



REINVENTING BUSINESS THROUGH DISRUPTIVE TECHNOLOGIES

Sector Trends and Investment Opportunities
for Firms in Emerging Markets

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Creating Markets, Creating Opportunities

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Abbreviations and Acronyms

AAD	advanced anaerobic digestion	IT	information technology
AHFC	Affordable Housing Finance Company	KYC	know-your-customer
AI	artificial intelligence	LED	light-emitting diode
API	application programming interface	LIC	low-income country
AR	augmented reality	LMIC	lower middle-income country
AWG	atmospheric water generation	LNG	liquefied natural gas
BCG	Boston Consulting Group	MCPP	Managed Co-Lending Portfolio Program
BOP	Bank of Palestine	MENA	Middle East and North Africa
BRT	bus rapid transport	MFD	Maximizing Finance for Development
BSP	Bank of the South Pacific	MFI	microfinance institution
CAGR	compound annual growth rate	MFSP	mobile financial service provider
CRB	credit reference bureau	MIC	middle-income country
CRISPR	clustered regularly interspaced short palindromic repeats	MNO	mobile network operator
CSP	concentrated solar power	MOOC	Massive Online Open Course
DER	distributed energy resource	MW	megawatt
DFID	Department of International Development	NGO	non-government organization
DG	distributed power generation	NHB	National Housing Bank
ECI	Economic Complexity Index	NPL	nonperforming loan
EDGE	Excellence in Design for Greater Efficiencies	P2P	peer-to-peer
EM	emerging market	PLC	programmable logic controller
EV	electric vehicle	PPA	power purchase agreement
FCA	Financial Conduct Authority	PV	photovoltaic
FCS	fragile and conflict-affected situations	ROE	return on equity
FDI	foreign direct investment	SDG	Sustainable Development Goal
FIG	Financial Institutions Group	SME	small and medium enterprise
FIT	feed-in-tariffs	SSA	Sub-Saharan Africa
FSP	financial service provider	STF	short-term finance
FSRU	floating storage and regasification unit	T&D	transmission and distribution
FY	fiscal year	TAT	turnaround time
GSM	Global System for Mobile Communications	UHC	universal health coverage
GSMA	Global System for Mobile Communications Association	UIDAI	Unique Identification Authority for Validation and Issuance
GW	gigawatt	UMIC	upper middle-income country
HEIP	Health and Education Impact Platform	UNCTAD	United Nations Conference on Trade and Development
HFC	housing finance company	UPI	unified payment system
IBRD	International Bank for Reconstruction and Development	USSD	unstructured supplementary service data
ICT	information and communications technology	VRA	variable-rate application
IDA	International Development Association	WBG	World Bank Group
IFC	International Finance Corporation	WIPA	Water Innovation Platform for Africa
IMF	International Monetary Fund	WSS	water and sanitation services
IOT	Internet of Things	YTD	year-to-date
IPP	independent power producer		

Note: All dollar amounts are U.S. dollars unless otherwise indicated

Glossary of Technological Concepts or Areas of Applications

(Sector or theme followed by number of chapter in brackets)

- 3D PRINTING** (Manufacturing, 7)
- ADAPTIVE SOLAR FAÇADES** (Climate-smart Cities, 12)
- ADVANCED ANAEROBIC DIGESTION** (Water, 5)
- APPLICATION PROGRAMMING INTERFACE** (Technology Transforming Society and Economies, 1)
- ARTIFICIAL INTELLIGENCE** (Technology Transforming Society and Economies, 1)
- ATMOSPHERE WATER GENERATION** (Water, 5)
- AUTONOMOUS VEHICLES** (Transport, 4)
- BATTERY TECHNOLOGIES** (Transport, 4)
- BIOMETRICS** (Digital Identification, 16)
- BLOCKCHAIN AND SELF-MANAGED IDENTITY** (Digital Identification, 16)
- BLOCKCHAIN TECHNOLOGY** (Agribusiness, 8)
- BULK WATER SUPPLY** (Water, 5)
- BUS RAPID TRANSPORT** (Climate-smart Cities, 12)
- CARDS AND CARD TECHNOLOGIES** (Digital Identification, 16)
- CLIMATE ACTION FOR URBAN SUSTAINABILITY** (Climate-smart Cities, 12)
- CLOUD COMPUTING** (Technology Transforming Society and Economies, 1)
- COLD CHAIN TRANSPORTATION AND STORAGE** (Agribusiness, 8)
- COLLABORATIVE CONSUMPTION** (Technology Transforming Society and Economies, 1)
- CLUSTERED REGULARLY INTERSPACED SHORT PALINDROMIC REPEATS/CA₉** (Agribusiness, 8)
- DATA MONETIZATION** (Microfinance, 13)
- DESALINATION** (Water, 5)
- DIGITAL LENDING** (Microfinance, 13)
- DIGITAL LOCKER** (FinTech, 10)
- DISTRIBUTED ENERGY RESOURCES** (Power, 4)
- DISTRIBUTED POWER GENERATION** (Power, 4)
- DRONE** (Manufacturing, 7)
- DIGITAL TRANSFORMATION OF FINANCIAL INSTITUTIONS** (Microfinance, 13)
- ECOSTRUXURE BUILDING PLATFORM** (Climate-smart Cities, 12)
- EFFICIENT IRRIGATION** (Agribusiness, 8)
- ELECTRIC VEHICLES** (Transport, 4)
- E-LOGISTICS** (Transport 4, 16)
- EXPONENTIAL ENERGY** (Technology Transforming Society and Economies, 1)
- FINANCIAL REGIONALIZATION** (Microfinance, 13)
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- GENE EDITING** (Agribusiness, 8)
- GEOSPATIAL ANALYTICS** (Technology Transforming Society and Economies, 1)
- GLOBAL POSITIONING SYSTEM** (Transport, 4)
- HIGH-EFFICIENCY, TRIPLE-EFFECT ABSORPTION CHILLERS** (Climate-smart Cities, 12)
- INITIAL COIN OFFERINGS** (FinTech, 10)
- INTERNET OF THINGS** (Technology Transforming Society and Economies, 1)
- MICROBIOME TECHNOLOGY** (Agribusiness, 8)
- MINIGRIDS** (Power, 4)
- OFF-GRID ENERGY** (Technology Transforming Society and Economies, 1)
- PNEUMATIC TUBE SYSTEMS** (Climate-smart Cities, 12)
- PROCESS DIGITALIZATION** (Microfinance, 13)
- QUANTUM COMPUTING** (Technology Transforming Society and Economies, 1)
- RISING SUPER-PLATFORMS** (Microfinance, 13)
- SEE-THROUGH SOLAR CELLS** (Climate-smart Cities, 12)
- SIDEWALK LABS** (Climate-smart Cities, 12)
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- TRANSPORTATION NETWORK COMPANIES** (Transport, 4)
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- VARIABLE-RATE APPLICATION** (Agribusiness, 8)
- WATER INNOVATION PLATFORM FOR AFRICA** (Technology Transforming Society and Economies, 1, 5)
- WIRELESS SENSOR TECHNOLOGY** (Agribusiness, 8)



FOREWORD

Technological innovation defines the destiny of humankind. From simple early tools to today's smartphones, technology has changed what we make and how we make it, determined the path of economic growth, and shaped societal norms and behaviors. And while technological innovation is ever-present in our societies and economies, technologies periodically emerge that fundamentally disrupt the existing economic order and shape the future.

Modern history is the story of just such technologies—most prominently the steam engine, electricity, and the computer. These have led to dramatic changes not only in the ways we manufacture and process goods, the ways we trade and access markets, and the ways we communicate—they have also fundamentally changed the nature of work, the geography of our cities, the structure of our economies, and the essence of our societies.

Today we are at the beginning of a new and accelerating phase of technological innovation, one that may alter the development path of emerging markets in particular. This new phase is supercharged by the convergence of rapid connectivity and digitalization, which, by linking billions of individuals, businesses, and machines in new ways, is creating an unprecedented tsunami of data.

As documented in the *World Development Report 2019: The Changing Nature of Work*, digital technologies have grown and spread quickly, and hold enormous potential for emerging markets. Businesses and governments are harnessing this data revolution to connect directly with individuals, businesses, and citizens, and to gain new insights into both microeconomic transactions and aggregated macro-level trends. We have all witnessed this revolution in real time: the transformation in retailing and logistics that online commerce has wrought; the unimagined changes that social networks have had on communication, social behavior, emerging markets, and the advertising industry; the impact of ridesharing platforms on the taxicab industry; and the access to new services that digital finance has brought to billions of previously unbanked individuals.

The chapters that follow provide an in-depth look at disruptive technological innovations. These are broadly defined as emerging technologies that result in significant changes in the cost of or access to products or services, or

that dramatically alter the ways we gather information, make products, or interact with each other. The report surveys current trends in eight selected sectors: power, transport, water and sanitation, digital infrastructure, manufacturing, agribusiness, education, and financial services. In addition, it examines disruptive technologies with regard to gender, climate change, microfinance, housing, logistics, and personal identification systems.

Such disruptions will be critical to achieving the Sustainable Development Goals, many of which can be advanced and accelerated—particularly in emerging markets—through technological innovations and the alternative paths to development that they offer. Examples include technologies that ensure availability and sustainable management of water and sanitation, provide new and cleaner sources of power, and deliver identification technologies that allow more people to access basic rights and services. There are many others.

The goal of this report is to help companies and investors seize the potential offered by the disruptive technologies described herein by allowing them to stay ahead of the curve when entering or expanding into emerging markets. Private enterprises are at the forefront of innovation and application of technology in these countries, and IFC, as the largest global development institution focused on the private sector in emerging markets, is uniquely equipped to support their efforts. In the chapters that follow you will find numerous descriptions of disruptive technology trends in addition to examples of IFC partnering with clients looking to invest in these markets and technologies. We invite you to explore these trends and sectors we examine and the promise they hold.

ATUL MEHTA, Senior Director, Telecom, Media, Technology, Venture Capital and Funds, IFC



EXECUTIVE SUMMARY

This report examines how disruptive technologies impact private-sector business models in emerging markets, and what disruptive technology means for the enabling environment—including national and international policy and regulatory regimes—that will be needed to allow these technologies to work their magic.

Several questions are addressed in each chapter: How do we define disruption in the respective sector? What are the technologies doing the disrupting? How does the disruption differ in emerging and advanced economies? What are the opportunities in fragile and low-income countries? And what are the key lessons and remaining challenges and constraints?

INTRODUCTION

CHAPTER 1. Disruptive Technology is Transforming Society and Economies

Disruptive technologies have a transformative impact on societies and economies, as well as on the ways that technological innovation evolves and spreads through emerging markets, which tend to adopt and adapt technologies developed elsewhere. Also, it is inevitable that some emerging markets will harness disruption more rapidly than others. Similarly, there are distinct risks and opportunities for private firms with regard to technological innovation in emerging markets.

CHAPTER 2. Creating an Enabling Environment for Disruption

Technological innovation and disruption don't take place in a vacuum, but in the context of actual nations and their regulatory frameworks. Several important issues—privacy, data security, and competition among them—must be a focus for national and international regulators if the current wave of disruption is to benefit all. IFC and the World Bank will play a critical role in helping to create and implement appropriate regulation.

SELECTED SECTORS

CHAPTER 3. Disruptions in Power

Access to clean, reliable, affordable electricity is essential to development in emerging markets, and technological

and market disruptions are transforming how that energy is created, stored, and distributed. The ongoing evolution from centralized to distributed power, including innovations such as hybrid photovoltaic-plus-storage and mini-grids, have enormous potential to broaden access to clean energy. Digitalization of the energy system and the proliferation of electric vehicles, which can be a distributed energy resource, will be central to energy sector transformation. And floating storage and regasification units are an innovation providing natural gas power in emerging markets.

Examples of IFC efforts in this sector include a 7 MW rooftop solar photovoltaic plant in Gaza and an LNG-to-power project in Brazil that will displace heavy fuel oil and diesel-fired generation.

CHAPTER 4. Innovations in Transport

Innovations in transport can be transformational for societies—merely consider the impact of the locomotive and the mass-produced automobile in recent centuries. Today, transport technologies in emerging markets such as global positioning and Big Data analytics allow for real-time tracking of goods and people, fleet optimization, and increased productivity. These technologies are also reducing food waste in developing countries. Internet-enabled ride-hailing services are bringing increased mobility to citizens in these nations. And e-logistics—which can involve the use of blockchain technology—can help entrepreneurs in smaller and less developed markets link more closely with advanced economies.

CHAPTER 5. Disruptions in the Water and Sanitation Sector

Water and sanitation are major global development issues in need of innovation. Membranes, reverse osmosis, and atmospheric water generation are a few technologies creating better access to clean water in developing countries. IFC supports implementation of efficient water technologies through the Water Innovation Platform for Africa.

CHAPTER 6. Digital Infrastructure

Investing in digital infrastructure has enormous potential to benefit the poor. Seven in ten people in the bottom fifth of the population (in terms of income) in developing countries now own a mobile phone, improving their connections and access to businesses and markets, employers, and government. Mobile telephony, the Internet, and broadband technology create and enhance those connections, while appropriate regulatory frameworks are essential to their success.

IFC and the World Bank helped finance a 10,000-kilometer undersea fiber optic cable to bring improved access to more than 250 million Africans, with knock-on effects for competitiveness and productivity.

CHAPTER 7. Leveraging Disruptive Technologies in Manufacturing

Industry is a minor piece of the economy in most low-income countries, and most of these nations have only simple, non-diversified manufacturing. But technology can help remedy this. IFC has identified three dimensions of economic complexity in manufacturing—product, process, and value chain complexity—all of which can be disrupted by technology, helping nations strengthen and accelerate economic growth and productivity. In one example of increasing process complexity, IFC loaned €15 million to help a Senegalese high-tech plastic and film packaging manufacturer expand to Côte d'Ivoire. Technologies that are disrupting manufacturing in emerging markets include Big Data, 3D printing, the Internet of Things, blockchain, and drones, among others.

CHAPTER 8. Disruptive Innovation in Agribusiness

While manufacturing complexity is a major development goal, agriculture remains central to most emerging markets. Technologies such as gene editing and microbiome techniques enable greater food production through more resilient crops. Precision agriculture—which relies on global positioning systems, wireless sensors, and the Internet of Things—can help farmers do more with available water and other resources.

CHAPTER 9. How EdTech Can Disrupt Business Models in Emerging Markets

Education technology, or EdTech, is a growing global market, projected to reach \$252 billion by 2020. Multiple technologies are transforming education in developing countries, including mobile technologies and learning applications that spread literacy and numeracy to the poorest and most remote learners. IFC is supporting several EdTech initiatives in Sub-Saharan Africa, and more broadly in low-income and fragile and conflict-affected situations.

CHAPTER 10. FinTech as Disruptive Technology in Emerging Markets

The financial services sector provides well-known examples of the power of technology to accelerate development. The widespread rollout and adoption of mobile telephony and banking apps have brought banking and payment services to millions of unbanked individuals in recent decades. Yet the job is not complete, with 1.7 billion adults in developing countries in need of a basic bank account.

In 2016 IFC invested in a Brazilian FinTech company that uses Big Data analysis to offer financial products to new users. Blockchain, cryptocurrencies, and Big Data may define the future of FinTech and spread additional financial services to individuals in emerging markets who lack them, from insurance and savings accounts to credit and beyond. Robust digital infrastructure and smart regulations are critical to these efforts.

SELECTED THEMES

CHAPTER 11. Disrupting the Gender Gap: How Technology Can Create Opportunities for Women

Giving women better access to technology can help overcome longstanding gender gaps. Ride-hailing technologies, for example, bring new opportunities for many women in emerging markets. And an online business education program sponsored by IFC helped women in West Bank and Gaza build business and entrepreneurial skills. Another IFC program in India and Asia created a market for off-grid solar lighting that focused on women as both distributors and customers.

CHAPTER 12. A Technology-first Approach to Climate-Smart Cities

Ongoing urbanization means 70 percent of the world's population will live in cities by 2050. Disruptive technologies can dramatically reduce resource consumption and improve air quality in urban environments, bringing rapid societal and economic changes that make them increasingly livable for all inhabitants. New technologies for producing and storing energy, rooftop and hydroponic farming, modernized transit, and new water capture and treatment methods are a few of the technologies that will play a role.

CHAPTER 13. Leveraging Technology to Disrupt the Microfinance Industry

The microfinance industry faces disruptive challenges to its model and markets, similar to those occurring in the broader financial services industry. IFC can help microfinance institutions benefit from digitalization in two distinct ways: through partnerships with both traditional financial services providers and new entrants, and through data analysis to automate loan making decisions. Data analytics, artificial intelligence, and process digitalization are a few of the technologies that will play a part.

CHAPTER 14. Disruptive Technologies Expand Housing Finance in Emerging Markets

A diffusion of technology innovations is expanding mortgage lending and housing finance in emerging markets, particularly to unbanked and underserved groups. Computer tablets and smartphones using sophisticated software allow for significant improvements to data collection and management. And data analytics can improve underwriting decisions and loan approval.

CHAPTER 15. E-Logistics: The Click of a Button Can Change How Goods are Transported

Inefficient logistics increases costs and impedes growth and development in emerging markets. Fortunately, technology driven solutions exist that can reduce inefficiencies and connect businesses to new markets, with economy-wide implications. IFC's investment in online e-logistics marketplaces in China and India have resulted in increased incomes and lower costs for truckers in those nations.

CHAPTER 16. Digital Identification for Development Creates New Business Models for Private Enterprises in Emerging Markets

One billion people lack any form of government-recognized identification. This inhibits their access to formal employment, education, social assistance, and other essential rights and services. Technologies such as biometrics, mobile authentication, and blockchain can transform the way identification is conferred and managed.

The most recent wave of disruptive technologies—detailed in the chapters that follow—is moving exponentially, disrupts business models at a faster pace, and radically alters consumer expectations and policy responses. These technological breakthroughs, combined with increased connectivity, are altering the ways individuals, businesses, and governments generate data and interact to create markets, unlock economic transactions, mobilize activity, and deliver services.

There are significant differences in how these technologies are harnessed in advanced and emerging economies. Whereas most technological innovations can marginally improve living standards and services in advanced economies, in emerging markets they are often necessary to the basic provision of certain goods and services. Renewable power generation and mobile digital infrastructure are examples. By the same token, because some emerging markets lack certain infrastructure, their adoption of new innovations may be more rapid, as it will not need to compete with legacy frameworks.

IFC, together with the World Bank, is working to help developing countries build digital economies and

harness disruptive technology, both by investing in the foundational elements of a digital economy—universal affordable connectivity, digital platforms, digital skills, and digital entrepreneurs—and by supporting private sector adoption of emerging technologies as a path to growth, job creation, and new markets.

Technology does not stand still. Even as current technologies are rolled out and spread to emerging markets, new ones emerge with additional potential for development. This report looks at those innovations already having an impact—solar energy and mobile communications are a few—as well as those, like artificial intelligence and blockchain, with much untapped potential. ■

INTRODUCTION

CHAPTER 1

Disruptive Technology is Transforming Society and Economies

By Priyanka Verma, Davide Strusani, and Jennifer Keller

Disruptive technologies are having a transformative impact on economies and societies.

Disruptive technologies are those that result in a significant change in the cost of, or access to, products or services, or that dramatically change how we gather information, make products, or interact. They are largely enabled by the dramatic increases in computing capacity and Internet bandwidth that has made their diffusion exponentially faster.

The broad and accelerating availability of disruptive technologies to citizens, consumers, and businesses has been a defining feature in recent years, with new services and markets emerging and spreading rapidly across populations and industries. And while such technological innovation is not new to economic development, the most recent wave of technologies is disrupting business models at a faster pace, and radically changing consumers' expectations and governments' policies. These technology breakthroughs combined with increased connectivity are impacting the way individuals, businesses, and governments generate data and interact to create markets, unlock economic transactions, mobilize activity, and deliver services.

The traditional pathway to economic growth for emerging economies—that of transitioning from agriculture to export-led manufacturing that achieves higher economic growth and economic specialization—is being radically transformed. Also, the adoption of disruptive technologies will become increasingly important in closing the “digital divide” between countries, and in helping to meet the United Nations' Sustainable Development Goals (SDGs).

Developing countries face twin challenges. The first is how to embrace the opportunities offered to close the digital divide between countries, while ensuring an inclusive approach that avoids creating new digital divides within and between countries. The second challenge is how to benefit from the opportunities while managing the downside risks. These include threats to cybersecurity and privacy, rent extraction, exploitative behavior by new monopolies, as well as the risk of a widening divide if technology is not developed in an inclusive way. All countries are facing these unprecedented challenges so developing countries have little opportunity to learn from elsewhere.

The rapid diffusion of disruptive technologies is changing traditional business models through a substantial change in cost, or access to goods and services.

Also, through the use of broadband Internet, technologies converge, often through the support of digital platforms, which can compound their transformational impact. Such technologies include solar panels and batteries, 3D (three dimensional) printing, distributed manufacturing, the automation of knowledge work through artificial intelligence (AI), and use of cloud computing and the Internet of Things (IoT). These can deliver enhanced services, self-driving vehicles and drones, and the creation of efficient materials (Figure 1.1).

Disruptive technologies are challenging business models too in ways that include: asset ownership, cost structure, service design, labor management, and approaches to regulation. These changes in how people work and the

terms under which they work are examined in detail in *The Changing Nature of Work*, the World Bank Group's 2019 World Development Report (WDR).¹

Disruptive technologies are not simply a driver of growth and opportunity—they are fundamentally changing the global economy and the way firms gain competitive advantage. An e-commerce platform can simultaneously be a multi-sector retailer, a logistics company, a media company, a health services provider, and a data-infrastructure company. Other platforms have emerged that operate a FinTech (financial technology) company, a multi-sector retailer, a logistics company, and a marketplace. However, unlike previous multinationals, their core competencies are centered less on their ability to raise and deploy capital efficiently, or to develop a cadre of global executives. Instead, their main source of competitive advantage is their ability to record and leverage data to connect consumers and suppliers, create new markets, and build new business models.

Digital technologies frequently have strong network effects, which favor the emergence of a monopoly provider unless government regulation prevents this. While a monopoly can provide a low-cost, ubiquitous platform that enhances competition and creates opportunities, a monopoly can behave in socially damaging ways too, such as extracting rents, controlling market access, and blocking further technological change.

Disruptive technologies hold the promise of widespread adoption in emerging markets, which could significantly increase the pace of technological catch-up and improvements in social welfare. In low-income countries a key challenge is how to raise productivity, which has previously been impeded by the limited diffusion of technology. In the past, adoption of technology in these countries has been limited, in part, by the lack of a supportive environment. However, disruptive technologies offer several features that can leapfrog these longstanding constraints and transform emerging markets.

The rise of disruptive technologies and changes to traditional business models create uncertainty for businesses and investors. For example, ride-hailing companies own no vehicles, digital retailers have no inventory, online accommodation providers own no

real estate, and social media companies own limited content. While the impacts of disruptive technologies have been studied in more detail in developed economies where these technologies typically begin, greater uncertainty prevails in emerging markets. In the latter, while there is greater risk, there is also greater opportunity for technology to leapfrog established models and create solutions that can be more transformative than in developed economies—as witnessed over a decade ago with mobile telephones and mobile payments.

This report shows how many private enterprises in emerging markets are radically altering their business models in response to disruptive technologies and trends. However, more analysis is required to fully grasp the implications of these disruptions for both businesses and investors. Our objectives here are to:

- Discuss how disruptive technologies are impacting business models in the private sector in emerging markets;
- Share a series of sectoral trends that IFC has identified in this space; and
- Invite further debate about the scope and potential of this disruption.

