and about reaching unserved and underserved populations in emerging markets: *Artificial Intelligence in Emerging Markets – Opportunities, Trends, and Emerging Business Models – Second Edition* (report, March 2021); *Reinventing Business Through Disruptive Technologies – Sector Trends and Investment Opportunities for Firms in Emerging Markets* (report, March 2019); *What COVID-19 Means for Digital Infrastructure in Emerging Markets* (Note 83, May 2020).

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1 ITU. 2018. "Setting the Scene for 5G: Opportunities & Challenges." https://www.itu.int/en/ITU-D/Documents/ITU_5G_REPORT-2018.pdf

2 ITU. 2018.

3 5G phones typically cost more than $1,000 and can only be purchased by a small portion of the population in emerging markets.

4 GSMA. 2020. "Mobile technology and economic growth." https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165922&file=121120-Mobile-Technology-Economic-Growth.pdf

5 GSMA Intelligence. 2020. "Mobile technology: Two decades driving economic growth." https://data.gsmaintelligence.com/api-web/v2/research-file-download?id=54165922&file=121120-working-paper.pdf

6 McKinsey, Businesswire, Thierer.

7 IHS Markit. 2019. "The 5G Economy." https://www.qualcomm.com/media/documents/files/ihs-5g-economic-impact-study-2019.pdf

8 See World Economic Forum, 2019. "Repository of 5G Use Cases." For use cases, mainly in advanced markets: http://www3.weforum.org/docs/WEF_The_Impact_of_5G.pdf

9 At the moment, the broad suggestion from the literature is that mass market solutions will drive 5G adoption in the short term through enhanced mobile broadband, while other types of use cases such as ultra-low latency and massive machine-type communications will be more business oriented and occur in the medium-to-longer term.

10 GSMA, 2020. "Great Expectations – Sizing the Opportunity for 5G in Vertical Industries." This reports confirmed the industry's high expectations for 5G industrial applications to drive business growth.

11 According to data from Ookla speed test, mobile download speed in low-income countries in 2019 is, on average, half that in upper middle-income countries.

12 In "A U.S. National Strategy for 5G and Future Wireless Innovation" Doug Brake (2020) provides a detailed description of mobile network technologies and especially 5G. https://itif.org/sites/default/files/2020-national-strategy-5G-wireless.pdf

13 Based on projections from GSMA Intelligence

14 Low latency of 5G will drive the need for complementary technologies like edge computing, but these are unlikely to be deployed in smaller markets.

15 Estimates based on data from GSMA Intelligence

16 Estimates based on data from GSAM Intelligence, 2019. EMs encompass low- to middle-income countries, whereas advanced markets correspond to high-income countries, per the World Bank's classification of FY21.

17 Estimates based on GSMA data on operators' revenue and capital expenditure.

18 Oughton, Edward J. and Zoraida Frias. 2018. "The cost, coverage and rollout implications of 5G infrastructure in Britain." *Telecommunications Policy* 42 (8) 636–652. https://doi.org/10.1016/j.telpol.2017.07.009

19 Motilal Oswal. 2020. "The 5G Saga." https://www.motilaloswal.com/site/rreports/HTML/637385292576715897/index.htm

20 Fierce Wireless. 2017. "China's 5G Capex Expected to Hit $280B over 10 years." https://www.fiercewireless.com/wireless/china-s-5g-capex-expected-to-hit-280b-over-10-years

21 World Bank. 2016. "Digital Dividends."

22 WEF. 2020. "The Impact of 5G: Creating New Value Across Industries and Society." White Paper in Collaboration with PwC. http://www3.weforum.org/docs/WEF_The_Impact_of_5G_Report.pdf

23 Cave, Martin. 2018. "How Disruptive is 5G?" *Telecommunications Policy* 42 (8) 653–658. https://doi.org/10.1016/j.telpol.2018.05.005

24 Boccardi et al. 2014. "Five Disruptive Technology Directions for 5G." https://arxiv.org/ftp/arxiv/papers/1312/1312.0229.pdf

25 Over-the-top players refer to digital contents and application service providers like WhatsApp (Facebook) and YouTube that provide telecommunication services (calls and text messages) without operating a telecom network.

26 Jeanjean, François, and Georges Vivien Houngbonon. 2017. "Market structure and investment in the mobile industry." *Information Economics and Policy*, Elsevier, vol. 38(C), pages 12–22. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2668649

27 ITU. 2018.

28 Cave. 2018.

29 Other attempts at assessing 5G readiness include: Incites (2019) built a composite index, but focuses on Europe. https://www.incites.eu/incites-map/Europe_5G_Readiness_Index_Report.pdf Intel (2019) uses a survey approach asking operators about their readiness to adopt 5G. https://www.intel.com/content/dam/www/public/us/en/documents/reports/futurum-5g-readiness-transformation-index-report.pdf

30 Arezki, Rabah, Vianney Dequiedt, Rachel Yuting Fan, and Carlo Maria Rossotto. 2021. "Liberalization, Technology Adoption, and Stock Returns: Evidence from Telecom." Policy Research Working Paper; No. 9561. World Bank, Washington, DC.