The evolution of technological innovation and the Fourth Industrial Revolution.

Technology-driven disruption is not new. Over the last two centuries, technologies have emerged and combined to fundamentally change the structure of our economies and societies. The First Industrial Revolution began in the 1800s and was driven by widespread adoption of the steam engine. This technology established the machine as a primary means of production and significantly displaced human and animal labor. In doing so, it precipitated the mechanization of agriculture, rapid urbanization, long-distance mechanized transport, and the rise of mass industrial production. The Second Industrial Revolution, which began in the late 1800s and lasted until the 1920s, involved intense disruptive transformation through the use of electricity. It allowed for the production and consumption of energy to be disaggregated and transmitted over distances, bringing industrial production to the world, greatly increasing

Examples of Disruptive Technologies

3D PRINTING ●

3D printing is the process of making a three-dimensional solid object from a digital model through an additive process where successive layers of material are laid down in different shapes. 3D printing is rapidly growing in use and cost-effectiveness, and has demonstrated promise across fields ranging from manufacturing to consulting to health care.

ARTIFICIAL INTELLIGENCE ●

Artificial intelligence (AI) is an area of computer science that emphasizes the creation of intelligent machines that work and react like humans. Some of the activities computers with artificial intelligence are designed to include speech recognition, learning, planning, reasoning, and problem solving.

DRONES ●

Drones are advanced remote-controlled vehicles that can be used for a variety of applications in government and the private sector. Unmanned vehicles are either controlled by 'pilots' from the ground or autonomously follow a pre-programmed mission.

AUGMENTED REALITY ●

Augmented reality is the overlay of digital information onto real-world environments, aligning both real and virtual objects with one another in a complementary manner. AR often focuses on visual data, but can include other senses as well (audio, touch, etc.)

ROBOTICS ●

Advancements in robotics are producing robots more cheaply and more efficiently. These robots are smarter, possess greater dexterity, and are safer to operate. As a result, industries including manufacturing, maintenance, prosthetics, and surgery are relying more and more on advanced robotics.

QUANTUM COMPUTING ●

Quantum computers can perform complex calculations exponentially faster than the fastest computers known today. Quantum computing is based on atoms existing in different states and places at the exact same time.

Examples of Disruptive Applications

● BLOCKCHAIN

Blockchain is a shared, encrypted "ledger" that cannot be manipulated, offering promise for secure transactions that allow anyone to get an accurate accounting of money, property, or other assets.

● COLLABORATIVE CONSUMPTION

Collaborative consumption is essentially a social and economic system that allows individuals to swap, share, rent out, or otherwise exchange their possessions or skills. It is driven by network technologies and collaborative software, and it is changing the way people transact business and consumer goods and services.

● CLOUD COMPUTING

Cloud computing is often characterized by its high storage capacity and ability to be accessed remotely from multiple locations. The cloud allows the on-demand sharing of resources, software, and information among computers, smart phones, tablets, and other devices.

● EXPONENTIAL ENERGY

Exponential energy is resulting in cheaper, more efficient renewable energy options, as improved energy storage is also rapidly advancing and being applied in new ways. As a result, energy systems are more efficient and higher quality, creating new opportunities for multiple industries.

● GEOSPATIAL ANALYTICS

Geospatial analytics refers to the statistical analysis of data that can be tied to a location on, above, or below the earth's surface. The analysis of this data supports more informed decision-making, reduced risk, more efficient operations, and enables new business models.

FIGURE 1.1 Examples of Disruptive Technologies and Their Applications

Source: IFC, based on Deloitte analysis

production efficiency, and giving rise to long-distance communication. The Third Industrial Revolution, also known as the Digital Revolution, began with the invention of the computer, which caused the replacement of analog electronic and mechanical devices with the digital technologies that are available today. This technological revolution included mobile telephony, eventually paving the way for development of the Internet.

The recent wave of technological innovation has the potential to be more disruptive in a shorter period of time than past technologies. Telephones and electricity, both late nineteenth-century innovations, took decades to spread from Western to non-Western countries for reasons that include the significant investment costs associated with the technologies. By contrast, today's technologies can spread more rapidly, and can also evolve and become obsolete at much faster rates than previously experienced. The World Economic Forum calls this most recent innovative wave the *Fourth Industrial Revolution*—one that is characterized by the emergence of technologies that evolve at an exponential, rather than a linear pace.²

The Fourth Industrial Revolution is driven by a combination of disruptive and emerging technologies that began with widespread access to the Internet, mobile communications, and exponential increases in the processing power of computers. The data generated by billions of individuals, devices, businesses, and government agencies connected to the Internet, along with the capacity of computers to process these data, are accelerating the development and adoption of technological breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing.

Current technological innovations, if adopted widely, have the potential to significantly narrow income differences between developing and industrialized countries by reducing the gap in adoption of technology. Developing countries have been characterized by both the late arrival of disruptive technologies as well as much lower intensity of their use. Even over the past century, while the gap in the arrival of disruptive technologies has narrowed between developing and industrialized countries, the gap in

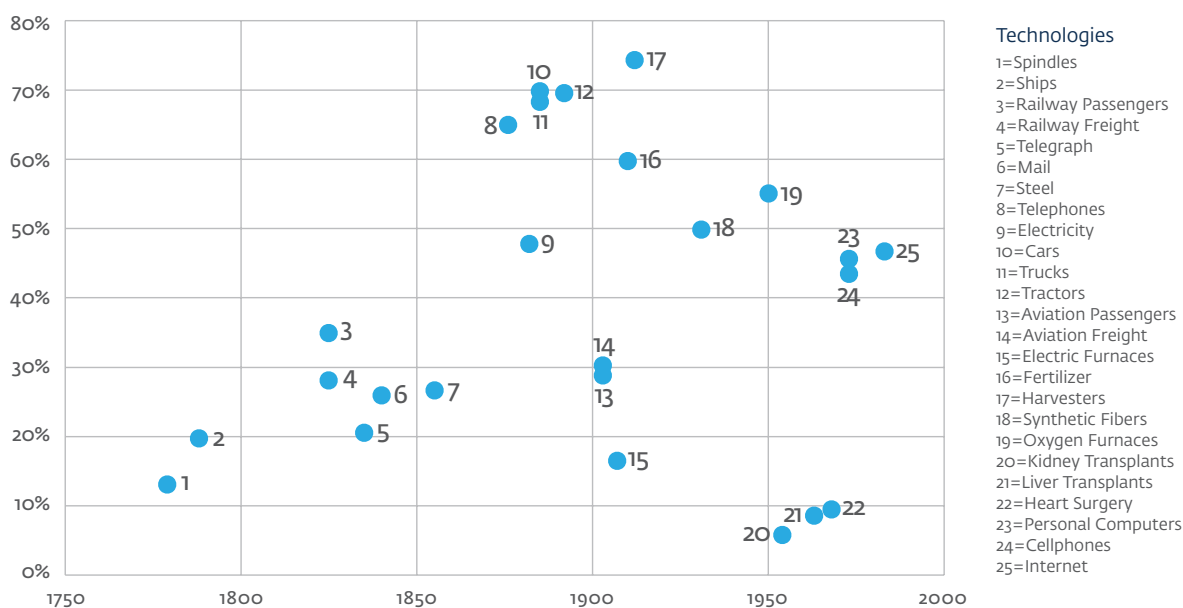


FIGURE 1.2 Median Divergence in Intensity of Use of Technologies, Western vs Non-Western Economies by Year and in Percentage Points

Source: Comin, Diego A., and Martí Mestieri Mestieri, 2018. "If Technology Has Arrived Everywhere, Why Has Income Diverged?" *American Economic Journal: Macroeconomics*, Vol. 10, No. 3, pp. 137-78.

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the intensity of using these technologies, once they arrive, has increased (Figure 1.2). Reducing poverty and increasing shared prosperity in emerging markets depends on improving the rate at which these markets adopt the new technologies. Indeed, a recent study suggests that over the last century, most of the income divergence between Western and other countries has been due to differences in the diffusion of technology.³

There are reasons to believe that today's wave of technologies offers opportunities for much greater adoption than previous technologies. In the past, several factors impeded greater use of technologies in developing countries. These included lack of a technologically literate workforce, a poor investment climate that deterred the creation and expansion of firms adopting higher technology, inadequate access to capital, poor enabling infrastructure such as energy and transport, and government institutions that were unable to promote the diffusion of critical technologies when market forces were inadequate.⁴ Several features in the new wave of technologies (as well as changes in the country context for technology adoption) improve the potential for greater intensity of adoption.

What drives the diffusion of disruptive technologies?

One factor that increases the diffusion of disruptive technologies is their ability to reduce costs. Many of today's disruptive technologies are not capital intensive, which lowers new firms' barriers to entry. Digitalization supports asset-light business models, resulting in both lower upfront costs and lower operating expenses. FinTech's online scalability and low fixed-cost structure has allowed it to fundamentally challenge—and ultimately disrupt—traditional banking models. Financial services have traditionally been bundled to enable the cross-subsidization of product profitability. In contrast, FinTech's business model enables disintermediation by focusing on individual parts of the value chain.⁵ In spite of the barriers to entry that precluded capital markets from similar disruption, technological advances such as artificial intelligence (AI), blockchain, and the cloud can continue to reduce the cost of entering this market while delivering innovation that was previously difficult to achieve.⁶

One of the major technological trends that is lowering fixed costs is the shift to shared resources. Cloud computing eliminates the need for significant capital expenditures on information technology infrastructure. Service rentals—from ridesharing services like Uber to agricultural equipment and home solar systems—also lower costs, allowing a shift in consumer and firm behaviors from purchasing a product to requesting a service.

Disruption is compounded and amplified when multiple technologies are used in tandem and supported by digital platforms. For example, the key insights from IoT sensor data can only be obtained through the use of AI technology, which is needed to analyze the data. Performing maintenance on a 3D printed asset is much more efficient when combined with augmented reality goggles, which enable the digital version of the asset to be superimposed onto the physical environment.

In addition, disruptive technologies are causing the boundaries between industries to blur. Transport providers now compete with technology firms (and vice versa), online retailers have begun experimenting with drone delivery systems, and auto manufacturers may become the main stakeholders in building underground transit systems.

Finally, the convergence of disruptive technologies with emerging global trends amplifies their potential for disruption. Urbanization, shifting demographics, and climate change, among other trends, are driving more rapid adoption of disruptive technologies. For example, disruption in the power sector has been magnified by the convergence of various innovations, including the decline of renewable energy technology prices, increasing adoption of competitive procurement mechanisms, and the commoditization of financing for renewables—all of which have come amid technological advances such as battery storage, electric vehicles, new models of distributed power generation (for example, rooftop solar photovoltaic and microgrids), and digitalization of the electrical grid. And the traditional separation between energy producers and consumers continues to blur as the energy system becomes more distributed and digitalized. The convergence of these innovations, each one disruptive by itself, is amplifying opportunities for transformation.⁷

The interplay between disruptive technologies, digital connectivity, and the digital economy.

The convergence of disruptive technologies, changing cost structures, and the global forces described above have the potential to lead to, and be further reinforced by, the rise of platforms and digitalization.

Increased connectivity has spurred the rise of digital platforms that connect individuals, institutions, and enterprises, both big and small, in completely new ways, amplifying their reach and impact. Platforms do

not own the means of production, but rather the means of connection, creating economic and social value by enabling users to share or offer knowledge, labor, or digital and physical assets over an online network. These platforms facilitate interoperability, creating markets and connection points where they did not previously exist due to economic failures. Increasingly, platforms are shaping communities along the lines of common belief systems or shared economic needs, rather than traditional nation-states.

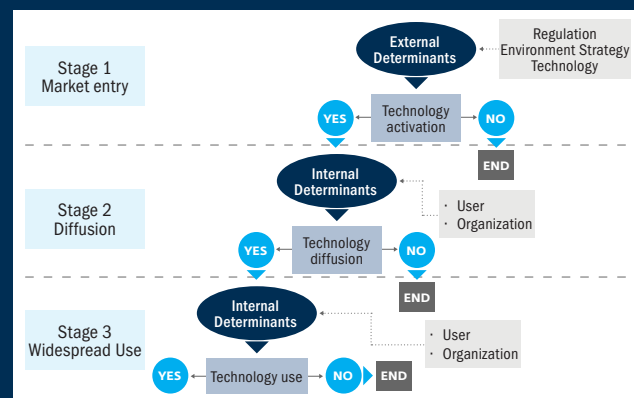
BOX 1.1 Pathways to Technology Adoption

Adequate diffusion of emerging technology is important if countries are to realize the full benefits of these technologies, but disruptive diffusion is influenced by a range of factors. Diffusion will be influenced by various agents, beginning with the individual firms introducing a new technology into the market, and extending to downstream industries. Macro-level conditions will influence technology activation, as well as speed or slow the ability for economies to rapidly adopt technology. They will also affect how successful an economy is in transitioning legacy firms and workers. Adequate diffusion of emerging technologies is important if countries are to realize the full benefits of these technologies, but the path from introduction of a new technology, to a disrupted market, to successful resource relocation, differs depending upon the innovation, the product, and market factors.

Analysis of how radical innovations taking place at the organizational and managerial levels diffuse at the industry level is just beginning, despite rapid growth of new digital technology. The empirical evidence on disruptive technologies suggests that widespread diffusion is a multi-stage process, where further advancement is enabled or hindered at each stage in the process. The figure below generalizes the points at which technological diffusion either advances or ceases. At the market entry stage, the interplay of external conditions is largely outside the control of potential investors. These conditions include the regulatory landscape, market structure, the economic environment, and the presence of government-supported strategic alliances—all of which can catalyze or hobble the introduction of technology-based innovations. At the technology diffusion phase, a technology can either spread across

a market or be derailed, depending on both external factors, as well as those under the disrupter/adopter firms' control. The latter include learning by doing, information spillovers, and resistance. Finally, the phase of widespread diffusion/use is characterized by additional internal, adopter-related features that determine if the technology is broadly recognized as a valuable asset, and diffusion increases.

Life Cycle of Technological Diffusion



Source: Adapted from Ghezzi, Antonio, Raffaello Balocco, and Andrea Rangone. 2013. "Technology diffusion theory revisited: a Regulation, Environment, Strategy, Technology model for technology activation analysis of Mobile ICT." In: *Technology Analysis & Strategic Management*, Vol. 25, Issue 10, pp. 1223-49.

Separate from the diffusion process is the process of factor reallocation. The economic growth and development benefits of disruptive technologies are magnified when labor can be shifted from the "legacy technology" firms to the higher-productivity, disruptive technology entities. The scope for successful reallocation depends on a variety of factors, including the skills profile of the labor force relative to the new technology factor's needs, and the regulatory environment impacting the pace of job reallocation.

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Platforms have significant potential to increase access to goods, services, and participation in many areas that lack it. They are increasingly being used to provide key public goods and services, and they enable small enterprises and entrepreneurs to tap into global markets, democratizing the creation of economic and social value. Platforms tend to have network economies of scale. That is, more value is created as a platform gains wider use. This affects incentives for competition, which can be between platforms or within a single platform. An example of the latter is a mobile wallet platform in Peru that brought together mobile money issuers, telecom enterprises, and the government to create a single platform that fosters competition.⁸ The primary benefits of collaboration include the facilitation of rapid scaling and the ability to reach additional users, both of which generate greater value for all actors on the platform.

As platforms scale, their growing influence—through both the collection of data and expanded reach—raises issues about competition, data ownership, and privacy. Concentrated platforms can also increase inequality, as data may flow from a platform’s periphery to a data core in the developed world. Because the global poor remain vulnerable to these risks, appropriate caution and regulation are required to exercise control over information flows and privacy.

Disruptive technologies are enabled and amplified by a successful digital economy. The digital economy is the economic activity that results from everyday online connections among people, organizations, devices, data, and transactions. In 2016, according to a report by Huawei and Oxford Economics, the global digital economy was worth \$11.5 trillion, or 15.5 percent of global gross domestic product (GDP).⁹ Many disruptive technologies build on top of the digital economy, as they rely on Internet and mobile penetration.

The digital economy will not develop organically in emerging markets; instead countries need to work on building certain foundational elements in order to help spur the digital economy. These elements include:

- Digital infrastructure—the backbone of a digital economy—that is universal in coverage and universally affordable to bring people, businesses, and governments online;

- Digital platforms—for example, for self-identification—to offer digitally-accessible products and services for all aspects of life;
- Digital financial services to allow people, businesses, and governments to pay and transact digitally;
- Digital entrepreneurship to create an ecosystem of young, growth-oriented companies;
- Digital skills to create a digitally-savvy workforce and foster competitive markets.

Implications for Firms and Private Sector Investors in Emerging Markets

The pace and trajectory of disruptive, technology-driven change in emerging markets is a key unknown.

While much of the research on the impact of technological disruption has focused on advanced economies, there is growing desire to understand how emerging markets will be impacted. Traditionally, these countries adopted and adapted technologies created elsewhere to “leapfrog” the steps in the traditional development ladder.¹⁰ For example, low-income nations that have yet to establish a fully-functioning retail banking system could bypass development stages by using the profusion of innovative financial digital services.

The new wave of technologies could have similar—and even more disruptive—outcomes for developing countries, but their trajectory remains unclear. Because many of the leapfrog technologies are foundational in nature, there is capacity for spillover effects that can further expand markets. For example, the steam engine expanded markets for power across a range of consumers and industries. In the case of textiles, new, more precise steam-powered engines allowed for the production of higher-quality textiles. Leapfrog technologies in core infrastructure could expand downstream markets severalfold. Some examples of market-multiplying technologies include off-grid energy, which could expand the market for irrigation and thereby boost agricultural production, and cloud computing, which enables the Internet of Things.

Key characteristics of emerging markets—large infrastructure gaps, lower income levels, younger populations, and growing urbanization—create uncertainties about the trajectory of technological diffusion, while multiplying opportunities for investment. There are several examples of how these uncertainties need to be taken into account. Emerging markets, with lower incomes and higher levels of inequality, may not be able to provide the high capital outlays required to fund new technologies such as autonomous vehicles and 3D printing. Technologies such as automation and AI may struggle to take off too in some emerging markets due to concerns about potential job losses, coupled with the fact that these markets have a rapidly growing labor force and considerably cheaper labor costs. This differs from many developed countries that have a stagnant or declining working age population. Additionally, while urbanization is increasing in most emerging markets, these countries still lag behind developed countries, which may slow the diffusion of certain applications and business models such as those in the urban transportation sector. However, the younger demographics of emerging markets could be an advantage in achieving rapid adoption rates, especially for some digitally-based disruptive technologies.

Firms in emerging markets face conditions distinctly different from those in developed countries so the solutions and uses of technology will also differ. For example, in emerging markets, battery storage will most likely be used to solve the widespread problem of access to electricity, while in the developed world battery storage will primarily be used in electric vehicles. In advanced economies, technologies have typically been driven by the increasing sophistication of consumer needs, and by the need to reduce labor costs. In emerging markets, technology use is often driven by the need to circumvent bottlenecks or solve problems that do not exist in wealthier nations. Thus, technologies that take off in emerging markets are likely to be developed locally, and in response to consumer needs and constraints in those markets.

Firms face a new set of opportunities and competitive pressures.

Technology-enabled, asset-light business models have decreased barriers to entry, which is particularly

beneficial to small and medium enterprises. The large upfront costs of establishing and growing a business can be particularly constraining for small businesses in developing countries, which have very limited access to long-term risk capital. Disruptive technologies allow upfront costs to be transferred from capital expenditures to operating expenditures. For example, cloud computing enables firms to access shared IT infrastructure on an as-needed basis, and gives them flexibility to alter their IT expenses in line with business requirements. This “pay-as-you-go” model eliminates the need for large initial capital investments, and by doing so has reduced new businesses’ financial barriers.

Firms can also grow more rapidly, as disruptive technologies enable scalability, access to larger markets, and opportunities for increased innovation through knowledge sharing. With up to a third of all new firms unable to survive beyond two years, digital platforms can offer crucial supporting infrastructure.¹¹ These platforms provide small firms with “plug-and-play” infrastructure and instant access to large global markets at minimal cost. (For example, Amazon hosts two million third-party sellers, and around 10 million small businesses have become merchants on Alibaba platforms).¹² Other technologies also enable rapid knowledge sharing between firms, which allow them to innovate and scale at a faster rate than normally possible. For example, the application programming interface (API) economy enables the exchange of business functions and services that use APIs, and many leading companies have developed rich ecosystems by including participants who create APIs and apps, which helps to spread knowledge. Firms such as Starbucks and Trip Advisor have used Uber’s API to improve the functionality of their own apps, as well as save time in the development process.¹³

Product and process differentiation that can be targeted specifically to customer preferences will be a competitive advantage. Technology has also changed consumers’ expectations, with immediacy and personalization becoming the norm. Just as brick-and-mortar retail stores responded to the online threat with strengthened online presences as well as modified physical channels that allow online customers to pick up their purchases, traditional service providers will need to respond by adopting disruptive technologies

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across products and processes. Big Data¹⁴ gives firms the opportunity to target products specifically to consumer preferences, based on more accurate information about consumer behaviors. This provides customers with better quality services and product differentiation, which can force competing firms to innovate.

Increased competitive pressure due to changing business models will mean that firms need to continuously innovate. Due to the rise of disruptive business models discussed above, achieving scale and being quick to take market share will be a key competitive advantages for firms. The network effects of platforms have created a winner-takes-all dynamic, so firms that are able to scale the fastest will be more likely to set industry standards and precedents. They will also be faster to innovate and respond to customer needs as the platform is iterative and self-optimizing (the more users on the platform, the more it is able to use their behavior and feedback to improve the system). In advanced economies, many of the biggest success stories have come not from product or process innovations, but from market entrants that achieve enough scale to create new markets through their platforms. However, it remains to be seen if emerging markets will be able to replicate this.

Traditional investment and business models suffer from a rapid obsolescence risk.

While disruptive technologies provide “leapfrog” opportunities for investors in emerging markets, they also pose the risk of obsolescence. There is considerable uncertainty about which technologies will emerge as dominant, how long they will take to truly create disruption, and which sectors they will impact the most. Mobile phones leapfrogged conventional technologies and left investors of landlines stuck with obsolete infrastructure, while early backers of mobile phones emerged as winners. Not all technologies fulfill their potential: telecommuting was expected to radically change how and where people work, but never fully realized this potential. Between these two extreme examples is the case of the electric vehicle, which was introduced decades ago but only recently emerged as viable. Thus, for long-term investors, it is becoming increasingly difficult to identify which assets will remain competitive in emerging markets, and the

various complexities and issues that contribute to high levels of uncertainty.

In fact, investors in new and innovative firms might be susceptible to a “first-mover disadvantage.” As a first mover in bringing renewable energy to emerging markets, IFC has frequently encountered this phenomenon. It is not uncommon for a first mover to be quickly overtaken by a start-up firm with a more innovative business model or better technology. For example, IFC made several early investments in companies connecting small stores into payment networks that enabled unbanked consumers to pay their utility bills, transfer money, and receive government assistance payments. While IFC assumed these companies would become central points for the conversion of cash to electronic money, it did not foresee the rapid rise of mobile phones as effective payment transfer devices.¹⁵

How the future unfolds may depend to a significant extent on whether development challenges are met by centralized or decentralized networks. For example, under decentralized networks in the power sector, production will be localized, electricity will be delivered through distributed generation, and transactions will be enabled by blockchain. In a centralized scenario, incumbent corporations and new large-scale stakeholders will be the primary drivers of innovation and change by acquiring smaller firms, start-ups, and intellectual property. This latter scenario could create a market where innovation thrives, yet critical skills remain with incumbents and large players, instead of being dispersed into the wider economy. Thus, taken to their extremes, the shift to either a centralized or a decentralized system could create very different outcomes for investors and firms alike.

New and existing firms will face continuous pressure from new business models. Such models, coupled with lower-cost structures, are enabling agile innovators to enter traditional sectors, and they also allow some infrastructure to be “unbundled.” The “utility of the future” is expected to be a significantly more service-oriented and multi-functional business—very different from the traditional electricity delivery business. In the energy sector, the so-called “smart-grid”—the application of digital communications technology

to identify and adjust to local changes in electricity supply networks—has proven to be a disruptive catalyst that could enable new market entrants to enter the electricity supply market. This could include collaborations between telecom operators, local communications centers, schools, small and medium enterprises, and other parties that benefit from expanded information and communications technology (ICT) access and delivery.

Success can be inconsistent and irregular, and some developing countries will be better than others at harnessing disruption.

While technology can enable disruptive business models, it is not always sufficient, and implementing appropriate regulatory and other policies is critical to its success. M-Pesa, which took off in Kenya but failed to launch in other African markets, is a case in point. The service boasts 19 million mobile subscribers in Kenya, compared with just 76,000 active users in South Africa (based on 2015 data).¹⁶ Other than requiring users to register, the Central Bank of Kenya imposed few restrictions during the mobile money service's early deployment, which played a key role in its success.¹⁷ However, M-Pesa's difficulty in replicating this success in South Africa was partly due to that nation's stricter digital wallet regulations.¹⁸ This demonstrates that technology alone is not sufficient to achieve the creation of fully functioning markets, and that it must be complemented by an enabling ecosystem that includes appropriate regulation. Conversely, obsolete policies can restrict the introduction of disruptive technologies, and may allow disruptive technologies to become monopolies. Countries with flexible policy environments are more likely to innovate, with regulations that can scale and adapt, along with innovations.

It remains uncertain how successfully developing countries will adopt these technologies, and which countries will be the leaders in doing so. While emerging markets have adopted new technologies at different paces, penetration rates of technologies such as mobile phones vary greatly, and in some countries adoption remains limited. Thus the level of adoption of the new wave of disruptive technologies discussed in this report remains difficult to determine. Factors that account for

low penetration levels can be categorized under country-specific characteristics (for example political risk), firm-level characteristics (such as the level of managerial quality), and general bottlenecks (access to finance and a lack of infrastructure, among other factors)—all of which are common in emerging economies.

Some features that have aided the diffusion of digital and other disruptive technologies include:

- *Investors' use of adaptive business objectives and models.* For example, Lighting Africa continually adapted its program based on the results of early field trials in Ghana and Kenya, and found that on-the-ground engagement required dedicated local specialists, in addition to global expertise.¹⁹ To be successful in the low-income market, companies need to adapt production processes, supply chains, business models, consumer education, payment methods, and the people involved.²⁰ Uber adapted to African markets by allowing cash payments, moving away from its core model of frictionless finance, in order to better serve a customer base that distrusted e-commerce.
- *Making seed financing available to test technical feasibility and affirm market potential, particularly in the early stages of technology innovation.* Bilateral development agencies and private foundations have played an important role in funding disruptive technology start-ups, and venture capital has enabled rapid scaling. M-Pesa's mobile money was launched through a partnership between the Department for International Development (DFID) and Vodafone. Sanergy, which makes prefabricated toilets that turn human waste into fertilizer, was incubated in the Massachusetts Institute of Technology's Media lab and initially funded through USAID. Private foundations have also become important players in helping new technology start-ups to expand. Major technology companies, including Microsoft, Google, and Facebook, are interested in financing infrastructure projects to ensure wireless connectivity across Sub-Saharan Africa. Important investments in agricultural technology (AgTech) for small shareholders are being funded through partnerships with the Bill and Melinda Gates Foundation.

- *Through use of incubators or “sandboxes,” early-stage technology companies and governments can learn by doing.* Since getting to scale is a key challenge for broader diffusion in developing countries, partnerships and incubators are important. Incubators provide a range of support services to start-ups and early-stage companies, and the incubation process allows policymakers to learn what is important on the ground and how to avoid costly policy mistakes. Incubators also allow companies and policymakers to experiment and develop capacity in the local context.

Inviting a Debate on How the Private Sector Can Harness Technology Disruption for Development

The disruptive technologies discussed in this report are becoming critical to emerging markets. They have the potential to transform and propel economic growth and private sector expansion—and to accelerate development.

However, the speed at which technology spreads and combines with economic and social trends, as well as countries’ varying abilities to absorb and adopt these technologies, create new and unfamiliar risks for investors and businesses alike. In many countries, these risks can add to existing macroeconomic and political risks.

While the impact of disruptive technologies on *developed* economies has been analyzed extensively, in emerging markets, significant gaps remain in our understanding of how technologies can be harnessed to create markets and strengthen the private sector.

This report documents and discusses a number of trends in the disruptive technology space that IFC has identified as relevant for the development of private financing across eight sectors—power, transport, water and sanitation, digital infrastructure, manufacturing, agribusiness, education, and financial services. In addition, this report examines disruptive technologies

with regard to gender, climate change, microfinance, housing, logistics, and identification (ID) systems.

IFC’s knowledge of these trends and approaches is derived from our extensive experience as a development investor, our role within the broader World Bank Group, and our access to in-depth industry insights and market information in emerging markets. In addition, our analysis is informed by our approach to, and experience with, investing in disruptive technology. This approach is based on making direct investments in early-stage companies at the leading edge of technology and disruptive business models—investments that are relevant to our traditional areas of business in financial markets, manufacturing, services, agribusiness, and infrastructure. We also support the development of an entrepreneurial ecosystem in emerging markets as a key component of the innovation and technology adoption process. We invest too in venture capital and early-stage funds that provide scarce capital and advice to entrepreneurs in emerging markets, as well as advisory engagements that support technology transfer. Together with our partners in the World Bank, we help governments to think through the policy and regulatory challenges involved in capturing the benefits of disruptive technologies, while managing new and unfamiliar risks.

Recognizing that investors need to understand and manage the growing impact of disruptive technology better, we want to encourage international development and private financial institutions, individual investors, and businesses to debate the scope, potential, and risks of the disruptive technologies they are encountering and harnessing.

IFC’s overarching objective is to support innovation as a driver of economic growth, inclusion, and sustainability in emerging markets. Leveraging technology for the development of the private sector is a significant and growing opportunity, yet more needs to be done to increase awareness, reduce risks, and boost investment. ■

CHAPTER 2

Creating an Enabling Environment for Disruption

By Gordon Myers

New technologies will pervade and accelerate development in emerging markets, in areas ranging from financial inclusion to renewable energy and delivery of humanitarian aid. However, as in prior technological revolutions, disruption will not take place in a vacuum. Just as railroads gave rise to standardized timekeeping, new forms of industrial organization gave rise to antitrust and labor legislation, and earlier information technology innovations gave rise to new privacy and intellectual property frameworks. The latest wave of technologies will also require reconsideration of both national and international regulatory regimes. These frameworks will need to adapt to realize the potential benefits and opportunities of disruption, manage sweeping change in an equitable manner, and enable new kinds of property and new kinds of markets to function. For these reasons, the intersection of disruption and regulation has become a focus for IFC and its clients.

Emerging policy priorities

Of the emerging policy priorities, privacy regulation has perhaps received the most public attention. Many new technologies, and notably artificial intelligence (AI) applications, are powered or enabled by personal data. This means that these new technologies depend on trust. In a recent case, when a national government offered its citizens the ability to opt out of electronic health records, online communication and phone systems struggled to keep up with demand. In other jurisdictions, there are reports about similar concerns over bias and privacy that have resulted from the use of AI in financial inclusion.

For these reasons, the question of personal data “ownership” is front and center: Deciding who has the ability to use and control personal data is a central concern for regulators and relevant industries. This

focus is particularly acute in the area of financial inclusion, for example, where oversight of information brokers important to FinTech and alternative credit innovations is considered a key regulatory gap.

Competition is a second but equally important policy concern. Competition is often a proxy for deeper concerns about equity and job creation, but the underlying economics also matter. The network effects of large-scale adoption, giving strong “first-mover” advantages, and the potential for “platforms” to leverage access to transactional and personal data into anticompetitive advantage, have led some regulators to question whether new models of consumer welfare are needed to guide competition authorities. Some commentators and regulators have gone so far as to propose utility-type regulation of information businesses. The United Kingdom’s Financial Conduct Authority (FCA) has established a regulatory sandbox that includes an express competition mandate.

Finally, cybersecurity, risk governance, and corporate governance have all emerged as core regulatory priorities. Several key trends motivate their interest: the increasing pace of cybersecurity attacks; the increased reliance on cloud computing and other outsourced operations, including software-as-a service applications licensed from new providers who rely on “fourth party” arrangements; and the realization that direct regulatory oversight may not be achievable or desirable except for some critical regulated applications. Among other things, regulators are increasingly demanding that corporate boards exercise appropriate oversight over cyber-risk operations, and are holding board members responsible for the appropriate business and technical safeguards needed to manage risks appropriately. The likelihood of increased reliance on decentralized computing operations such as blockchain may only accelerate regulatory tendencies in this direction.

Regulators and disruption

Beyond these specific concerns, the scale, pace, and pervasiveness of disruption also are key drivers of regulators improving their capacity to adapt to the disruption environment. Even where there are no changes to policy aims, disruption will require regulators to rethink the context and implications of laws premised on a pre-disruption world. For example, the simple possibility that underlying “real” assets or interests can be represented in digitized form will generate many discussions on how security can be perfected and represented by digital tokens. Additional questions for regulators to consider are whether an exchange of assets is merely barter or something else, and whether the representation of digital assets in a decentralized ledger is admissible in court. Another question is which law is appropriate for the direct exercise of voting rights by “token” in a decentralized autonomous organization, or a dematerialized bond offering, or any of a number of organizations and interests that may be translated into a digital environment.

Similarly, the development of “smart contracts” may demand new thinking on the premises of contract formation. There is also the question of liability—what happens if a digitized contract performs in a way that

does not meet the intent of the parties or fails because the outside information required about performance is unavailable. Even in advanced versions, how can the intent of parties be determined from a contract that is only expressed in its underlying code? And finally, the very business processes and regulated parties may require rethinking in a digitalized, disintermediated environment. The allocation of anti-money laundering and know-your-customer obligations, for example, might no longer fall on “money transmitters,” but might instead be placed on other gateways to a digitalized financial system.

Moving forward

In sum, regulators will need to find new tools to manage the wave of issues that confronts them, including “principles-based” regulation that allocates more accountability to regulated entities, at the cost of certainty and reliance on standard-setting bodies to convene stakeholders and develop paths forward, even ahead of regulation. Recent industry efforts supported by national regulators, notably in the area of cybersecurity and cloud computing, may be models of this approach. Also, the emerging efforts of IFC and the World Bank Group, as honest brokers in the new economy, will be no less critical. ■



REINVENTING BUSINESS IN SELECTED SECTORS THROUGH DISRUPTIVE TECHNOLOGIES

CHAPTER 3

Disruptions in Power

By Julia Heckmann and Tonci Bakovic

The power sector is undergoing a profound transformation driven by technological and market disruptions.²¹ Power generation is shifting from fossil fuels to renewables; battery storage is being mainstreamed; the transport sector is undergoing electrification; and the historically centralized grid is becoming more distributed—fundamentally altering the way electricity is delivered and consumed. These innovations provide us with new tools to close the energy access gap in emerging markets in a sustainable manner.²²

How do We Define Disruption in Power?

Access to clean, reliable, and affordable electricity is central to development in all emerging markets, as it links economic growth, social equity, and environmental sustainability. Delivery of reliable and affordable energy services contributes to poverty reduction and shared prosperity—indirectly through its contribution to economic growth, and directly by enriching the lives of the beneficiaries of such services. Electrification is critical to achieving a number of the Sustainable Development Goals—including those concerning health, and education, and creating employment in poor communities. Moreover, clean energy sources help reduce local air and soil pollution, and decrease land degradation associated with fossil fuel extraction.

Despite several decades of progress toward electrification, nearly 1 billion people remain unconnected, about half of whom reside in Sub-Saharan Africa and a quarter in India.²³ Yet extending the centralized power grid is often not a feasible option,

as grid-based electrification is the most cost-effective approach to reach only 46 percent of the off-grid population in Sub-Saharan Africa by 2030. At present, the poor must obtain electricity from sources that are prohibitively expensive, environmentally unfriendly, and often dangerous to consumers.

Looking ahead, there are three energy-related development challenges: closing the energy access gap, addressing rapidly rising electricity demand, and curbing power sector carbon emissions. These are exacerbated by population growth, urbanization, rising living standards, and the digitalization of everyday life. Energy demand is expected to grow 60 percent by 2040, with over 85 percent of this growth coming from developing countries, and 67 percent from Asia alone.²⁴ Comprising 25 percent of total emissions, the power sector is the largest emitter of carbon dioxide (CO₂).²⁵ However, curbing carbon emissions while also meeting increasing power demand will be a challenge.

The convergence of innovative technologies, business models, and power market designs provides new tools to respond to these challenges, with new methods of producing, storing, managing, and consuming electricity that are disrupting the power sector.

Which Technologies and Policies are Disrupting Power?

Recent technological disruptions in the power sector provide renewed impetus to achieve affordable and reliable energy for all, while significantly reducing carbon emissions. Distributed power generation—especially hybrid photovoltaic-plus-storage systems and smart and

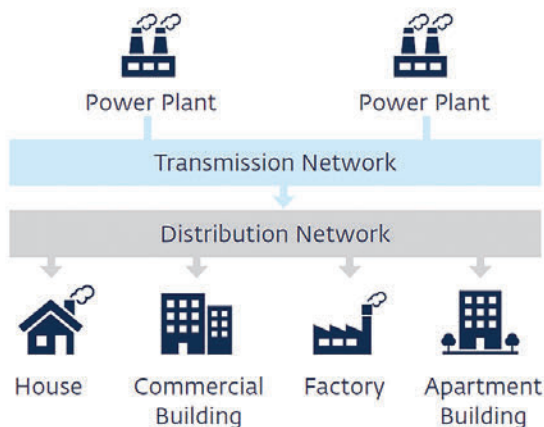
energy-efficient mini-grids—are creating opportunities to reach populations that are currently unserved or underserved. Renewable energy, more efficient grids, and fuel-switching from coal and oil to natural gas can significantly reduce emissions. Positioning gas as a cost-effective alternative to coal is especially important in Asia, and will help ensure that the power sector’s share of CO₂ emission growth falls dramatically.

Two phases of technological change have caused market disruption in the power sector. The first, beginning in the early 2000s, brought new renewable energy sources that began to disrupt the reliance on traditional energy sources. As part of an effort to curb global carbon emissions, various countries rolled out support mechanisms such as feed-in-tariffs (FITs)²⁶ to support the deployment of “new renewables” including solar photovoltaic (PV), wind, concentrated solar power (CSP), and biomass.²⁷ In 2016, for the first time, renewables accounted for more than half of new power capacity additions globally, and overtook coal in terms of cumulative installed capacity.²⁸ Due to the virtuous cycle created by the deployment of renewables, technological improvements, economies of scale, and more competitive supply chains, the price of solar PV and wind power has dropped significantly. In parallel, a shift in natural gas markets

occurred through innovation in the liquefied natural gas (LNG) trade. LNG has become more accessible to emerging markets through the recent decrease in oil prices, new LNG production capacity, and the advent of floating LNG import terminals. These factors have turned natural gas-fired power generation into a cost-effective, low-carbon energy option for markets without domestic gas resources, and an ideal complement to intermittent renewables such as solar and wind. Gas is a key transition fuel until batteries can compete in terms of price for storage capacity and rapid power ramp-up needs.

The second phase of disruption is characterized by the convergence of technological innovations, decentralization, digitalization, and evolution of power market design. Beyond the continuing decline of renewables prices, the increased adoption of competitive procurement mechanisms, and the commoditization of renewables’ financing, new innovations are changing the power sector landscape. These include advances in battery storage, the advent of electric vehicles, new models of distributed power generation (for example, rooftop solar PV, hybrid solar, and battery storage minigrids), and the digitalization of electricity systems via artificial intelligence, the Internet of Things, and blockchain. The convergence

CENTRALIZED POWER HAS BEEN THE NORM...



BUT SIGNIFICANT CHANGES ARE UNDERWAY.

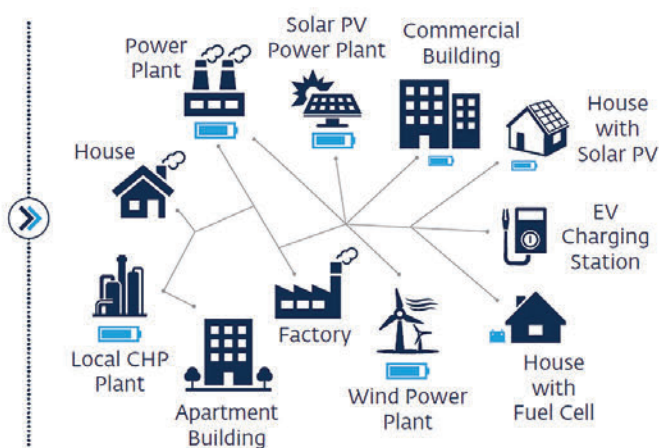


FIGURE 3.1 From Centralized to Distributed Power

Source: Adapted from John Farrell. 2011. “The Challenge of Reconciling a Centralized v. Decentralized Electricity System.” *Institute for Local Self-Reliance*. October 17.

of these innovations is creating a “perfect storm” of transformation. The centralized electricity system is becoming smarter and more distributed, with behind-the-meter generation and storage blurring the traditional line between energy producers and consumers (and creating “prosumers”). Some detailed examples of this transformation follow.

Decentralization. The traditionally centralized power system is becoming more decentralized as distributed power generation (DG) increases. DG refers to small-scale technologies (such as rooftop solar) that produce power at the point of consumption, as opposed to centralized assets such as large utility-owned power plants located far from consumers. The broader term distributed energy resources (DER) encompasses a variety of distributed technologies that go beyond power generation, including energy storage, electric vehicles (EVs), demand management, and virtual power plants. Decentralization and DG deliver development impact not only by enabling off-grid energy access, but also by improving grid resilience and increasing the reliability of electricity for businesses, which also supports job creation, including livelihoods for low-income individuals.

Solar PV and wind power are on the rise. Due to the continuously declining cost of solar PV, solar energy is becoming cost competitive without subsidies in more and more countries, and is on track to become the cheapest form of new electricity in many of these countries. PV and wind are already cheaper than building new large-scale coal and gas plants in many major markets, including India and China.²⁹ Rooftop solar installations are becoming ubiquitous. In Mexico, for example, distributed solar is expected to grow from near zero in 2017 to 11 percent in 2028.³⁰ In China, rooftop solar is already cheap enough to compete with industrial and commercial retail power prices, and new rooftop PV installations are expected to surge significantly in 2018.

Offshore wind is reaching grid parity in more and more markets. Thanks to advances in technology, project scale, and competitive procurement, offshore wind has quietly crept into the range of “grid parity,” competing against conventional generation in Europe. The sector is set to expand to emerging markets in much the same way that solar PV and onshore

wind did a decade ago. Offshore wind presents a distinct opportunity for emerging markets due to its competitive cost (7-9 US cents/kWh and falling quickly); large scale (typical projects are between 500 and 1,000 MW); proximity to load centers (thanks to excellent wind resources close to major cities); and strong economic impact (due to high project capital expenditure in the range of \$2 billion to \$4 billion). Recognizing this opportunity, an increasing number of oil and gas companies are leading development, drawing on their experience in managing complex, capex-intensive marine projects.

India, for example, received a very positive response to its recent expression of interest for the country’s first gigawatt (GW) of offshore wind generation. Renowned global offshore wind players as well as local players expressed interest. This strong response prompted the government to set a new long-term target of 30 GW of offshore wind by 2030, on top of the existing target of 5 GW by 2022.

Floating LNG import terminals offer new access to gas. The advent of floating storage and regasification units (FSRUs) has meant that emerging markets now have a much lower cost infrastructure option than was previously available. Because the floating component can be leased, the capital mobilization challenges are lower. With access to growing global gas markets, in the future, developing countries can confidently choose gas as the fuel to complement renewables. Although this is not yet common, several emerging markets are now looking to complement renewables with LNG.

In 2018, IFC financed its first LNG-to-power project featuring an FSU. The 1.5 GW Port of Sergipe Power Plant in Brazil will be Latin America’s largest and most efficient combined cycle gas turbine plant when it becomes operational in 2020. By providing flexible gas generation that can ramp up and down, the power plant will help displace the use of heavy fuel oil and diesel-fired generation. Carbon emissions from this plant should be approximately 56 percent less than diesel plants, and 65 percent less than coal-based plants of equivalent capacity. Given expected average dispatch, the project is expected to help reduce carbon dioxide (CO₂) emissions by some 2.5 million tons annually.

Battery storage is becoming economically viable for some applications, and further price declines are expected, while efficiency gains continue. Despite the current dominance of lithium-ion batteries, there is currently no single winning energy storage technology. A diverse blend of battery technologies is currently being deployed because each technology suits different uses (demand response, peak shifting, frequency regulation, renewables firming and smoothing, and transmission investment deferral). Incumbent technologies are gathering scale (such as lithium-ion batteries) while newer technologies are improving in performance (solid-state batteries, for example).

IFC is currently studying how battery storage could be used in Mexico to relieve a transmission bottleneck in Baja California Sur. This would help with the integration of renewables. On the alternative battery chemistry side, IFC invested \$7 million in NantEnergy (formerly Fluidic Energy) in 2013. While still relatively high cost, NantEnergy's zinc-air batteries have the potential to become a low-cost, less-environmentally hazardous option than lithium-ion batteries for long-duration energy storage.

Flexible grid storage will become an important tool for maximizing grid flexibility to integrate renewables into the grid, making solar and wind more like baseload generation and more easily dispatchable. This is particularly important in emerging markets that do not have the same grid sophistication as developed markets. Chile was among the first nations in the world to install grid-scale lithium-ion batteries to provide short-term flexibility. The first 12 MW were installed in 2009; since then a total of 52 MW have been added.

It should be noted that storage is not the only solution to achieve the needed grid flexibility and is certainly not the cheapest one. Other tools include solid infrastructure (for example, a good transmission and distribution network), advanced grid operational practices, and system operator tools (such as demand response and wind forecasting).

Grid-connected solar-plus-storage systems. As the penetration of renewables on a grid increases, co-locating PV and storage can greatly increase the value of a solar resource by extending the electricity it supplies into peak evening hours. Combining

renewables with storage can make renewable power dispatchable and displace gas and coal as the baseload. In December 2017, hybrid projects in the United States yielded prices between 3.6 and 4.5 US cents/kWh (including a tax credit) for systems with four hours of storage at 25 percent of the solar PV plant's nameplate capacity, to be delivered in 2019 and 2023. The hybrid combination allows for shared system and engineering, procurement, and construction (EPC) costs, which can represent around 15 percent of costs for each technology if they are considered separately.

Digitalization of the energy system is turning the grid into a "smart grid." While the energy sector has experienced some digitalization in the past, the current wave is being enabled by wireless connectivity and the Internet. The demand for digitalization is driven by intermittent renewable energy sources, which require greater grid flexibility. In addition, energy storage and electric vehicle (EV) charging introduce switchable resources that can be charged and discharged to match generation. This alters the current relationship between generation and consumption of electricity—the first major architectural redesign of the grid in more than a century. "Smart grid" enabling products will be increasingly needed as the penetration rates of renewables increase and other disruptive technologies scale within the overall power grid system. Emerging economies can benefit from this development on all fronts, including by using smart meters to help utilities reduce electricity theft. Digital networks also now allow microgrids to operate without the need of a large, expensive control system.

Electric Vehicles (EVs). The ongoing shift in the automotive industry toward electric and autonomous driving vehicles will have a significant impact on the power sector. EVs are not only a driver of electricity demand, they will also become a distributed energy resource via vehicle-to-grid (V2G) capability to help manage the grid and support the integration of renewables. Recharging EVs overnight or during the day can increase flexibly to manage peak demand. However, fast-charging load profiles could also increase the volatility of demand, resulting in higher overall costs for the power system.

How Does the Disruption Differ in Emerging and Advanced Economies?

Disruption is occurring in both advanced and emerging economies, with important differences. Facing the imminent threat of climate change, advanced economies are under pressure to drastically reduce their carbon emissions to meet their Paris Agreement goals. Geopolitical and energy security concerns are also driving these nations to reduce their reliance on fossil fuels, as are more fundamental cost considerations now that solar and wind power have become the cheapest sources of electricity in many countries. The move to distributed generation is motivated by both cost savings and the desire to build a more weather resilient grid.

In emerging markets, by contrast, the desire for power sector disruption reflects a more fundamental need: reliable access to cleaner, cheaper, and less toxic sources of power for 1.1 billion people. This means that advanced and emerging economies will adopt different elements of disruptive technologies. And the reality of current power systems in emerging economies—where large populations live off the grid or have spotty access to electricity—will require more rapid introduction of disruptive technologies than in advanced economies.

In many nations without sufficient transmission and distribution (T&D) networks in place (especially in Sub-Saharan Africa and India) solar-plus-storage minigrids are creating the opportunity to leapfrog into a connected energy world. These minigrids enable nations to skip rungs on the ladder of conventional energy sector development by taking entire sites off the grid (for example, homes, campuses, companies, or communities). But minigrids can also work in conjunction with the traditional grid, increasing reliability and power quality if a site such as an industrial park can switch to “islanded mode” during blackouts. This increases the competitiveness of businesses and contributes to job creation.

Similar to the mobile telecommunications revolution, consumers in developing nations may soon have a tangible alternative to the traditional, centralized power grid—one that delivers more than just lighting. Minigrids are becoming smarter and helping to optimize

users’ energy consumption to maximize the amount of power available. Global engineering companies are now selling turnkey offerings that combine solar and storage, with fossil fuels for backup, which brings new scale and expertise to the minigrid space.³¹

Switching to solar and battery storage is already attractive in markets with high fuel prices—for example, in island countries and off-grid communities that rely on diesel generators. Indonesia has built a 600-kW hybrid solar and lithium-ion battery minigrid on Morotai Island. This PV plant benefits from a 2.7 MWh energy storage capacity, and the project reduces the island’s oil consumption by an average of 800 liters per day. With battery and solar PV prices continuing to decline, solar-plus-storage minigrids are becoming more viable every day.

How is Power Technology Disruption Achieving Scale and True Development Outcomes in Low-Income Countries, and Fragile and Conflict-Affected Situations?

Minigrids, in combination with disruptive technologies in other sectors, have the potential to be a game changer for development in remote communities in low-income countries, and especially in Sub-Saharan Africa. The off-grid solar industry has made tremendous strides in recent years, moving from solar lanterns that provide a few hours of light each night to full minigrid systems capable of powering energy efficient appliances like televisions and charging cell phones. Rapidly declining solar PV and light-emitting diode (LED) prices were technological enablers, but the mobile phone-enabled pay-as-you-go business model changed the paradigm of off-grid electrification—moving it from selling solar modules to selling electricity as a service.

Now, access to electricity via solar-plus-storage minigrids, in combination with advances in digital infrastructure, are enabling remote Internet connectivity. This, in turn, provides access to services far beyond electricity, including banking, communication, and information services, as well as access to markets. Pay-as-you-go service models are creating a new economy that is reaching “last-mile”

consumers who are unbanked and unconnected. In less developed markets, more efficient appliances are enabling productive uses of solar, including irrigation, pumping, refrigeration, agricultural processing, and manufacturing.

Distributed generation offers an opportunity in fragile and conflict-affected situations, where the supply of fossil fuels may be interrupted by war or other causes of supply shortage. In December 2017, IFC financed a 7 MW rooftop solar PV plant in Gaza. This is the first privately financed infrastructure project in Gaza in over a decade, and is designed to provide electricity to the only industrial park in Gaza. The project is expected to have a substantial development impact in a very fragile economy in the Middle East, which is particularly affected by acute power shortages (with supply at less than 50 percent of average demand and one-third of peak demand). Through supplying critical energy infrastructure for Gaza's industrial park, the solar PV plant will improve the reliability of its electricity supply, with positive impacts for both the park's output and employment.

Key Lessons and Remaining Challenges and Constraints

While disruptions' benefits in emerging markets are clear, substantial challenges may prevent consumers from fully benefitting from the innovations. Weak institutions and financially unsustainable distribution companies are the biggest bottlenecks to the adoption of disruptive innovations in emerging markets. In many of these, utilities are still vertically integrated and wholesale power markets do not exist. Private sector participation and fair competition are necessary to successfully deploy disruptive technologies. Unfortunately, however, in many emerging markets a centralized energy sector model is well entrenched, and this is especially the case in poorer and smaller markets, which have the most to gain from disruption. The low creditworthiness of many state-owned distribution companies leads project developers to prefer signing power purchase agreements (PPAs) with federal government guarantees, which impose contingent liabilities on the federal budget that would be better allocated to sectors such as education or

health. Without creditworthy off-takers, developing countries (and ultimately their consumers) will not be able to benefit from the rapid advances in technology that are affecting the wholesale level. Thus, commercializing inefficient state-owned distribution companies is crucial. This is especially important for utilities in Africa and South Asia, where the poor quality of distribution utilities, and underinvestment in them, stalls electrification plans.

While the grid is becoming more distributed, investment in transmission and distribution (T&D) remains critical to facilitate the rapid deployment of grid-tied renewables, and this especially so in emerging markets with weak networks. T&D infrastructure is necessary both to utilize power from wind or solar projects located far from load centers, and to effectively manage renewables' intermittency. The use of storage to integrate renewables, manage peak demand, and provide ancillary services to help enhance the quality and reliability of electricity supply bolsters the value of T&D in the power system. The rise of electric vehicles further increases reliance on distribution networks for charging. Not surprisingly, of the annual \$750 billion in global power sector investments expected through 2040, roughly 40 percent will be for T&D (and approximately 39 percent for renewable generation).³² Without comprehensive rethinking to open up the T&D sector to private investment, African utilities will struggle to significantly improve electricity access.

With the advent of solar-plus-storage systems, the wealthy in poor countries may start defecting from the unreliable grid. Instances of this have already been seen in India and Nigeria, and the incentive is even stronger for commercial and industrial (C&I) clients with rooftop space. But this could force the poor to pay for amortizing the grid. However, if EVs reach substantial market penetration, affluent populations may increase their reliance on the grid. Technological disruptions are clearly pulling the market in opposite directions, so avoiding negative outcomes for the poor is a regulatory challenge for governments in emerging economies.

The "utility of the future" is expected to be a significantly more service oriented and multi-functional business—and one that is radically different from the traditional electricity-delivery business. Accordingly,

regulatory frameworks and tariff setting methodologies will need to evolve to support and sustain the next phase of the utility business model. Clear regulations are a prerequisite for attracting private capital. Given the speed of technological disruption, emerging markets no longer have the luxury of introducing holistic reforms that take years to design and implement. “Regulation by contract” via concessions may be a better way to achieve this goal. Minigrids, for example, require clear technical standards and clarity about what will happen when the central grid arrives so that preexisting private operators and investors in minigrids feel secure.

Looking to the Future

Technological disruptions have direct effects on the logic of power markets and require new approaches to overcome these challenges.

With the increasing speed of technological disruption and ever lower spot prices in deregulated markets, offtakers are becoming less willing to sign long-term (usually 20-year) power purchase agreements (PPAs).³³ With an increasing share of renewables in the power mix that have near zero marginal costs, in many markets, spot prices are trending toward zero at certain times of the day, removing the price signal for which wholesale markets were designed. Thorough analysis of merchant market risk and well-organized auctions are crucial to addressing this challenge.³⁴

In merchant markets, which are becoming more prevalent, new structures such as retail aggregation may offer a solution to this problem. Electricity customers, and especially C&I clients, generally want to lock in power prices for three to five years. On the other hand, the capital costs involved in financing generation assets usually requires predictable cash flows lasting longer than 10 years. An aggregator could enter into: (1) long-term PPAs with the independent power producers (IPPs) on the electricity supply side; and (2) shorter-term, back-to-back PPAs with the customer on the demand side, thereby reconciling the two diverging needs. The skill of the aggregator lies in managing the inherent risks, including counterparty credit risk, contract rollover risk, and the volume and

price mismatches that can arise over time, especially due to the intermittency of renewables.

Blockchain may have the potential to manage the increasing complexity of the grid in a cost-effective manner, but this technology is still nascent. As more distributed energy resources connect to the grid, the size of energy transactions is decreasing, while at the same time, the volume of transactions is increasing exponentially. Blockchain could reduce these transaction costs and increase transaction speed by eliminating the need for a centralized clearinghouse, and instead using self-executing “smart contracts.” Emerging applications in the energy sector include peer-to-peer trading of renewable energy and management of distributed energy resources. Other possible uses include EV charging and sharing, as well as renewable energy certificates or carbon credit trading.

As the world tries to further decarbonize, longer duration seasonal storage of carbon-free power will become essential. Due to the seasonal variability of renewables, there will be times when countries can meet their entire electricity demand from renewables, and other times when this is not possible. To avoid having to keep significant fossil fuel capacity online, seasonal storage of renewable power is needed. Hydrogen produced via electrolysis that uses renewable power may offer a solution. The hydrogen can be stored and eventually re-electrified via fuel cells. The efficiency of this process today is as low as 30 to 40 percent, but it could increase if more efficient technologies develop. Despite this low efficiency, the interest in hydrogen energy storage is growing due to much longer discharge duration and higher power capacity when compared to lithium-ion batteries (small-scale storage) or pumped hydro and compressed air energy storage (large-scale storage).

Minigrids that use hydrogen as a complement to batteries are currently being tested. For example, on Semakau Island in Singapore, ENGIE Lab Singapore is developing an innovative minigrid in partnership with Schneider Electric.³⁵ The minigrid has a hydrogen storage capacity of 2 MWh for 80 kilograms of hydrogen, which is providing a green fuel that is directly produced and consumed on site and is a major asset in allowing remote regions to be energy self-sufficient. ■

CHAPTER 4

Innovations in Transport

By Ian Twinn

How Do We Define Disruption in Transportation?

Transport plays a key role in our lives. It determines access to goods, work, medical treatment, and education, and even influences where we choose to live and take a holiday. For these reasons, transport is a key enabling technology, essential to economic growth, poverty reduction, shared prosperity, and environmental sustainability. It is also a relatively complex sector, with multiple modes of operation (sea, land, or air; truck, rail, or road) that interconnect and also compete with each other, based on the value and priority of the cargo being transported.

Innovations in transport can have a transformational effect. One example is the steam locomotive (Richard Trevithick's Pen-y-Darren, 1802). Within 50 years of the first ride, the cost of moving goods over long distances decreased dramatically, enabling the rapid spread of industrialization, and the opening up of vast continents such as North America. Use of the steam locomotive also led to the standardization of time zones across the world.³⁶ Other key transport innovations over the past 200 years include the mass produced automobile (Oldsmobile Curved Dash, 1901), which transformed personal mobility and the layout of cities, including the rise of suburbs. The advent of the commercial container ship (Ideal-X, 1956) radically reduced shipping costs and paved the way for globalization. Another key innovation, the commercial jet plane (De Havilland Comet, 1952) transformed international travel, changing patterns of connectivity and vacationing.

These disruptions have a few common themes: they make transport better (more reliable, comfortable, and cheaper), faster, and/or safer—or all three. They also create new markets and value networks, displacing established market leaders. And they have major, although not necessarily obvious, impacts on how we live.

Which Technologies and Policies are Disrupting Transport Today?

Rapidly developing digital and battery technologies now threaten to upend significant parts of transportation systems around the world. At the same time, political pressures to reduce the environmental impact of transportation, and particularly greenhouse-gas emissions, are growing. Transport accounts for about 14 percent of greenhouse-gas emissions globally as almost all of the energy that transport utilizes (95 percent) comes from petroleum-based fuels.³⁷ These factors are driving a number of changes that affect how the industry operates:

- **Digitalization:** A Global Positioning System (GPS), combined with Big Data analytics and computer technology, is being incorporated into cars, trucks, locomotives, ships, and even containers. This change means it is now possible to track the performance of transport assets in real time, including their location, condition, driver performance, and so on. This, in turn, enables fleet optimization and increased productivity, efficiency, safety, and compliance. To some extent, digitalization is also creating an incentive to formalize the transport sector given the scale effects of managing the data that these technologies now generate. In addition, digitalization is enabling new players to disintermediate existing transport network stakeholders. For example, web-based applications that match businesses with delivery drivers through a digital marketplace can now collect data on the most efficient transportation routes.
- **E-Logistics:** Logistics, the business of moving goods from origin to the point of consumption, is a critical factor in choosing where to locate production. Logistics account for 15 to 25 percent of GDP in many developing countries, which is significantly greater than the 6 to 8 percent spent, on average, in Organisation for Economic Co-operation and Development (OECD) countries.

In addition to being more expensive, logistics in emerging markets can be less effective. For instance, post-harvest food waste can range from 15 to 40 percent in developing countries, versus an average of 5 percent in OECD countries. These higher losses and their costs are often a result of inefficiencies in the transport and logistics systems, including insufficient and inadequate cold storage facilities. Historically, most trucking operations, particularly those in emerging markets, have been small scale with only a handful of trucks, and have used brokers or informal networks to source cargoes. Because of information asymmetries, such brokers have secured a disproportionate share of the value of the transaction, which results in shippers paying higher rates, and truck operators often receiving little more than their operating cost. In emerging markets, lack of market transparency and lack of data have also led to many return trips with no cargo.

In recent years, e-logistics companies have emerged that can directly match cargo owners to truck operators using apps or websites such as load boards. These reduce or eliminate the need for cargo brokers to intermediate. This has led to both lower shipping costs and higher incomes for truck operators, particularly when they are able to source cargo for their return trip. By reducing empty runs, the use of e-logistics providers also has a positive climate impact through reducing greenhouse-gas emissions. The rise of these e-logistics technologies has had an effect on the long-haul, inter-city truck market, and increasingly the intra-city “last-mile” delivery segment.³⁸ (For more on e-logistics, see Chapter 15.) Although not yet commercially deployed outside the controlled environments of warehouses, drones may trigger further disruption to last-mile delivery systems by allowing deliveries without a delivery truck.

- **Transportation network companies (TNCs):** Sometimes known as mobility service providers or ride-hailing services, TNCs such as Uber and 99Taxi are another recent innovation that has emerged from the digitalization of transport. These businesses pair passengers with drivers using websites or mobile telephone apps. Since their launch around 2010, these companies have spread rapidly to countries around the world, substituting or complementing traditional

taxi services. Proponents argue that such apps raise the incomes of drivers while charging lower rates than taxis, and provide service in sparsely populated or poorer areas of cities that previously were neglected by taxicabs. The effects of booking and paying via an online app rather than in cash may also make it safer for both the driver and the passenger in some developing countries. Such safety and security considerations are particularly important for women, who benefit disproportionately from the transparency and safe travel opportunities that ride-hailing services offer (see Chapter 11).

Opponents of these apps contend that they circumvent taxi regulations and aggravate traffic congestion in some cities. In addition, because of the variable pricing strategies adopted by TNCs, rides may also become significantly more expensive at times of peak demand. These factors have led some cities to ban ride-hailing services, while others such as New York City have restricted the issuing of more licenses to ridesharing vehicles. To address the charge that companies increase congestion, ridesharing companies have launched other services that aim to reduce the number of vehicles on the road. One is “pooling” (for example, Uber Pool or Lyft Line) which enables several passengers to share the same vehicle and reduce their cost per trip. In developing countries, three-wheeled vehicles are sometimes used with this technology, as are bicycles and electric scooters. These complement mass transit networks by moving passengers over the last mile.

- **Autonomous vehicles (AVs):** Self-driving vehicles are widely discussed and are already being deployed in specific, controlled environments. While there is strong debate about when they will be fully rolled out on a commercial basis, the technology is advancing rapidly. One provider (Waymo) has already achieved Level 4 on the 0-5 automation scale, where Level 5 indicates full automation.³⁹ Several original equipment manufacturers (OEMs) have indicated that they also expect to achieve Level 4 by 2020 and Level 5 by 2022. Given the high cost of the technology, it is likely that initially TNCs will only deploy AVs in commercial applications, and in mass transit and logistics operations, but not as personal vehicles. Indeed, by eliminating the

need for a driver and thereby reducing costs, such technology could reduce the incentive for personal ownership of vehicles and lead to the emergence of transport as a service, or TaaS, where instead of households owning a vehicle, they book one from a TNC when needed. As well as potential safety benefits, proponents point to the low utilization rate of the average car (thought to be around 5 percent) and significant cost savings, particularly if users are willing to share rides. Depending on how TaaS vehicles are regulated, such a development could either remove cars from the road and complement mass transit, or further congest cities. And like cars before them, AVs could unleash unforeseen changes in how cities are organized and how we live.

- **Electric vehicles:** Electric vehicles (EVs) are not new; the first electric car was manufactured in 1884, and there was a fleet of electric taxis operating in London by 1897. However, they were gradually displaced by internal combustion engine (gasoline-powered) vehicles that were cheaper, faster, and had better range. In recent years, EVs have started to become relevant again, driven initially by concerns about air pollution, climate change, and a desire to optimize local energy sources. They have also been aided by changes in regulations and subsidies to promote cleaner fuels. As battery prices continue to fall, they are now approaching cost competitiveness with internal combustion engine vehicles. Given the low marginal cost per mile, this is particularly the case for high-mileage applications. For instance, high-use electric buses and three-wheelers are already competitive in some markets on a total-cost-of-ownership basis, and there is already a rapid increase in trials and/or utilization of electric buses across a range of middle-income countries. Light electric trucks used for intra-city deliveries and other local applications are also rapidly approaching cost parity and, given possible regulatory advantages, may be widely deployed in the near future. Electric heavy-duty trucks are being developed too by several manufacturers, although presently their widespread deployment is likely to be slower, given that with the substantial weight of their batteries, these trucks can carry less. One alternative to address this could be hydrogen fuel

cells, which are under development, but not yet commercially cost competitive. Deployment of EVs offers significant health and pollution benefits at the point of use and, depending on the energy mix of the grid providing electricity, possibly reduced emissions overall. However, because of the higher upfront cost and lower marginal cost per mile, EVs are most economical for high mileage applications and create an incentive for maximizing utilization rates. This creates an additional argument for shared use (such as TaaS) rather than individual ownership.

- **The greening of maritime and air transport:**

Although both shipping and aviation were initially excluded from greenhouse-gas emission reduction targets, both are coming under increasing pressure to reduce their emissions due to their generating significant greenhouse-gas emissions and other pollutants.

In 2018, the International Maritime Organization (IMO) adopted a strategy to reduce greenhouse-gas emissions from shipping, with the target of reducing total greenhouse-gas emissions by at least 50 percent by 2050, while pursuing methods to phase out greenhouse-gas emissions entirely.⁴⁰ This would build on other recent initiatives, including the obligation to reduce sulfur emissions by 2020.⁴¹ Given the expected growth of cargo over the next few years, such a regulation implies a very significant reduction per ton transported. In the short run, there are a number of technologies that can be adopted to help make vessels more efficient. Technical innovations such as telemetry and route optimization for weather and port arrival slots have already been widely adopted by forward-looking vessel operators. Other options include retrofits to optimize the propeller, and “bulbs” fitted to the front of modern ships to minimize fuel use. These efficiency improvements can also include more frequent hull cleaning, which can reduce fuel burn by 5 to 12 percent.⁴² Depending on the type of vessel, rotor sails and other new sources of propulsion could be adopted or different fuels used such as LNG.⁴³ But reaching the ambitious targets set by the IMO will require technological innovations such as fuel cells or electric batteries with the capacity to power vessels over long distances. In the near term, given the inherent owner-

agent problem, implementing retrofits will require the development of innovative financing solutions. The ship owner bears the cost of investments to improve fuel efficiency but the charterer benefits from the fuel savings. This is a particularly important challenge given the current depressed state of many segments of the maritime industry.

- **Aviation:** Air traffic presents its own challenges. For historical reasons, aviation fuel is not taxed, and only the greenhouse-gas emissions of domestic flights are captured under the Kyoto protocols. Not only is air traffic continuing to grow rapidly as rising incomes enable people to travel, but emissions from aircraft are expelled higher in the atmosphere, and so contribute more to global warming. To address this issue, the industry has been experimenting with biofuels, but these remain significantly more expensive. Several airplane manufacturers (both incumbents and startups) as well as airlines are experimenting too with electric or hybrid electric-conventional aircraft. These remain at the development stage but with a significant chance of commercial deployment in the next decade, particularly for smaller planes of up to 70 seats. If successfully developed, these technologies could have a major positive impact on greenhouse-gas emissions, and ultimately disrupt the aviation sector.
- **Near shoring:** The adoption of containerization has been a major transformation in shipping over the past 60 years. It has dramatically reduced shipping costs and played a key role in globalization, including the economic development of much of Asia. However, a confluence of factors now threatens prospects for growth of the industry. Improved robotics and the development of 3D printing are reducing the cost advantages of producing products in countries with lower labor costs, while incentivizing production in places that are closer to areas of consumption. Recent political trends and trade pressures are exacerbating this, further incentivizing shorter supply chains. Reflecting these developments, the growth rate of container traffic has declined in many trade lanes. This has put intense pressure on the industry to cut costs, and triggered alliances and mergers. It has also led some

shipping lines to expand into related businesses such as inland logistics, and also to begin digitizing the documents required for forwarding goods.

For instance, in 2017, the Maersk Group announced an open source blockchain initiative for recording all the steps in the movement of a container. To some extent, such initiatives are a defensive attempt to avoid digital disrupters disintermediating the industry, and turning it further into a commodity business. But success could allow the shipping lines to make closer connections with their customers, and by reducing inefficiencies and costs, both speed the flow of cargo, and reduce transportation costs. These impacts could, in turn, fuel a new round of international trade and exchange, with possible benefits for the growth of developing countries. They also threaten to disrupt the existing ecology of freight forwarders who manage the relationship with the cargo owner and book the trip with the container line.

- **Public-private partnerships:** The implementation of public-private partnerships, or PPPs, has also had a significant impact on transport systems over the past few decades. PPPs are arrangements under which a government grants a concession (a port or airport, for example) to a private operator that commits to making an investment and maintaining a minimum level of service. While not a particularly new concept, PPPs have become increasingly common, especially in the road, port, and airport sectors, and have spread from developed markets to emerging markets, including International Development Association (IDA) countries and fragile and conflict-affected situations (FCS). PPPs enable the development, operation, and maintenance of needed infrastructure without spending public funds, and sometimes achieve dramatic gains in efficiency and service standards.
- **Other technologies:** There are several other emerging technologies under development such as hyperloops or self-flying air taxis (currently being trialed in Dubai), which could further disrupt the transport sector. However, how quickly these will progress from experiments to widespread commercial deployment is unclear.

How Does Disruption Differ in Emerging and Advanced Economies?

The above disruptions will affect both advanced and emerging economies, but at different speeds, and to different extents.

Given the greater inefficiencies in the logistics systems in emerging markets, the benefits from using e-logistics could be greater. As a result, innovations from tech hubs in developed countries have spread relatively quickly to their developing country counterparts. Truck load boards, or freight market places, and other logistics innovations, which have emerged in advanced economies over the past five years, have spread first to larger and more sophisticated developing countries and then, more recently, to smaller and less developed countries. To succeed, entrepreneurs need to adapt these technologies to meet the local physical and institutional constraints. Physical issues can include lack of access to smart phones, weak mobile phone coverage, the absence of central warehouses for loading, and, for inter-city operations, congestion around ports. Institutional barriers include weak regulations, lack of insurance, and the local trucking unions and cartels that control certain routes—all of which may be barriers to formalizing the sector. A final consideration is the smaller size of certain markets, which makes them less attractive to innovators.

To some extent, the pattern of transportation network company deployment is similar to that seen since 2010. First, there is rapid spread in the developed markets of North America and Europe, together with quick replication in larger, more advanced, developing countries (such as China and Mexico). This is followed by a slower spread through other emerging markets where the business model is adapted to the local context (for instance, using three-wheelers or even motorbikes rather than cars).

Due to differences in regulations and the complexity of the traffic, the rate for deploying AVs will vary between, and within countries.⁴⁴ Relatively organized cities in North America and Europe will likely be first, with cities in emerging markets coming later, starting with the large, better organized, and comparatively wealthy cities that have more control over traffic. In such emerging economies, bus rapid transit (BRT)

systems which, by design, operate in more controlled environments, could be adopted more quickly. However, in emerging markets with chaotic traffic, the deployment of AVs could take much longer. The lower cost of labor is another disincentive for investments in capital intensive, labor-saving technologies such as AVs.

Fuel and electricity prices vary significantly across countries due to differences in regulations, taxes, and subsidies, as well as the use of alternative fuels such as natural gas or biofuels. As a result, the attractiveness of switching to EVs, and the payback on investments through vehicle efficiency, as well as the speed of adoption, will vary significantly by country. For instance, the total cost of ownership (TCO) of an electric car has likely already reached parity in Europe but will not be met in the USA until sometime in the 2020s. The developing countries that heavily subsidize fuel are also likely to be later adopters. The capacity and stability of electricity grids is another factor that will affect the speed of EV adoption. This is especially the case with electric buses that could place significant demands on a grid when fleets of these are deployed, and require recharging at scale. The availability of charging infrastructure will also play a role for personal vehicles.

Effectively implemented PPPs are likely to benefit developing countries, given the generally weaker infrastructure in those countries. However, near shoring would tend to benefit the economies of developed countries at the expense of those developing countries where goods are produced.

What are the Disruptive Technology Opportunities in Low-Income Countries and FCS?

For low-income or IDA countries and fragile and conflict-affected situations, the implementation of PPPs offers a way of financing the rehabilitation or expansion of core transport infrastructure, particularly airports and ports, and obtaining best-in-class management while minimizing the burden on the state's budget. The deployment of e-logistics and TNCs also offer significant potential benefits. Logistics costs can be particularly high in such countries, so the benefits of innovations such as load boards could be especially significant. One challenge to their widespread use, however, is the relatively small size of

some markets, and consideration of the local context (local truckers unions, for example) is also essential.

Some of the other emerging technologies may be less applicable. EVs, for instance, will require reliable power supply and stable transmission grids that may not be available in IDA countries or FCS.

Key Lessons and Remaining Challenges and Constraints

Transportation is a complex ecosystem in which competing modes (road, rail, air, and sea) contend for traffic based on cost, but also on safety, reliability, speed, and other factors. At present, risk capital is fairly freely available for the development of new technologies such as TNCs, AVs, EVs, and, to a somewhat lesser extent, e-logistics (with the caveat that risk capital will be attracted first to larger and more prosperous markets where the payoffs from investments will likely be larger). As a result, the primary constraints are technical, regulatory, institutional, and political.

As already noted, in emerging markets, weak mobile and Internet networks, and the low penetration rates of smart phones constrain the swift adoption of both e-logistics and TNCs. Technical challenges also constrain the development of AVs, and of reducing the cost of batteries. The latter would bring EVs to cost competitiveness on a life-cycle basis, without the need for subsidies (although in both these cases, rapid progress is being made). The technical issues with decarbonizing aviation and shipping are more challenging. Although technologies already exist that can reduce the environmental footprint of both industries, as yet there is no commercially competitive technology that can move them to zero emissions. However, if prices decrease, hydrogen fuel cells could be an alternative.

The interplay between institutional factors and regulations plays a key role in nudging cargoes toward one method versus another. As already mentioned, trucking unions play a key role in freight transportation in some developing countries, and may hinder the rapid adoption of e-logistics. Similarly, groups of taxi drivers have resisted the deployment of TNCs, although this has tended to be at a city level. Regulations at the national or local level are another factor that has played a key role in determining the speed of adopting TNCs, and will be especially important in the rollout of AVs. In

addition to determining whether AVs can be deployed at all, regulations are likely to be a key determinant of whether deployment works to the advantage of the city or not. Because AVs will have a low marginal operating cost, there is likely to be an incentive to “flood” a city with vehicles, particularly during the early rollout phase as different operators seek market share and scale. Regulations on issues such as congestion pricing or access fees could play a key role in managing this, and in incentivizing the use of AVs and pooled vehicles, rather than individually owned vehicles. For the cities of tomorrow, effective regulations could help ensure that AVs bring positive benefits by reducing personal car use and thereby recapturing road space.

Given the extra-territorial nature of the shipping and aviation industries, international politics will play a key role in how aggressively these industries reduce greenhouse-gas emissions. Since fuel is a significant input cost, if energy saving measures are economical, they will be adopted quickly. But it is unlikely that operators will make the more dramatic changes needed to achieve a carbon free world on their own. This is particularly the case for shipping, given the mismatch in costs and benefits between the vessel owner and the charterer. Similarly, international politics will play a key role in how near-shoring evolves, with potentially significant implications for both the container industry and global manufacturing.

Looking to the Future

Transportation is essential to how we live and interact. By altering incentives and economics, the innovations enumerated above have the potential to trigger radical changes. Consider how, over a couple of decades, the advent of the mass-produced motor car in 1902 led to the displacement of horses and the development of suburban living. Autonomous vehicles and transport-as-a-service have the potential to end private vehicle ownership, and unleash great changes in cities. The electrification of transport has the potential to radically improve air quality, at least at the point-of-use. The pressure on transportation providers to innovate and decarbonize is likely to only increase. Commitments such as the IMO’s new guidelines to eliminate greenhouse-gas emissions from shipping will spur on the creation of new technologies. All of these developments should make transport better, faster, safer, and cleaner. ■



CHAPTER 5

Disruption in the Water and Sanitation Sector

By George Butler

How Do We Define Disruption in the Water and Sanitation Sector?

Water and sanitation improvements relate to all 17 of the United Nations Sustainable Development Goals. Ensuring access to water and sanitation services (WSS) is one of the most critical of all development objectives, and key to addressing multidimensional poverty. Inadequate WSS negatively affects health, gender, education, economic growth, and the environment. Among the Sustainable Development Goals (SDGs) for 2030, SDG 6 specifically aims to “ensure availability and sustainable management of water and sanitation for all.”

Consider these facts about water and emerging markets:

- Some 844 million people worldwide lack basic water services; 2.3 billion lack basic sanitation services.⁴⁵
- Water and sanitation access is a particularly serious challenge in rural areas.
- The 2015 Millennium Development Goals (MDGs) for water and for sanitation are not expected to be met by 2030. Forty countries are unlikely to meet the MDG for water, and more than 50 countries are unlikely to meet the MDG for sanitation.⁴⁶

The water and sanitation sectors are characterized by three interrelated issues: access to basic services, water

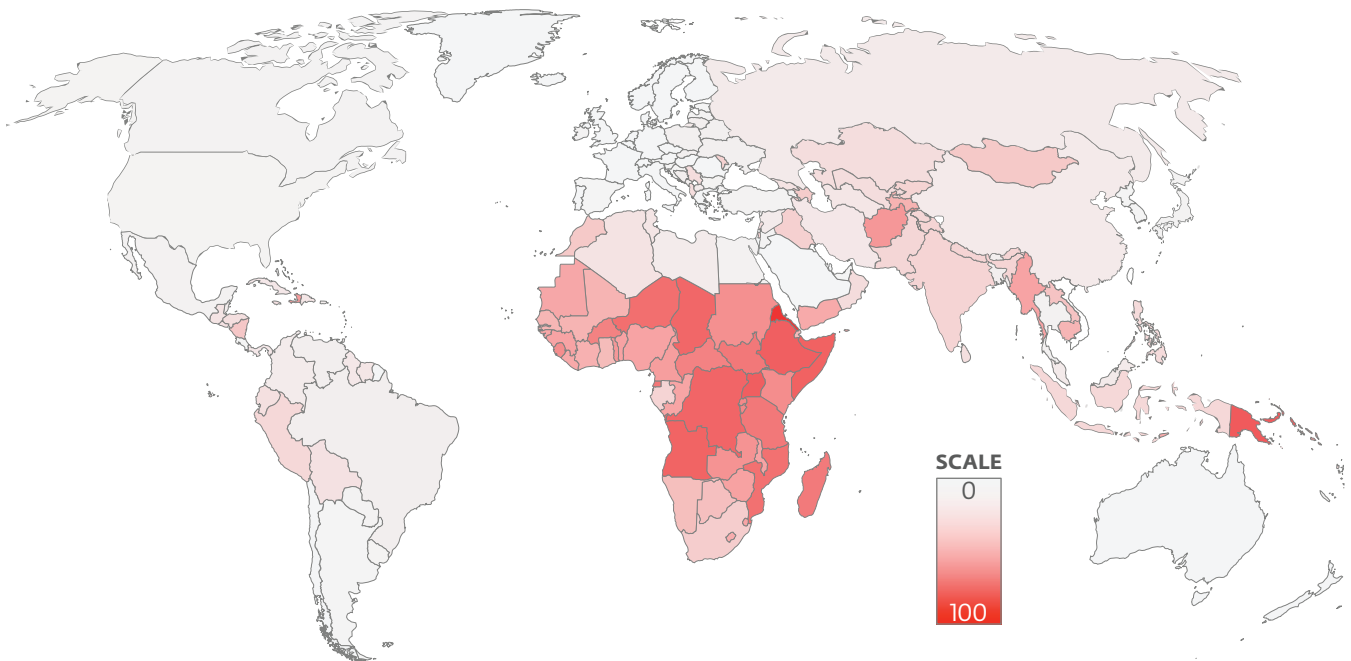


FIGURE 5.1 Basic Drinking Water Service is Lacking in Emerging Markets – Percentages of Populations Not Using at Least Basic Drinking Water Services in 2015

Source: IFC

scarcity (which is exacerbated by climate change), and the impact that conflict and competition for water has on populations.

Urbanization, population growth, and climate change—all of which are profound and ongoing trends in emerging and developing markets—will only raise the demand for water. Water demand is projected to rise from 4.5 trillion cubic meters today to 6.9 trillion cubic meters by 2030—a figure that is 40 percent above the current accessible supply.⁴⁷ The energy, industrial, and agricultural sectors will all compete for scarce water resources. And because electrification, industrialization, and expanded agriculture are all development goals, water scarcity has the potential to become a significant drag on improving living standards in low-income countries, and in closing the gap with advanced economies. Finally, water insecurity can raise the risk of conflict, creating further development obstacles for many nations.

Disruption in this sector will require technologies that can address challenges to fundamental development outcomes. These challenges concern:

- **Health:** Water-related diseases are among the world’s leading causes of preventable deaths, especially in children and vulnerable groups.

- **Gender and education:** Poor water and sanitation has an unequal effect on women, elevates infant and maternal mortality rates, and pushes females out of the classroom at adolescence.
- **Economy:** Rising incomes in developing economies are associated with greater demand for water.
- **Environment:** Unsustainable extraction of water and improper wastewater treatment lead to the deterioration of ground water and surface water quality and supply.
- **Affordability:** The poorest households in many emerging economies use a large portion of their income to pay for what are often inadequate water services.

Which Technologies are Disrupting the Water Sector?

To deliver on SDG Goal 6, additional investment of approximate \$150 billion per year is required for WSS.⁴⁸ This gap can only be filled by leveraging both municipal and private financing sources. However, similar to other sectors, lack of an enabling environment that encourages private investment, is a formidable problem for the water and sanitation sector.

In most of Sub-Saharan Africa, South Asia, and the Middle East and North Africa, water tariffs (the amount consumers pay for water supplied through a utility) do not meet sustainable cost levels.⁴⁹ In these regions, the water sector is underwritten predominantly by the government or official development assistance.

Technology—and the disruption it can bring—must then play a large role if water and sanitation services are to expand and improve enough to meet the increasing demands in emerging and developing nations. Yet the sector is a conservative one and has always been cautious about introducing new technologies and ways of working. Fortunately, there are several disruptive technologies that are changing the market now, or have potential to supplement the current model. These are altering the way water and sanitation is delivered at both the municipal and industrial levels.

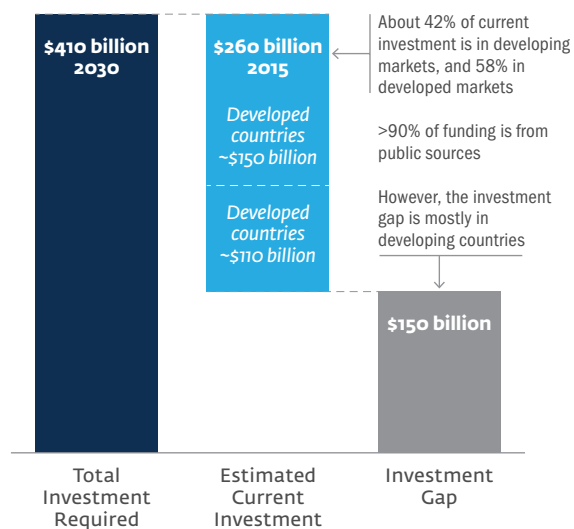


FIGURE 5.2 Annual Investments Required from 2015 to 2030 to Achieve Sustainable Development Goal 6 (forecasted investments, and the investment gap – \$ billions p.a., constant prices)

Source: UNCTAD, *World Investment Report 2014*

Bulk water supply, or the generation of drinking water from raw water, is the first of these disruptions. Desalination uses a power source (usually electricity, but heat can be enough) and saltwater (either seawater or a brackish aquifer) to create fresh water.

The nearly limitless supply of seawater, the falling cost of desalination, and improvements to the technology have rendered desalination mainstream in many markets, especially in the Middle East and North Africa. Using increasingly common renewable power sources is ideal for desalination.

Membranes and reverse osmosis, in particular, have been disruptive in the desalination process, replacing thermal processing as the most common technology used now.

Desalination is rapidly growing in emerging economies as equipment prices fall. It is considered a disruptive technology as it can provide water when other sources are unavailable or uneconomical. However, desalination is not likely to replace conventional water treatment if raw water is readily available.

Technology is also helping to protect raw water supplies and catchments in new ways. Emphasis is now on preventing the pollution of raw water sources, rather than merely increasing the level of treatment to make it suitable for drinking. Satellite monitoring, better catchment management, and the availability of cheaper analytical techniques to test water for pollutants have accelerated this progress. However, this is a gradual process that is supplementing the current model of treating water, rather than one that will displace it.

Techniques for irrigating farmland are benefitting too from new technologies, including drip and other types of micro-irrigation. In addition to its advantages for improving yields, drip irrigation is the best delivery system for soluble fertilizers. It also drastically reduces the propagation of weeds, and therefore the need for herbicides.⁵⁰ As a large share of raw water is used for agriculture in emerging markets, this technology has enormous disruptive potential.

Water distribution is another area that is ripe for disruption in emerging markets, as losses during distribution are routinely greater than 40 percent. This is even more the case in cities, where commercial

losses—water theft, non-billing for water, and so—and technical losses due to leakage from the network, can result in the loss of about half of treated water.

Certainly, the primary way to reduce water loss is to incentivize better management of water utilities. But technology can also help. Satellite monitoring and innovations to network monitoring systems are now being used to identify leaks and better manage networks. These technologies (which include green buildings), while not revolutionary, can lead to a significant reduction in network leakage, which reduces the volume of bulk water required, and significantly reduces the costs associated with pumping and water treatment.

Atmospheric water generation (AWG), which condenses potable water from water vapor in the air, is currently too expensive and has limited capacity for widespread adoption. The technology may not produce the quantities needed for all domestic uses, and has constraints in low humidity atmospheres. But in some locations, it could leapfrog conventional water treatment and distribution systems. AWG can use household pipework, and so it does not require a traditional distribution network of large water pipes laid below the ground. It is also probably the most distinctly disruptive technology in the water industry because, at least in theory, home based units (or units on apartment roofs) can generate all the drinking water required (and some washing water too) without treatment, a distribution network, or other infrastructure.

What are the Opportunities for Low-Income Countries and FCS?

To date, private water companies have not functioned well in the poorest nations, or those plagued by fragility or conflict, although there are some positive examples of management contracts, including leases and affermage contracts.⁵¹ For such projects to work in challenging countries, they require long-term political will, sustainable tariffs, and some form of protection for investors such as independent regulators or enforceable contracts. Otherwise, the private water sector requires public subsidies, which are always politically fraught if the contract is long term or supported through grants. Many of the political issues that obstruct water sector projects in emerging markets are even more challenging in FCS.

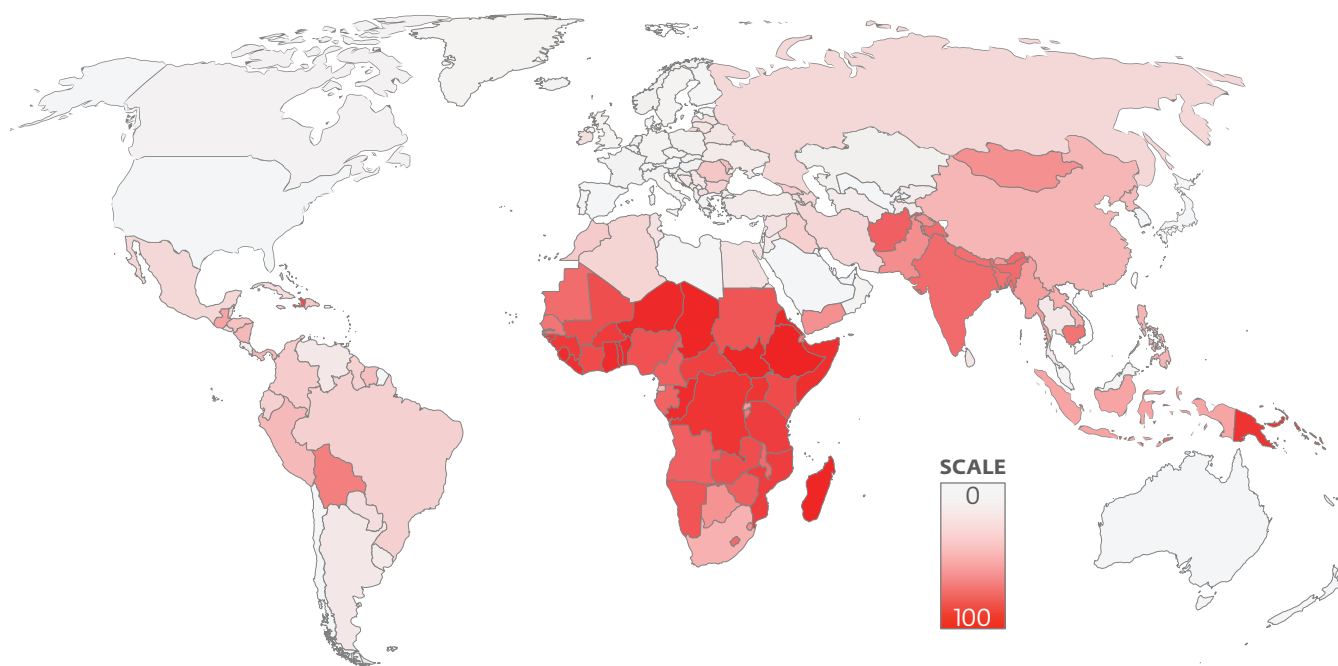


FIGURE 5.3 Sanitation Services are Lacking in Emerging Markets – Percentages of Populations Not Using Sanitation Services in 2015

Source: IFC

Key Lessons and Remaining Challenges

Probably the area most in need of technology disruption in emerging and developing countries is wastewater collection and treatment, as the majority of people lack access to even basic sanitation services.

The primary technology for wastewater treatment, called “activated sludge,” was invented in 1914 and is the most common process used worldwide. However, efforts are underway to “reinvent the toilet,” and supersede the current approach to municipal sewage management that uses water borne sewerage (the pipes and systems that convey sewage). These new toilets should be more economical to install in cities in emerging markets. Seven technologies (suitable for commercial development for different uses such as home-based, community-based, and others) were unveiled in China in late 2018 by the Gates Foundation. Currently, the Gates Foundation and the World Bank Group are funding development and

trials of these disruptive technologies as part of their inclusive sanitation initiative for cities in developing countries.

At this time, the cost of building a conventional water borne sewerage system and associated wastewater treatment plant is prohibitively expensive, so most sewage in developing country cities is not treated, but instead is discharged directly into the nearest river or water body. For example, only 12 percent of the volume of sewage collected in Ho Chi Minh City, Vietnam, is treated, and this leads to environmental degradation of rivers and contamination of drinking water sources.

Advanced anaerobic digestion (AAD) can significantly increase the amount of energy that is generated from sewage sludge over normal anaerobic digestion. Thus, it can turn treating sewage residuals into an asset, rather than waste. AAD uses pressure and temperature to produce methane gas from sewage sludge, and the methane can be used to generate electrical power. In large wastewater treatment plants, AAD can generate

the power required to run the plant, and even export “clean” power to the grid. This helps to improve the economics of wastewater treatment, and even produces a useful bi-product (the digested sludge is a good and safe soil conditioner).

As illustrated in Figure 5.3, many developing countries do not have the expensive systems (sewerage and wastewater treatment works) required to collect and treat municipal and industrial wastewater. However, even when they do have this infrastructure, the final effluent (the cleaned wastewater) is discharged into the environment, rather than reused. Treated wastewater, sometimes with additional (tertiary) treatment, is suitable for irrigation, as cooling water (for power stations, for example), and as a feed for indirect raw water supplies (pumped into a storage dam, or into the ground to replenish an aquifer).

As well as re-using water, industry should use water more efficiently. Many industrial processes use large amounts of water—the textile, steel, chemical, and thermal power sectors are all heavy users of water. Significant savings can be achieved by optimizing the use of water in the processes, and recycling water where possible. This has the benefit of not only using less raw water, but also reducing the volume of wastewater generated.

Lack of efficient water management will impede development in some countries. In water scarce areas, government authorities may not allow development, or stipulate that efficient water systems must be used to conserve water. Where industrial pollution is a problem, a tightening of discharge standards or even zero liquid discharge may be required.

Looking to the Future

As described above, new water and sanitation technologies are significant improvements, and several technologies have the potential to disrupt the sector in developing countries. However, a major issue remains—economic water poverty—which occurs where water resources are readily available, but governance, funding, and/or organization are lacking to provide people with water in a sustainable way.

Due to insufficient public funding for the water sector, and in some cases, a lack of institutional expertise, private enterprises can play an important role in providing expertise and funding for the water sector. If the regulatory and investment environments are suitable, and there is sustained political will, the water and sanitation sectors can attract large investors such as pension funds and insurance companies that are seeking low-risk, long-term returns. ■

BOX 5.1 IFC and WIPA - Water Innovation Platform for Africa

The Water Innovation Platform for Africa (WIPA) is an innovation platform set up by IFC in 2017 to introduce proven new technologies to African water utilities. IFC works with funding organizations, the contractor, Isle Utilities (Isle), and the African Water Association to provide the WIPA platform. WIPA conferences were held in 2017 in Ghana (WIPA 1) and in 2018 in Uganda (WIPA 2) to present new water sector technologies that can be used by utilities to improve the lives of the millions of people living in water poverty.

IFC is supporting the implementation of more efficient water technologies through the WIPA platform, and investing in the providers of innovative technologies that are seeking finance to scale up their projects. IFC will also fund public utilities’ investments in new technologies if the sector governance and economics are suitable. IFC works as well with both municipal and private sector organizations to implement pilot studies and trials of new technologies to address challenges across the entire water sector.

A wide range of technologies are assessed by Isle, which then chooses the best fit for a water utility’s needs. To date, technologies selected for the WIPA platform include leakage reduction, satellite imagery, low energy/cost water treatment, disinfection solutions, and innovations for water filtration.⁵²

Technology trials or pilots utilizing these technologies are underway or planned in Mali, Uganda, the Central African Republic, Cameroon, Ghana, Nigeria, and Senegal.

CHAPTER 6

Digital Infrastructure

By Simon Andrews and Ariana Batori

The physical infrastructure of connectivity is the foundation of any digital economy. Technology developments have sparked a revolution in connectivity, driving the need for increased Internet penetration and wholesale wireless networks—and leaving many countries unable to cope with increased demand. This digital divide is quickly widening, with the least developed countries falling farther and farther behind. In emerging and advanced economies alike, innovation and disruption are required to close this gap and connect the world.

How do We Define Disruption in the Infrastructure Sector?

Digital infrastructure—or the physical infrastructure of connectivity—is the backbone of a digital economy. It (Figure 6.1) comprises undersea, underground, and above-ground cables, towers, data centers, and satellites, as well as the invisible spectrum, and the great variety of equipment that connects the world through the Internet and facilitates the delivery of information, products, and services in all sectors.

In creating digital connectivity, digital infrastructure can disrupt the development and economic growth paths of emerging economies through three main channels: inclusion, efficiency, and innovation.

- Digital connectivity helps reduce search costs and removes information asymmetries. By making it easier and less costly for individuals and entities to interact and transact, digital connectivity expands the information base and thereby promotes inclusion.
- The dramatic decline in the price of the technologies underpinning digital connectivity has led businesses and governments to replace existing factors (labor and non-ICT capital) and

to automate some of their activities. Yet these technologies also help complement the factors not substituted by making them more productive. Deloitte estimates that if developing regions achieved the Internet access levels seen today in developed regions, their long-term productivity could increase by about 25 percent.⁵³

- The rising returns possible with the growing scale of the Internet spurs innovation and new business models that are based on the zero or near-zero marginal cost of doing business on the Internet.

Investments in digital infrastructure have enormous potential to benefit the poor. Digital infrastructure helps connect individuals and businesses to each other, to government, to markets, and to opportunities. As individuals connect to markets and access financing through the Internet, a 10 percent increase in mobile broadband penetration can increase GDP per capita by up to 0.7 percent.⁵⁴ If Internet penetration in emerging markets were to reach developed-market levels, an additional \$2.2 trillion in GDP and over 140 million jobs could be generated. In Africa alone, the number of extremely poor people could be slashed by a third.⁵⁵

Nearly 7 out of 10 people in the bottom fifth of the population in developing countries own a mobile phone, which improves their access to markets and services. Internet connectivity in the agricultural sector can increase farmers' profits by up to 33 percent by providing them with information on weather conditions, disease control, methods of maximizing their crops, and enabling trading platforms. In rural Niger, information on agricultural prices obtained through mobile phones has reduced search costs by 50 percent. In rural Peru, access to mobile phones boosted households' real consumption by 11 percent between 2004 and 2009, reduced poverty by 8 percentage points, and extreme poverty by 5.4 percentage points.

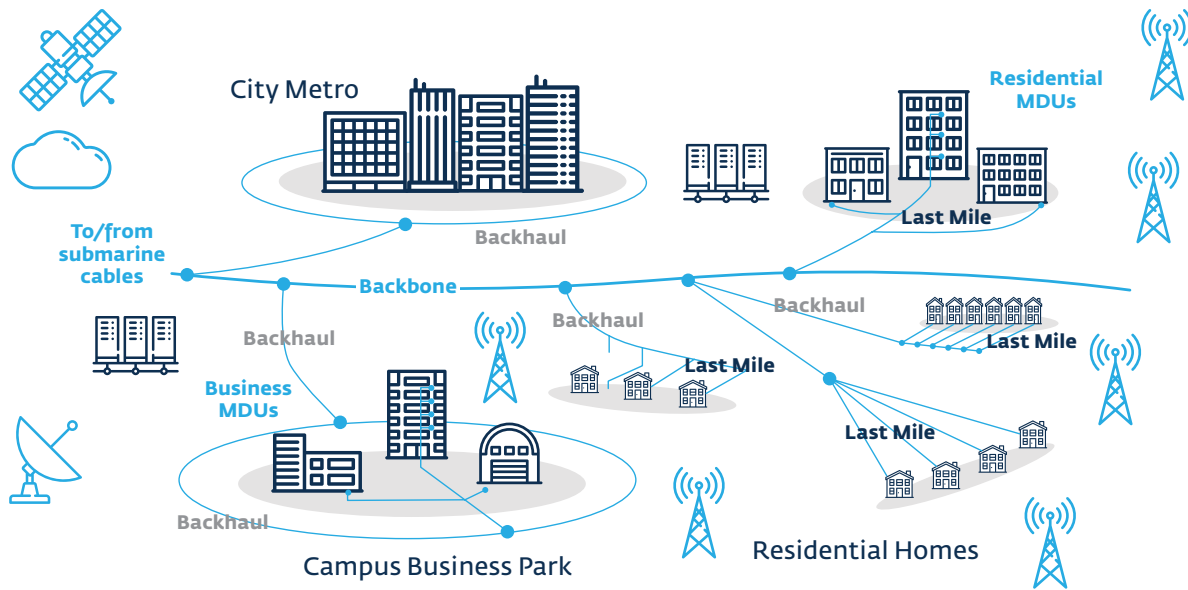


FIGURE 6.1 Components of Digital Infrastructure

Source: Adapted from Marino Garcia, Jose and Tim Kelly. 2015. “The Economics and Policy Implications of Infrastructure Sharing and Mutualisation in Africa.” World Development Report 2016, Background Paper, Digital Dividends; World Bank, Washington, DC.

Which Technologies and Policies are Disrupting Digital Infrastructure?

Mobile telephony, the spread of the Internet, broadband technology (from 1G to 3G data and beyond), and high-capacity fiber optic networks, along with the appropriate regulatory frameworks, can expand digital connectivity.

Over the last few decades in developing countries, telecom liberalization in many markets and the near-universal use of the Global System for Mobile Communications (GSM) have spurred investment in digital infrastructure. This mobile revolution began in the late 1990s, when many countries began liberalizing their telecom sector. Liberalization has typically involved the separation of sector policy, sector regulation, and investment/operations; creation of an independent regulator; privatization of the incumbent operator; and the creation of new markets for telecom services through the licensing of new operators, which are usually private wireless mobile network operators (MNOs).

Concurrently, market liberalization began to unfold, and GSM, the near universal standard for mobile voice telecom networks, was developed. MNOs in many industrialized countries, and the newly created

private MNOs in emerging markets, adopted the GSM standard for their networks.

Subsequently, economies of scale in the manufacturing, distribution, and sale of digital mobile telephony equipment, following Moore’s law-related improvements in performance, led to significant reductions in the cost of equipment for MNOs and the handsets bought by consumers. The exponential decline in costs has driven a rapid increase in mobile connectivity, and put a mobile phone within reach of most of the world’s poor.

How Does Disruption Differ in Emerging and Advanced Economies?

Technological disruption in infrastructure has become the norm in advanced economies, too. Faster data networks (such as 4G and 5G), increasingly powerful mobile devices, better optical networks, the cloud, and other infrastructure improvements continue to enhance the digital experience for hundreds of millions of people in higher-income nations.

Many of these trends are manifesting in emerging economies as well. But these have a set of obstacles, largely absent in advanced economies, which must

be overcome to close the digital divide for some four billion people worldwide who continue to experience gaps in coverage and usage. This offline population is disproportionately rural, low-income, elderly, and female.

- Lack of Internet access may be due to a “coverage gap.” Some 1.2 billion people live in areas where there is no mobile or fixed coverage, and therefore the Internet is not available.
- Lack of Internet access may be due to a “usage gap.” An additional 2.5 billion people are covered by mobile broadband networks (3G and 4G) but are not using the Internet because it is too expensive, they lack digital skills, or digital content is lacking.⁵⁶
- In Latin America, fewer than 1 in 10 poor households are connected to the Internet. In the Central African Republic, one month of Internet access costs more than 1.5 times the annual per capita income.
- Even mobile phones are expensive: the median mobile phone owner in Africa spends over 13 percent of her monthly income on phone calls and texting.
- Many low-income people lack the basic literacy and numeracy skills to use the Internet. In Mali and Uganda, about three-quarters of third-grade children cannot read. In Afghanistan and Niger, 7 out of 10 adults are illiterate, which presents a major barrier to benefitting from increased connectivity.
- Gender gaps persist in women’s access to, and use of, digital technologies. Women are between 12 percent and 50 percent less likely than men to access the Internet, and 10 percent less likely to own a mobile phone.⁵⁷ Closing the gender gap just in mobile ownership and data usage alone could generate \$15 billion in annual revenue for mobile operators.⁵⁸ However, women are often left out of digital infrastructure planning.

The digital divide in emerging and developing nations needs to be addressed to meet the ever-growing demands for digital infrastructure. The transition from 1G (voice only) to 2G (voice & basic data), 3G (full mobile data), and 4G/5G (faster and better data) requires digital infrastructure to keep up. As 4G is deployed in developing countries, with 5G on the horizon, and data storage becoming an increasingly

important element in connectivity infrastructure, meeting these demands requires larger government budgets and new models for infrastructure development that facilitate private investment.

How is the Disruption of Infrastructure Achieving Scale and True Development Outcomes?

For years, residents of Mexico suffered from spotty and expensive mobile service, leaving many behind as the banking, health, and education services sectors went digital. New government-provided wireless technology offers better and more affordable connectivity to over 110 million people. Within seven years, full wireless coverage, including remote, previously unserved areas, will be achieved.

In addition to improving service, the new network will improve access to banking, health, and education services, launch new ways to trade, and boost economic opportunities for digital innovators, as well as those who previously lacked service. The new, affordable coverage and access to technology and apps are expected to generate entrepreneurship projects, new work techniques for users, and new ways to create and deliver trade.

For many years, international Internet connectivity in East Africa depended on poor quality satellite infrastructure that constrained telephony and data/Internet access. Those who could get connected paid as much as 10 times higher tariffs than those in other regions, but often had poor service.

With assistance from IFC and the World Bank, a 10,000-kilometer undersea fiber optic cable system was built, bringing improved access and lower costs to over 250 million Africans. The cable system had knock-on effects on competitiveness and productivity. Lower connectivity costs and higher bandwidth helped spur demand for mobile broadband. This, in turn, led to increased smartphone usage and supported the development of new service sectors (e-banking, mobile money, and e-health, alongside an exponential rise in the use of social media networks). The cable system helped to launch knowledge-based small and medium enterprises and business process outsourcing, including

call centers, and in the process generated employment for local communities.

In **India**, Internet connectivity has enabled cities like Bangalore to become research-and-development hubs for skilled professionals. The benefits for the digital ecosystem have been tremendous, resulting in the growth of a cross-sector entrepreneurial culture that has turned Bangalore into an innovation center. These examples are typical of the disruption and ensuing benefits that digital infrastructure can deliver.

What are the Infrastructure Technology Opportunities in Low-Income Countries and FCS?

Closing the digital divide is more difficult in IDA countries and fragile and conflict-affected situations. In these countries, private investment is limited due to the relatively low bankability of projects. This means that shared infrastructure models, including public-private partnerships, are likely to be critical. Shared infrastructure allows competitors to use the same infrastructure for service delivery, and thereby provides end-users with the benefits of competition, while avoiding the cost of building unnecessary infrastructure. Such upstream interventions are particularly critical in low-income and IDA countries.

In addition, the poor can benefit from digital technologies even when they do not own a mobile phone or a computer. The Aadhaar digital ID program⁵⁹ in India provides an example of the beneficial impact of a universal coverage entry point that catalyzes connectivity and usage across a range of sectors. The digital ID program means that millions of poor people in India have an official identity, which gives them access to a host of public and private services, including finance, health, education, and more generally, access to markets.⁶⁰

Key Lessons and Remaining Challenges and Constraints

Closing the digital divide is among the most important challenges and opportunities for the next decade. The estimated cost of connecting people who are now unconnected is \$450 billion.

Connecting difficult-to-reach or very low-income people to broadband is not likely to attract investors. Many of the 1.5 billion people currently not connected to the Internet live in difficult-to-reach or low-density areas, and even if they were covered by services, it is unlikely they could afford current prices. Providing broadband to these customers requires different business models (such as open access shared networks or a satellite), and incentives to attract broadband companies and other market players.

The digital divide needs to be addressed in the context of the continually rising demands placed on digital infrastructure. Meeting demand requires new models that support private investment in infrastructure, combined with public investment. In addition, a variety of policy interventions are needed on the supply side with respect to first-, middle-, and last-mile connectivity. This means eliminating monopolies, liberalizing the market for building and operating backbone networks, implementing policies that permit and encourage competition among providers, and increasing the available spectrum. Also critical is a national broadband strategy, with a regulatory framework that supports investment and commercialization.

Looking to the Future

The deployment of 4G and 5G data service is expected to give major impetus to infrastructure sharing.

- Such technologies require an extensive and redundant fiber network to carry data traffic. Developing and/or expanding such networks by each MNO is no longer affordable and viable. Nor is it a competitive advantage in most markets to own such passive infrastructure.
- We expect infrastructure sharing to take many forms. MNOs may simply agree to share their existing infrastructure with each other, parcel out the building of new infrastructure, and then share this too. Others may spin off or sell their infrastructure altogether to a third-party, carrier-neutral operator, or leave any new building (and ownership of the new network) to the independent party. For economic benefits, MNOs may retain some ownership in these ventures.

- We also expect infrastructure sharing to move from passive to active sharing, similar to the Altan project in Mexico whereby MNOs will become pure service providers as the active network is owned by a neutral, third-party operator.

Independent data-centers are expected to grow significantly in emerging markets.

- The following factors will be driving this growth: an exponential increase in data traffic, the desire of governments to keep information onshore, and the need to host both foreign and local content close to the end users in order to increase the quality of their experience.
- The need for independent data centers will also be driven by the migration of mostly offline SMEs to an online environment, and the use of cloud-based services such as enterprise-resource-planning systems, and so on.
- We also expect convergence between towers, fiber networks, and data centers to create fully integrated digital infrastructure businesses.

New players are entering the connectivity and digital economy sector. Big-tech companies such as Google, Facebook, Amazon, Alibaba, and JD.com are becoming increasingly important players in connectivity infrastructure, which includes the building out of fiber networks, Wi-Fi, and data centers. The ability of these big-data platform companies to harness data; attract top engineering talent; cross-subsidize across service, content, and access businesses; and mobilize capital, is making platform companies significant players in providing connectivity solutions. For example, Google is rolling out free Wi-Fi networks across Asia, Facebook is building fiber networks in Africa, and both are working on low-orbit/high-altitude connectivity solutions that can connect remote and rural areas at low cost.

IFC has a unique opportunity to work with the big-tech players that have had limited experience with emerging markets. Many of these companies are beginning to roll out connectivity infrastructure in emerging markets, including IDA countries, and, as data flows grow, to invest in increasing data center capacity in these countries. ■



PLANNED

Time in Planned
01:29:18
01:29:18 / 01:29:18

DOWNTIME

Time in Downtime
01:29:18
01:29:18 / 01:29:18

SETUP

Time in Setup
01:29:18
01:29:12 / 01:29:18

RUNNING

Time in Running
01:29:18
01:29:18 / 01:29:18



15646
SLEEVES IN
245649/900000
SLEEVES OUT
245617/900000

- SHIFT
- JOB
- OUT
- EVENTS
- STARTS

CHAPTER 7

Leveraging Disruptive Technologies in Manufacturing

By Emmanuel Pouliquen, Hassan Kaleem, and Sabine Schlorke

Manufacturing is Critical for Economic Development in Emerging Markets

Manufacturing is critical to economic transformation because of its ability to improve living standards through greater productivity. Manufacturing does this through the division of labor, adoption of modern management practices, automation and use of new technologies, skills building, and—eventually—the connection of various production and services activities to create sophisticated economic networks and greater economic complexity. These factors combine to make manufacturing a principal driver of employment, social stability, and economic development. Its multiplier effects strengthen economic activity across an economy.

An overly narrow view of manufacturing—for example, workers doing piece work or “metal bending” in factories—has encouraged the idea that industrialization, or the creation and scale-up of a manufacturing sector,

may no longer be necessary to achieve development goals in emerging markets. Instead, some mistakenly believe economic goals can be achieved through the creation of robust services sectors.

Manufacturing engenders employment and economic activity far beyond the assembly line. Some 30 percent to 55 percent of service sector jobs are in manufacturing.⁶¹ And manufacturing accounts for 70 percent of global trade. The manufacturing sector undertakes three quarters of all research and development spending; it drives innovation through the creation and transfer of new technologies; and it fosters the development and transfer of new skills that improve and strengthen a nation’s labor force. Manufacturing promotes formal employment, higher wages, and cheaper goods for consumption.⁶² Perhaps, most tellingly, the manufacturing sector accounts for by far the largest share of higher skilled and higher paying jobs. In the United States, for example, manufacturing has the highest wages of any private industry.⁶³

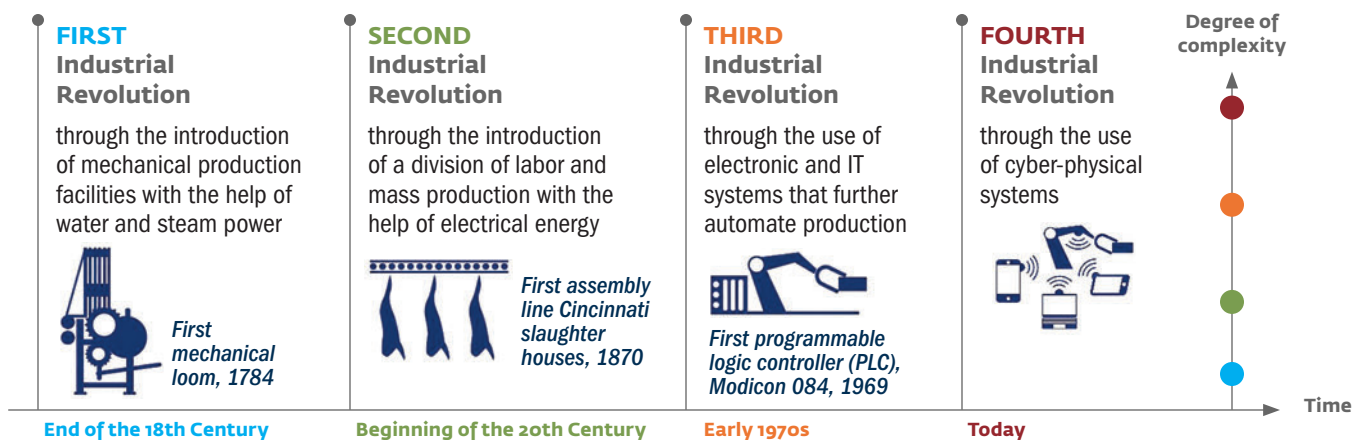


FIGURE 7.1 Manufacturing Shapes and is Shaped by Technology

Source: Pouliquen, Emmanuel, Hassan Kaleem, and Sabine Schlorke. 2018. “IFC Manufacturing Sector Deep Dive: Unlocking the Value of Manufacturing for Development.” International Finance Corporation, World Bank Group, slide 11 (internal document).

Manufacturing Shapes and is Shaped by Disruptive Technology

While manufacturing fosters the adoption, creation, and spread of technology, it is also highly *dependent* on technology. In fact, the two are inextricably linked. Technology has always been a key driver of manufacturing, and has led to product and process improvements through multiple industrial revolutions.

As illustrated in Figure 7.1, *technological disruption is the essence of manufacturing*. Harnessing water and steam power enabled mechanical production facilities; electricity brought mass production; information technology allowed for automation; and cyber-physical technologies such as artificial intelligence and the Internet of Things are now giving rise to the factories of the future.

Technology disrupts, destroys, and creates, and is therefore central to economic growth in the modern era. As such, it has always been necessary for—and will remain integral to—industrialization in any nation, rich or poor. Beginning with the first industrial revolution in eighteenth-century Britain, technological change has taken place mainly in the manufacturing sector.⁶⁴ Moreover, technological change in the manufacturing sector has acted as a driving force for productivity growth in a number of other economic sectors.

The Three Dimensions of Economic Complexity in Manufacturing

There is a strong relationship between economic complexity and economic growth in all economies.⁶⁵ Manufacturing activities contribute to economic complexity through three main dimensions: **product complexity** (automobiles, for example, which contain a large number of separately produced components); **process complexity** (for example, cement is a routine product, but the process to produce it ranges from mining to sophisticated chemical engineering); and **value chain complexity** (the iPhone is a prime example, with its many tiers of suppliers in different countries).

Economies that can produce a diverse range of sophisticated products, using complex production processes that are integrated into complex value chains,

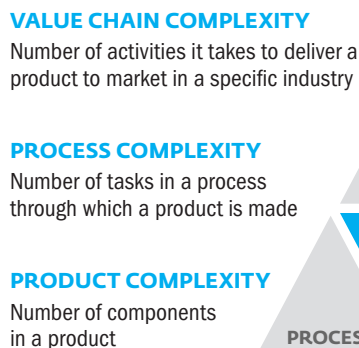


FIGURE 7.2 Manufacturing Contributes to Economic Complexity

Source: Pouliquen, Emmanuel, Hassan Kaleem, and Sabine Schlorke. 2018. “IFC Manufacturing Sector Deep Dive: Unlocking the Value of Manufacturing for Development.” International Finance Corporation, World Bank Group, slide 10 (internal document).

are considered to have high economic complexity. As mentioned above, various technological disruptions occur regularly in manufacturing, and each time increase complexity along one or more of these three dimensions.

Manufacturing in Emerging Economies

The pattern of technology-driven industrialization leading to economic growth and increased complexity has been the case not only for advanced economies, but for emerging and developing economies as well. The path and pace of this process differ, however. In low-income countries, manufacturing’s share of the economy is also low, and its contribution to economic growth is relatively minor. When and if manufacturing increases as a portion of economic output, output and labor productivity also increase across the economy.⁶⁶ As the examples of Taiwan and South Korea demonstrate, industrialization and economic growth can decrease inequality, too, leading to better outcomes across the income spectrum.⁶⁷

However, such poverty reduction has not been the case in most of IFC’s target markets. Instead, most low-income economies have developed only simple, non-diversified manufacturing bases and, as a result, have achieved only low levels of economic complexity. Additionally, manufacturing largely takes place in

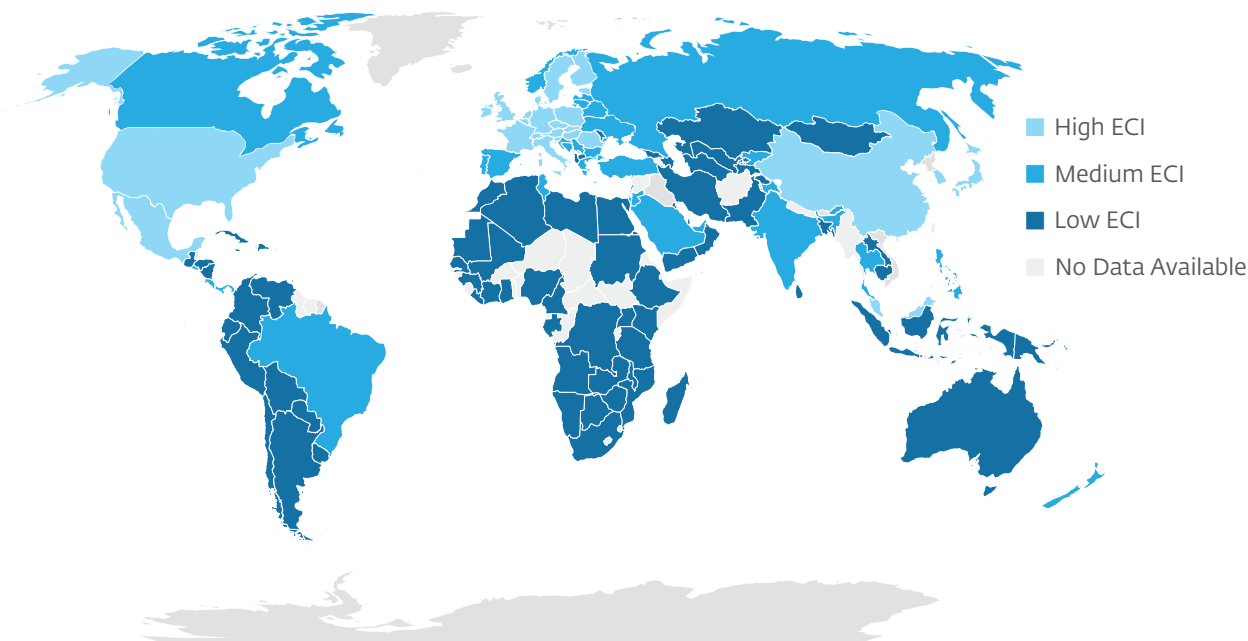


FIGURE 7.3 Most of the Markets IFC Targets Have a Simple, Non-Diversified Manufacturing Base, and Thus a Low Rating on the Economic Complexity Index

Source: Pouliquen, Emmanuel, Hassan Kaleem, and Sabine Schlorke. 2018. “IFC Manufacturing Sector Deep Dive: Unlocking the Value of Manufacturing for Development.” International Finance Corporation, World Bank Group, slide 17 (internal document).

the informal sector in most low-complexity emerging markets. Putting it bluntly, most developing countries do not have the capacity to produce diverse or sophisticated goods. This is particularly the case in Sub-Saharan Africa and Latin America.

Investment—or more accurately, the lack of it—is a large part of the problem. Low-income countries, particularly in the Middle East and North Africa, Sub-Saharan Africa, and South Asia, are not attracting significant foreign direct investment (FDI) flows to manufacturing. Manufacturing FDI in low-income and lower middle-income countries is barely a third of that in upper middle-income and high-income countries.⁶⁸ So while the greatest need for manufacturing FDI is in poorer countries that have attained little economic complexity, the bulk of manufacturing FDI goes to higher income countries.

To counter these issues, IFC has adopted a manufacturing strategy built on the following three strategic pillars, which are designed to help clients unlock the power of manufacturing to strengthen and accelerate manufacturing complexity.

1. Laying the foundation for industrial production. This includes building commercially viable, resource-based industries for local consumption and higher value-added exports; strengthening basic supply chains that target local and regional demand; and supporting production and assembly of simple products in global value chains. There is a focus on building basic skills via facilitating knowledge transfer between expatriate and local staff and providing training on basic industry standards.
2. Supporting more advanced manufacturing. This is done through a continual build-up of foundational manufacturing capabilities; developing production focused on local and regional markets; and helping countries become more competitive by entering multiple global value chains.
3. Enhancing and deepening manufacturing complexity. Methods include strengthening inter-industry links to sustain global competitiveness; supporting leading domestic and regional firms so they build a global footprint; and encouraging research and development and brand-building activities.

Technology and the disruption it can cause are central to these pillars. Enterprises should adopt the technologies that are suitable for their stage of development in the economies where they operate. For example, product handling or sorting robots—which would be a highly productive investment for manufacturers in Germany or Japan—might not be suitable for firms in emerging markets due to the high cost of the robots and the skills required to operate them.

However, several IFC clients have successfully adopted disruptive, state-of-the-art industrial technologies when they have proven to be economically and strategically justified—for example, using robots for hazardous tasks or tasks that are ultra-precise and repetitive (see Appendix A).

Future Technologies and Manufacturing Disruption

New technologies emerge every day that are certain to further disrupt manufacturing, both in advanced and emerging economies. These include Big Data, 3D printing, and the Internet of Things, as well as blockchain (for traceability and payments), and drones for delivering goods (to offset the lack of infrastructure for delivery that plagues many emerging economies).

Virtual reality may help accelerate technical training for manufacturing staff, as well as lower the cost of prototyping new products and processes. And ultra-high transmission broadband, as well as very large and cheap computing and storage, will make real time, quality control and machine capability monitoring both economically feasible and widespread, reducing quality rejects and machine breakdowns, while also boosting productivity. Artificial intelligence will help manufacturers analyze and forecast causes of breakdowns or low-quality before they occur.

These technologies, the majority of which were created in advanced economies, can be adopted and implemented in emerging and developing economies, allowing them to leapfrog many of the traditional steps up the development ladder.⁶⁹

As already noted, there are constraints to adopting and using these technologies in emerging markets. Low-quality or nonexistent infrastructure is the most

important constraint. Power, transport, and broadband access problems routinely hamper and obstruct manufacturing growth. Education systems need improvement too in many regions so that workers have the foundational skills to learn how to use and operate new technologies. Burdensome bureaucracy, corruption, and a lack of appropriate regulatory structures are additional challenges to the growth of industry. And so is access to finance so that entrepreneurs, and especially women, and underserved small and medium enterprises can access the financing and working capital they need to purchase equipment, expertise, and services.

Addressing these issues to create markets and foster robust manufacturing sectors in emerging markets, while leveraging new and potentially disruptive technology—and ultimately building economic complexity—will require coordinated deployment of the World Bank Group. In this regard, IFC is well placed to lead the way in strengthening the role of manufacturing in the private sector as this requires investment and the mobilization of private capital; advice on energy and resource efficiency; de-risking solutions to attract private stakeholders; skills development; assistance in improving regulations and standards; and assistance in the continued adoption and promotion of innovative and disruptive technologies.

Appendix A: Three examples of IFC investments in disruptive manufacturing technology

Plastic Packaging in West Africa

For developing economies, the first step on the path to complex economic activity often involves processing simple consumer goods—for example, hygienic packaging for products and small appliances.

Côte d'Ivoire's economy is almost completely dependent on agriculture, with little manufacturing. In 2016 IFC provided a loan of €15 million to SIMPA, a Senegalese producer of plastic and thin film packaging products, to finance a manufacturing subsidiary in Abidjan, Côte d'Ivoire's capital.

SIMPA is the largest manufacturer of plastics in Francophone West Africa and is on the cutting edge of manufacturing technology in the region. It is the first West African producer to use high-speed, in-mold

labeling machines that allow it to offer injection molded products—food buckets and jars are typical—at much more competitive prices than products made using older technologies.

SIMPA is transferring its technologies and management expertise to its new Côte d’Ivoire plant. When completed, the facility will have state-of-the-art equipment, including extruders, high-speed flexographic printing lines, laminating machines, slitters, and in-mold labeling machines. The plant will also have its own flexographic studio and be fully autonomous for computer-based print designs.

The Abidjan facility is creating employment—increasing to about 280 staff in 2018—while boosting the efficiency of local SMEs. Until recently, these firms had to import their packaging, at higher cost. While increasing Côte d’Ivoire’s economic complexity along the process, product, and supply chain dimensions, the new packaging also reduces food waste and enhances food security in Côte d’Ivoire and neighboring countries. In addition, the new plant extends regional value and supply chains in West Africa, benefiting agricultural and other business, as well as consumers.

Disruptive Technologies in Ukraine

When firms reach a certain size, technology can enable them to grow through international expansion.

Ukraine, classified as a lower-middle-income economy by the World Bank, is home to one of the world’s largest producers of flexible packaging materials, films, and labels—IMMER Group—which uses high-tech digital printing to disrupt the flexible packaging market in Ukraine and other countries.

A 2018 loan of over €30 million from IFC, which includes €15 million mobilized by IFC from other lenders, is supporting the export-led growth of Kyiv-based, IMMER. The company’s first move with this financing has been to offshore its production to a new plant in Latvia that focuses on digital printing, including Digital Mosaic and other state-of-the-art technologies that produce digitally printed films with low volumes and high margins. The new plant also gives IMMER access to largely untapped markets in Northern and Western Europe.

In the new plant in Latvia, IMMER has completed the rollout of digital printing of packaging film. New and more traditional offset or flexo printing lines will be installed in the plant in a second phase, depending on client demand. Additional digital printing capabilities will also be considered. These will allow the company to offer films made in very small batches, even down to the packaging unit, if needed for specific premium niche applications.

The benefits to customers are substantial. Customers gain product packaging with a professional feel, which was previously difficult to replicate, and they pay less to launch prototypes and limited packaging editions for promotional or premium products. IMMER’s technology has the potential to disrupt the flexible packaging market in much the same way that digital printing transformed commercial printing in recent decades, and this is increasing economic complexity, primarily along the manufacturing process dimension.

Automotive Manufacturing in India

The achievement of world-class automotive manufacturing is a major development step for any economy. India’s Craftsman Automation began as a small-scale machining operation in 1986 in the southern Indian city of Coimbatore, and has since grown into a leader in precision manufacturing of good quality auto parts, and a supplier to global vehicle manufacturers that include Tata Motors, Mercedes, Volvo, John Deere, and Caterpillar, among many others. Thus, the company has become a model emerging market industrial enterprise. The high standards, which Craftsman ensures in its manufacturing processes, is particularly important for the Indian automotive market, where there are key constraints in enhancing supply chain competitiveness (such as the prevalence of counterfeit products in the components and parts market).

IFC invested \$37 million in Craftsman in 2010, and may invest more. Not only is it a successful investment for IFC, with future predicted financial returns, but it also spurs long-term South-South economic development via vertically integrated supply chains, and positively impacts a broad array of sectors, from automotive to automation, agriculture, energy, and

infrastructure. Craftsman plays a strong role as well in the integration of local suppliers into domestic and global value chains. Suppliers benefit from building their capacity to use new engineering tools and processes, and diversify their product line such as with aluminum castings.

Since its inception over 30 years ago, by adopting customized robots and sophisticated computer aided design systems, among other disruptive technologies, Craftsman has continued to innovate and automate to boost its efficiency and output. These high-tech advances have allowed the company to expand into new markets and boost its bottom line. Craftsman

now employs more than 1,500 people, had sales of \$186 million in 2017, and in 2018 filed papers for an initial public offering. IFC estimates that the employment multiplier in the Indian automotive sector is higher than the global median, and the company's operations support additional indirect and induced jobs through backward and forward linkages.

Craftsman's success strategy showcases how the best light manufacturing enterprises can harness the latest technologies to fill specific economic niches, while creating markets and increasing economic complexity, primarily across the process and supply chain dimensions. ■

CHAPTER 8

Disruptive Innovation in Agribusiness

By Anup Jagwani, Gene Moses, and Jennifer Keller

Raising incomes across the food supply chain is an essential pillar of almost every low-income country's approach to poverty alleviation. In addition to providing food, agriculture is the main source of income for 70 percent of workers in low-income countries.⁷⁰ The percentage of jobs for which the larger food system accounts is even higher. As climate change is increasing volatility, accelerating soil degradation, and reducing water availability; and population growth and changing diets are increasing food demand; greater food productivity is not just a priority for poverty reduction, it is a global food security imperative.

How do We Define Disruption in the Agribusiness and Agriculture Sectors?

Leveraging disruptive innovation in agriculture involves more than applying technologies to make farming more productive. It means improving efficiency and transparency across the entire food supply chain through precision farming; improving and maintaining soil health; reducing input use; reducing post-production food loss; reducing waste at the retail and consumer levels; and creating mutually beneficial linkages among market participants.⁷¹

There have been pivotal advances in agribusiness technology across the entire food chain. Many of these technologies provide cutting edge solutions to a range of risks and costs faced throughout the value chain, from smallholders to consumers. These solutions mitigate risks related to variable conditions, reduce information asymmetries among economic actors in the food chain, and crowd in knowledge and data-driven solutions for higher productivity. And while many of these technologies have been in use for a decade or more in advanced economies, only now are they becoming more widespread in low-income nations and regions. From improving crop varieties and yields to enhancing the operational efficiency and effectiveness

of the food value chain, food-related disruptions could become transformative.

Which Technologies are Disrupting Agribusiness Across the Food Value Chain?

Seeds and Soil

Advanced biotechnology for stronger, climate-resistant crops. Variations in climate conditions, pathogens and insects, and poor quality agricultural inputs and seeds, can prevent farmers from producing consistently good yields of high-quality crops. Advanced biotechnology, including gene editing and microbiome technologies, is enabling greater food production through the development of more climate resilient crops (for example, through drought-tolerant and higher salinity-tolerant varieties), helping to improve crop nutrition, and preserving or improving soil biology.

Gene editing is a new generation of targeted genome editing technology, which is used to make precise changes to a plant's DNA in order to emphasize and increase desired traits or remove undesirable ones. CRISPR/Cas9 uses a set of molecular "scissors" to edit the DNA that already exists in a plant.⁷² These edits are not significantly different from the plant mutations that occur naturally (which are subsequently exploited to improve certain crops through breeding), but gene editing allows the process to take place rapidly. It also allows scientists to edit multiple target traits simultaneously.

Scientists see gene editing technologies like CRISPR/Cas9 as transformational, akin to the introduction of genetically modified (GMO) corn and soybeans in the 1990s. But unlike GMO technology, gene editing does not involve the introduction of foreign DNA into a species (a method known as transgenics). That makes it significantly more palatable to consumers. Ultimately, these technologies could be instrumental

in the development of more resilient food systems—for example, by enabling the cultivation of crops that are more tolerant to extreme weather conditions or that meet specific market needs.

Other **microbiome technologies** can also enhance crop resilience and crop nutrition. Microbiomes are the environment of organisms around a plant—around the roots, in the soil, on the leaves, and even within the plant itself. There is a continuous molecular dialogue between a plant and its microbiota—one that has an important impact on plant survival and growth. Microbiome technologies work with the microbes populating the below-ground habitat to achieve agricultural yields that can be more bountiful, nutritious, and flavorful. Microbiome technologies can also make crops more resistant to drought and harmful insects, and grow well in low nitrogen, salty soils.⁷³ This technology is particularly relevant in regions where the use of chemicals over a sustained period of time has weakened and damaged the microbiome of soils.

Input and Production

While improvements in seeds and soils are important for raising yields, more efficient management and optimal use of farm inputs requires more consistent and precise monitoring. **Precision agriculture** encompasses the spectrum of products and services that can allow farmers to use data more accurately to manage the process of growing crops and raising livestock. And by using these tools, farmers can maximize yields, minimize inputs, and reduce farm losses.

An array of technologies, including GPS guidance, mobile devices, robotics, sensors, variable-rate application (VRA) seeding, and precision irrigation are critical to this farm management approach. By mapping fields and deploying sensors, these tools can monitor conditions related to climate change (air, soil, and moisture levels), as well as insects and diseases, to provide treatments that mitigate crop loss. Through increasing production while also reducing inputs, precision agriculture does more with less, and achieves positive climate benefits through direct and indirect reductions in greenhouse-gas emissions.

Fundamental to precision agriculture is **wireless sensor technology** (electrotechnical devices) that measure

physical conditions in the environment and convert those measurements into information that is useful across the food supply chain. For instance, farmers can utilize sensors to collect data on weather, soil conditions, air quality, and crop maturity, and even the locations and physical conditions of herds. Integrating these and other **Internet of Things (IoT)** technologies (such as cameras and weather stations) into IoT platforms (such as Zenvus, a Nigerian precision start-up) allows collected data to be transformed into performance analysis and crop- or herd-specific recommendations. IoT technologies can also be leveraged to automate irrigation, fertilization, and other farming processes, reducing the need for manual intervention.

Online and mobile platforms (including both marketplaces and information hubs) such as “Hello Tractor” in Kenya and Nigeria, match farm equipment owners with small landowners who cannot afford to buy such machinery. Using IoT devices, poorer farmers can rent equipment from those who own “smart tractors,” and through low-cost monitoring devices, owners can ensure that their tractors are properly maintained.

Other technologies, many of which need only a mobile phone, can be transformative by providing crucial information on production, harvesting, marketing, credit, weather, and climate, which is based on just location and crop preferences. Other applications connect farmers to markets and help agribusinesses to understand current market trends, manage transactions, cut costs, increase revenues, and manage risk. The range of low-cost knowledge solutions available to farmers and agribusiness agents through mobile applications is vast and fills a significant gap in agricultural extension services that is prevalent in low-income countries.

Supply Chain/Processing

A major advancement in the tracking and transparency of food has come through **blockchain technology**, which enables the gathering, interpretation, and sharing of information across the food supply chain. Every entity handling a particular item submits relevant data, which is then recorded and available to all others in the process, making it possible to track food origin and characteristics (for retailers and consumers), as well as payments and deliveries.

The potential benefits of blockchain are truly significant. Perhaps most important, blockchain can create links among participants in the food chain, enabling market creation and developing new relationships. Blockchain can make the food chain significantly more transparent, and can remove asymmetries between farmers and buyers. This allows farmers to earn better prices for their products, which can increase farm incomes. For consumers, blockchain can provide vital information on food products, from the locations where livestock were reared and what they were fed, to crop growing techniques, potential allergens, and even the shelf life of a product.

While new technologies like mobile applications and data driven solutions can be transformative in developing countries, traditional “low-tech” agriculture technologies, which could have even greater influence on agribusiness markets, have yet to be fully adopted in low-income countries. **Efficient irrigation** is arguably the most transformative of these technologies. Irrigation is a vital need in farming due to uneven distribution of rainfall and seasonality of water resources. Irrigation can more than double the productivity of rainfed land, but in low-income countries, other than for large-scale farms, irrigation is rarely used.⁷⁴ Also, the use of drought-tolerant seeds is rare, and there has been almost no adoption of precision agriculture tools, drip irrigation, and sprinkler irrigation in Sub-Saharan Africa or most of India (in Africa, only 6 percent of the land is irrigated).⁷⁵

A more traditional transformational technology is **cold chain transportation and storage**. Worldwide, about 45 percent of fruits and vegetables are lost or wasted every year.⁷⁶ While food loss in developed countries is largely attributable to consumer waste, in low-income countries it results primarily from inadequate post-farm transportation and cold storage.

Both post-farm transportation and cold storage are hobbled by a lack of reliable energy sources (other factors, such as a lack of financing and lack of knowledge, also limit adoption). Reliable energy and infrastructure augments efficiency across the entire food system—from the production of crops and livestock, to post-harvest operations, and to food storage and processing, food transport and

distribution, and food preparation. The lack of stable, affordable, and available energy sources has been one of the main deterrents to higher value agribusiness in low-income economies. Investments in foundational infrastructure for irrigation, including the cold chain, remain among the most important investments for increasing yields, stability, and food quality.

Transformations Outside Agriculture

Disruptions outside agriculture can play an important role, too. Affordable **off-grid renewable energy generation and storage** may be a game-changer for farmers in low-income countries. If 50 to 75 percent of farms without access to grid electricity had access to renewable energy technologies and battery storage systems, food loss from lack of appropriate storage could be reduced by 10 to 15 million tons by 2030, and farm incomes could increase by as much as \$100 billion.⁷⁷ Also by 2030, irrigation systems enabled by access to energy could reduce water use and increase food production by as much as 530 million tons.

However, for these improvements to occur, the costs of renewables and battery storage must decline.

Solar pumps that lift well water to feed drip irrigation systems could alleviate irrigation energy gaps. According to official estimates, over 20 million well pumps operate today in India, roughly split between those with electric and diesel power.⁷⁸ Widespread use of solar pumps is hindered by upfront system costs (which remain prohibitively high for most farmers), and by public subsidies for gas and electricity that are still pervasive in many countries. Pay-as-you-go mechanisms for renewables could play an important role in reducing the price (and therefore the adoption gap) by providing farmers with flexible payment options.

Access to finance also remains a key constraint to wide adoption of high impact technologies, particularly for smallholder farmers. As a result, many farmers continue to use traditional processes that depend on rudimentary equipment such as hoes and cutlasses. Farmers need the right incentives and opportunities, not only to install and use disruptive technologies such as IoT systems through pay-as-you-go schemes, but also through existing technologies that can deliver major benefits (such as drip irrigation).

Aside from finance and credit, the rise of integrated supply chains and mobile banking solutions for farmers is advancing at a rapid pace. In Kenya, the mobile money technology M-Pesa has transformed how economic actors manage money by allowing customers to send and receive money through a simple text message. For smallholders and others in rural environments, this can significantly increase access to banking and payments, as well as access to much needed inputs and services.

Key Lessons and Remaining Challenges

An array of disruptive technologies has emerged with the potential to transform agriculture and agribusiness in emerging and developing countries. Yet various challenges remain to their implementation and widespread use.

Getting farmers to effectively use these data services and other technologies is not as simple as merely providing the technologies. A role remains for intermediaries and extension agents to teach and advise new users. In addition, new technologies may not be effective or transformational if they are not accompanied or layered on top of existing and traditional technologies such as irrigation and proper storage and transport.

Finally, a lack of access to reliable energy could prevent or retard the rollout of any technology. And access to finance for farmers at all income levels is necessary if disruptions are to occur.

Looking to the Future

Since its advent, agriculture has changed dramatically, and will likely continue to do so. Technologies—from the plow to fertilizers to mechanical harvesters and beyond—have revolutionized food production.

Yet by 2100, the global population is expected to exceed 11 billion, from the current 7.6 billion.⁷⁹ Thus

dramatic improvements to farm productivity and yields remain necessary, especially in emerging markets where the bulk of this population growth will occur.

Fortunately, agriculture technology (AgTech) is beginning to become better leveraged. The application of a range of technologies is now demonstrating positive impacts on farm yields, farmers' incomes, and efficiencies in the supply chain, and also reducing inputs, losses, and waste. Furthermore, many developing countries are beginning to see AgTech ecosystems emerge, and are already acquiring or deploying innovative technologies in both large-scale and smallholder farming contexts.

AgTech is now at an inflection point where there is a virtuous circle of falling costs of technology, which allows scalable companies to be built and leads to product adoption and greater capital flows. In addition, high-potential entrepreneurs are attracted by growing market opportunities. In terms of new technologies, advanced biotechnology—from bioengineering to market-assisted breeding and gene editing—will likely play a major role.

AgTech investors are participating at all stages. In 2016–2017, 25 new accelerators were launched across the globe. While specialist AgTech funds and agro-corporate venture arms are still the most active investors, the base is diversifying, and generalist venture capitalists are beginning to target AgTech as a key subsector. In addition to global companies scaling to enter emerging markets, indigenous startups are visible in many regions, resulting in rapid international growth of AgTech.

If all goes well, the combination of innovative and disruptive technologies, appropriate policy changes, and the development of capital markets and infrastructure can meet the food needs of a growing world population without significantly increasing agriculture's environmental footprint. ■

CHAPTER 9

How EdTech Can Disrupt Business Models in Emerging Markets

By Juliana Guaqueta Ospina, Sean Petersen, and Salah-Eddine Kandri

Major new technological developments are providing targeted and tailored education with more focus on skills, solutions that provide teachers and educational institutions with a broader range of teaching tools, and more choices of learning methods for students. EdTech is in its early days, but already some business models have shown their ability to scale and help address the education crisis in developing countries.

How do We Define Disruption in the Education Sector?

Education is fundamental to improving human lives and living standards, boosting economic competitiveness, and achieving inclusion and social mobility. While significant progress has been made in recent decades toward ensuring access to education at all levels, education systems in many countries face challenges in reaching all children and providing them with quality education. Some 124 million children are out of school, and 250 million children are unable to read or write, despite attending school.⁸⁰ At the same time, millions of additional young people and adults in developing countries are unable to afford or access tertiary education or professional training.

In addition, the world is facing a learning crisis. A 2018 World Bank report, *Learning to Realize Education's Promise*, describes how millions of children “are getting schooling without learning,” are growing up without basic academic skills, and that learning gaps are widening.⁸¹ In Latin America, more than half of the students who participated in the PISA⁸² test in 2015 did not reach the baseline level of performance.⁸³ And where there is progress, it is often slow. At the current rate of improvement, it is expected to take around 75 years for Brazilian 15-year-olds to reach the average math score of their peers in high-income countries. In reading, the gap is

even wider—263 years. In Sub-Saharan Africa, the gross enrollment rate in tertiary education is a mere 9 percent, which contrasts sharply with the rates in middle- and high-income countries (33 percent and 74 percent, respectively). Moreover, most of the roughly six million people who join the labor force globally every month (one million in Sub-Saharan Africa alone and another million in India) have very little training and are often unemployable due to a lack of both foundational and job-specific skills.

Looking forward, low-skill jobs that emphasize manual and routine tasks—which have been at the core of the traditional path to industrial development for many countries—will be replaced by automation or by workers whose productivity is enhanced by the proliferation of information and communication technologies, as well as by more leading-edge technologies such as artificial intelligence and augmented reality.

For these reasons, **disruption is sorely needed in the way students in developing nations are educated.** Technologies are needed that can enhance the provision and teaching of foundational cognitive skills such as literacy and numeracy, as well as the skills needed in a modern economy. These include:⁸⁴

- **Nonroutine, higher-order cognitive skills.** These refer to the ability to understand complex ideas, deal with complex information processing, adapt effectively to the work environment, learn from experience, engage in various forms of reasoning, and overcome obstacles through critical thought. More specifically, these include skills such as unstructured problem solving, critical thinking, learning, and reasoning.
- **Technical skills, including information and communication technology (ICT) skills.** Technical skills are those needed to carry out a particular job—such as a plumber’s ability to

repair a water leak, a factory worker’s knowledge of machinery, or a bank employee’s facility with software. ICT skills range from the ability to develop, operate, and maintain ICT systems, to the use of mainstream ICT tools such as word processing and spreadsheet applications.

- **Socioemotional skills.** Socioemotional skills (also called soft or noncognitive skills) encompass a range of malleable skills, behaviors, attitudes, and personality traits that enable individuals to navigate interpersonal and social situations effectively. These include perseverance to finish a job or achieve a long-term goal, working in teams, punctuality, organization, commitment, creativity, and honesty.

Providing these essential skills and education on a large scale in mainstream education, and at levels affordable in developing nations, could benefit from technologies that upend traditional teacher-student-classroom delivery models by enhancing them—or replacing them in some scenarios—with affordable, skill-specific, location-neutral learning.

Which Technologies are Disruptive?

Education technology—EdTech—has emerged over the last 10 years as a potential solution to help address the learning crisis in the developing world. EdTech was initially developed as a niche product to supplement traditional educational methods. However, as Internet and mobile connectivity has expanded, it has rapidly evolved into a disruptive force—one with unique potential to address the learning crisis and improve education outcomes based on the following factors:

- The development of big-data analytics, which has improved understanding of the link between educational content, delivery models, and outcomes, has enabled the development of education solutions that are tailored to the specific circumstances of the individual.
- Digital algorithms embedded in EdTech products provide instant and interactive feedback that allows the learner to identify and focus on problem areas. Instruction and homework can also be tailored to an individual’s needs.
- The decreasing cost of technology and computing,

and the increasing reach of the Internet and mobile connectivity allow EdTech to reach the poorest and most remote learners—making education accessible and affordable.

- Online delivery provides students and teachers with best-practice materials and teaching methodologies, with the language of instruction as the only remaining barrier to usage. EdTech could deliver education solutions on a massive scale, as translation into local languages is the only marginal cost of delivery.

Beyond supplementing and accelerating learning of the foundational elements of literacy and numeracy, EdTech is transforming tertiary, technical, and vocational training. Universities and technical colleges are leveraging technology to enable blended instruction in which teachers shift from conveying content to focusing on high-value interactions.⁸⁵ EdTech tools also enable traditional education institutions to co-develop and integrate content from industry into their curriculum, with a positive impact on employability.

As technological disruption transforms economies and accelerates the pace of change, life-long modular learning will become a key element of an individual’s ability to adapt in an ever-changing workplace. EdTech facilitates this through the unbundling and modularization of learning, and provides skill-specific micro-accreditation, as opposed to the bundled learning and degree/certificate accreditation currently delivered through traditional educational institutions. The economic opportunity of this integration is large: online talent platforms could increase global GDP by up to \$2.7 trillion, and raise employment by 72 million full-time-equivalent positions.⁸⁶

How Does EdTech Differ in Emerging and Advanced Economies?

Technology has infiltrated education systems, methods, and strategies in countries across the economic spectrum; and in developing countries, EdTech has been key to expanding access to underserved populations. These include the urban poor and people in frontier regions of middle-income countries, as well as those in the poorest nations, in fragile and conflict-affected situations, and displaced in refugee camps.

EdTech is an enabler for students outside of formal

BOX 9.1 Example of the Types of EdTech Applications Used Today

- **Innovations to improve the quality of service delivery in public and private schools.** Integration of EdTech solutions can improve education quality by standardizing operations, streamlining curriculum, and introducing innovations in the classroom. EdTech can also improve out-of-school supplementary learning such as personalized learning software. An example is Brilliant, a self-learning tool that improves math and science proficiency.
- **Mobile-enabled education solutions.** Application of mobile technologies such as learning apps can make lectures, visualization models, virtual tutors, and assessments accessible in order to scale-up access to education anytime, anywhere. Examples include Byju's and Photomath.
- **Low cost courses/degrees.** Online education with relatively low unit economics can increase access for price-sensitive students, and has the potential to augment/improve face-to-face education through blended learning, continuous assessments, and personalization. Examples include Coursera and GetSmarter.
- **Reskilling/enterprise learning.** Diverse online learning models can facilitate continuous reskilling, respond to evolving business needs, and enable learning throughout a person's productive life. Examples include Digital House and Platzi.
- **Links to jobs (assessments/credentials).** Innovations in service delivery can include employers in the design and financing of training programs so that courses are relevant and facilitate transition to jobs, giving employers access to specialized skill sets, and overcoming talent shortages. AI tools help companies assess skill levels and predict the future performance of job candidates in order to recruit better-suited employees. Examples include Andela, Scoutible, and the Google IT Support Professional Certificate by Coursera.

education systems and presents opportunities to augment traditional learning experiences by making possible continuous assessments, just-in-time learning, and expanding the portfolio of lifelong learning opportunities. There are multiple initiatives expanding access to low-cost higher education in Africa, such as UNICAF—an online platform that is dedicated to making higher education accessible to African professionals and young school leavers.

Another example is Nafham—a MENA-based online kindergarten-to-grade 12 provider. Nafham, a crowdsourced educational platform linked to the mandated public curriculum, provides 5- to 20-minute crowdsourced videos that are revised by professionals. For example, Nafham offers Syrian curriculum to refugee children out of school in Syria. Similarly, organizations such as onebillion.org (one of the finalists for Elon Musk's \$15 million XPrize) and Open Learning Exchange in Africa have emerged in recent years to develop tech solutions that promote literacy and numeracy skills.

How is the Disruption of Education Through EdTech Achieving Scale and True Development Outcomes?

Basic education. Poor connectivity, weak technology infrastructure, and implementation problems have often limited the impact of EdTech. Impact evaluations so far have shown large variations in the results of technology-centric education interventions, particularly those that rely heavily on hardware (for example, the One Laptop per Child program). However, there are promising results coming from solutions that help adapt instruction to individual student needs. The evaluation of a computer-assisted program (Mindspark) in India showed that it can increase math and language scores in 90 days. Mindspark is an “interactive software and includes continuous student assessment alongside instructional games, videos, and activities from which students learn through explanations and feedback.” EdTech companies are increasingly partnering with academics to use new datasets and conduct large-scale studies to understand their impact.

Tertiary education. The use of education platforms has grown since the advent of Massive Online Open

Courses (MOOCs) in 2013. Through IFC’s investment in Coursera, the largest MOOC provider, we have observed that companies that started with business models designed to make high-quality content available online have matured to develop subscription models for access to premium content, offer certifications that are recognized by employers and other education institutions, and create low-cost master’s degrees in partnership with universities. The field has evolved to create stackable courses in high-demand subjects (data science, business, and technology, for example) that offer students meaningful learning experiences, and signal the development of skills to potential employers. Coursera also developed a platform to help address the complex education challenges of the refugee community through a special initiative that grants financial aid to aspiring students.

What are EdTech Opportunities in Low-Income Countries and FCS?

IFC is supporting a number of EdTech initiatives in Sub-Saharan Africa, and more broadly in IDA and fragile and conflict-affected situations. For example, the World Bank Group, the International Monetary Fund, and the Government of Indonesia co-sponsored the first-ever technology fair that brought innovation to the heart of the 2018 World Bank Group Annual Meetings in Bali, Indonesia. The objectives of the innovation fair were to reinforce the importance of disruptive technology in achieving development objectives, encourage the scaling of private sector solutions to improve educational outcomes, and enable government representatives to take innovative ideas back to their countries. IFC’s proposed Health and Education Impact Platform (HEIP), which is currently being developed, will support EdTech companies that may not generate venture capital-type returns, but still have potential for high development impact (for example, CodersTrust in Bangladesh, Kenya, and India). There are many other examples of promising EdTech in IDA countries and FCS.

Key Lessons and Remaining Challenges

EdTech does not yet present an all-encompassing solution to the education crisis. Studies examining the

link between EdTech and education outcomes have shown inconclusive results.⁸⁷ While EdTech can be a positive supplement to traditional education, and its costs are falling, there is no firm evidence the benefits of EdTech equal the cost of providing students with ICT equipment and developing online courses. Nevertheless, anecdotal evidence from IFC’s investment portfolio suggests that certain business models can provide affordable access on a massive scale, and have potential to positively impact outcomes.

EdTech is a growing market: The global EdTech market (excluding EdTech used by traditional providers) is forecast to grow to \$252 billion by 2020 (17 percent CAGR 2015–2020). This includes investments in education technologies around the world, including those in mobile applications, online courses, distribution platforms, and other tools and products. This also covers the different stages of learning from early childhood through life-long learning.⁸⁸

The distinction between EdTech and non-EdTech companies is gradually disappearing as traditional educators realize that incorporating these innovations is a key determinant of sustainability and a window of opportunity. There is evidence of this transition in Brazil, where the government has made regulatory changes to encourage the use of distance learning programs in tertiary education in order to raise the enrollment rate of 18–24 year-olds to 50 percent by 2024. Moreover, many universities in emerging markets (for instance, in Argentina, Colombia, India, Mexico, South Africa, and Turkey) joined MOOC platforms like Coursera or edX to provide their online courses to students around the world.

As EdTech becomes a more mainstream form of both foundational and skills-based education, five key factors are likely shape the future and determine the speed of the digital transformation in education:⁸⁹

- *Common accreditation standards for digital curricula and credentials.* Common standards will increase the efficiency of learning investments for individuals across formal and informal learning episodes, and will provide more reliable orientation for innovative digital solution providers.
- *Transparency around outcomes.* The new generation of education users will expect clearer outcomes before investing in learning. Conversely,

public and private funders should require more frequent, evidence-based insights on “what works.”

- *Data privacy regulations and IP rights.* Regulations will need to balance privacy rights with potential gains from the broader adoption of personalized, predictive analytics. In addition, sustainable crowdsourcing of digital content will require clearer rules and enforcement of IP rights.
- *Building and strengthening digital capabilities at all levels.* Managing the digital transformation successfully will require new skills and career pathways for both teachers and students, which need to be embedded systematically across education-system entities and institutions.
- *Efficient setup and deployment of secure IT infrastructure and devices.* To drive efficiency and faster adoption of new services and tools, decision-making on procurement and the setup of IT infrastructure will need to migrate from the local institution level to centrally administered cloud solutions.

Looking to the Future

The EdTech field is constantly evolving and there is much to be learned in terms of its impact. As the market matures in the developed world, IFC is building a strong foundation of knowledge about how EdTech solutions could help create EdTech markets and/or systematically expand existing markets to low- and middle-income countries. Through its investments and building in-house knowledge about EdTech over the last five years, IFC has been positioning itself at the leading edge of education.

EdTech is a clear example of how the private sector can be leveraged to achieve development goals, while complementing public investment, which comprises the bulk of resources in education. This approach is consistent with the Maximizing Finance for Development (MFD) framework that seeks to crowd in private sector funding and solutions to maximize development impact. Governments around the world are investing in EdTech solutions to equip their teachers with smart tools to improve learning outcomes at scale, and reach students in remote locations. Examples include Geekie, which offers adaptive learning solutions to public and private schools in Brazil, and the comprehensive approach of Plan Ceibal

in Uruguay. There are also a number of EdTech projects in Africa to improve reading and numeracy, and in the Middle East to cater to the needs of refugee populations. Such approaches are especially promising in IDA countries and FCS where the needs are greatest. ■

BOX 9.2 EdTech in Kenya

iMlango, Kenya's pioneering eLearning program, is a comprehensive educational technology program designed to improve Kenyan students' learning outcomes, enrollment, and retention.

iMlango, which uses technology to help improve education outcomes, was launched in 2014 by Kenya's Ministry of Education, with support from the United Kingdom's Department for International Development and several technology and courseware partners.⁹⁰ The program features online mathematics courseware and a data collection system that adapts to the learning level of individual students, while at the same time monitoring students' progress.

Within two years of launching, iMlango was operating in 205 primary schools in four counties, and had enrolled around 150,000 pupils. One distinctive feature of the project is real-time monitoring of attendance and individual progress in math. Teachers benefit by gaining e-learning tools that support the curriculum, generate new ideas, and encourage the teaching community to share these. The program uses a train-the-trainer model whereby the first batch of teachers that learn the application go on to train others in their schools.

The project has impacted local communities by providing Internet access during off-school hours, and parents report that their children are more enthusiastic about attending school. However, despite real-time data collection, little information is available about the platform's impact on math performance. One reason for this is the relative novelty of the intervention. Another reason is that although information and communications technology can complement teaching, there are underlying contextual conditions in Africa—including highly variable and often volatile learning environments—that affect the impact of digital technologies when they are introduced.

CHAPTER 10

FinTech as Disruptive Technology in Emerging Markets

By Simon Andrews and Kai Martin Schmitz

FinTech is disrupting the world of financial services and threatening the traditional business model of banks.⁹¹ Launched on the back of a revolution in connectivity and mobile communications, and with a business model that is innovative and agile, FinTech is providing access to financial services for hundreds of millions of unbanked people in the developing world. All parts of the financial services sector are being disrupted, from payments and remittances to lending, credit scoring, insurance, and savings. FinTech innovation is now as likely to come from developing countries as from developed countries.

What is FinTech and Why Does It Matter?

Broadly defined, FinTech is any technological innovation applied to financial services, including innovations in back-end financial services, financial trading and treasury, as well as the application of new technologies such as blockchain to financial transactions. This chapter focuses on the technological innovations that are changing access to financial services and driving a change in the structure of the banking and financial sectors.

Financial inclusion is critical for sustained growth and shared prosperity. While governments and banks play a critical role in mobilizing capital for infrastructure projects, and support for the growth of large job- and value-creating enterprises, access to finance for micro-economic actors—small businesses, households, and individuals—is at the core of sustained growth and shared prosperity. The ability of households to save for a rainy day, farmers to secure working capital for seed and fertilizer, and individuals to borrow for an education or to buy a house, is a major driver of microeconomic activity, a fundamental source of financial security, and a key to improving livelihoods.

In many developing countries with smaller underdeveloped markets, large informal sectors, and protected banking sectors, access to finance and financial services is restricted to the largest, most secure borrowers in the formal sector. Small businesses, households, and individuals have largely been locked out of the financial system. Unable to save, borrow, invest, or insure, and dependent on cash-based transactions, they are financially vulnerable and largely restricted to informal economic transactions.

In developing countries, 1.7 billion adults have no bank account, and only 21 percent of adults have access to formal financial services (credit, savings, and so on). In IDA countries and FCS, there are more than 550 million unbanked adults, the majority of them in Asia and Sub-Saharan Africa.

The last 20 years have seen dramatic improvements in connectivity, changing the game for the unbanked. The emergence of new technologies and a new level of communications connectivity in most markets has begun to change the equation between the cost of services and reach. The revolution in connectivity spurred by the widespread rollout and adoption of mobile telephony is a “leapfrog” in development.

The advent of 2G mobile phone technology caused the cost of sending data to drop significantly, allowing individuals to use their mobile phones to send and receive information. This led to mobile customers transferring airtime minutes to each other as an alternative form of cash, which they could transfer instantaneously, cheaply, and over a much larger distribution network than traditional cash management and transfer operations.

For example, mobile network operators (MNOs) such as Safaricom in Kenya were quick to spot the opportunity to provide quick, easy, and cheap money transfer services, and they established their own mobile

money networks. This was the beginning of mobile financial technology. FinTech has since evolved quickly from mobile money transfer operations to broader applications that fundamentally challenge—and will ultimately disrupt—the traditional banking model. While FinTech's online scalability and low fixed-cost structure is closing the access-to-finance gap in terms of reach and cost, it is the ability of FinTech to harness the power of Big Data that addresses the information gap.

Large mobile network operators are driving the FinTech revolution. While we generally think of FinTech as the domain of 20-something tech-savvy entrepreneurs in Silicon Valley, Shenzhen, or Bangalore, it is largely the mobile network operators (MNOs), traditional banks, and big-tech platform companies that have been quick to see the disruptive potential FinTech offers and bring it to scale. For example, by leveraging Safaricom's mobile network and its agent network, M-Pesa was able to quickly achieve scale and provide access to finance across Kenya, lifting thousands of households out of poverty.

Another example is Bank of the South Pacific, which is the largest retail and commercial bank in Papua New Guinea, with a nationwide network of 42 branches and 301 ATMs. To develop its retail and SME business, the bank harnessed the power of FinTech to develop digital financial services that allow it to reach customers in remote locations without having to develop an expensive branch network. More recently we have seen big-tech companies move into financial services as they leverage the enormous amount of data generated on their platforms to better understand consumer behavior.

FinTech has transformed three pillars of the financial services industry: transactions and payments; lending and credit; and retail savings, investment, and insurance. FinTech has also been a key driver behind disintermediation of the financial services value chain. While the traditional banking and financial services model was to bundle services and cross-subsidize product profitability, the scale and reach of FinTech has allowed disintermediation with new business models focusing on individual segments of the value chain.

Transactions and payments: Two of the earliest entrants into payments were GCash and Smart, both established by MNOs (Globe Telecom and Smart

Communications) in the Philippines, which allowed users to send and receive money through their mobile and agent networks. The model scaled quickly as it addressed the demand for affordable and convenient money transfers in a country where three-quarters of the population had no access to a bank account, and a large overseas working population was remitting money to families in the Philippines. One of the key lessons from the Philippines' experience is the importance of the physical presence of an agent network, with a regular user of services 40 percent more likely to live within a five-minute walk of an agent.

BKash in Bangladesh is neither an MNO nor a bank. It has built scale instead by building a network of over 80,000 agents. Since its founding in 2011, that network, rather than mobile telephone usage, has driven BKash's success by establishing a customer base of over 24 million users. China's instant messaging platform, WeChat, first started to allow its users to make payments between each other, then included an e-commerce offering in its chat service, and then expanded the payment function to physical stores. In the process, it reached 400 million users in 2017 and processed over \$1.7 trillion in transactions. In some markets, the interface was not entirely digitalized, and agent networks remain a key part of the distribution channel and of customer interactions. The reasons for this are varied and include trust and habit. In the case of the Philippines and Bangladesh, the share of people who hold bank accounts continues to be low. So the primary role of agents in these countries remains to facilitate the conversion of cash to digital money and vice versa. Agents also facilitate so-called over-the-counter (OTC) transactions, which are assisted transactions that also slow the process of full digitalization.

Lending and credit: As e-commerce, Big Data, MNOs, and FinTech companies gather more data about the transaction and payment behavior of online users, they can predict consumer behaviors and assess repayment risk. This behavioral profile has been widely adopted as an alternative to a credit history, and it gives the unbanked the opportunity to establish creditworthiness outside the traditional credit history model.

For example, Guia Bolso, a FinTech company in Brazil in which IFC invested in 2016, uses sophisticated

data analysis to understand its users' income and expenses, provide a financial wellness score, and offer preselected financial products from banks and other FinTech companies. Guia Bolso, which promotes its services mostly on Facebook, grew from zero to 2 million users in its first two years, investing less than \$0.30 per user. Similarly, in less than four years since its launch, Ant Financial, formerly Alibaba's payment platform Alipay, has provided over \$95 billion in online consumer lending and has launched its own credit rating operation, Sesame Credit.

Harnessing the huge amount of data generated by the Internet economy, using it to predict consumer creditworthiness, and sharing it with others raises important questions about cyber-security and data privacy. It is clear from recent high-profile security and privacy breaches that regulators have not kept pace with developments. Much remains to be done to protect consumer data.

Retail savings, investment, and insurance: FinTech is also moving into financial services beyond payments and lending, most notably into insurance, savings, and wealth management products. Kenya's M-Shwari, a partnership between the Commercial Bank of Africa and Safaricom, operating on the M-Pesa network, provides savings and loan accounts to over 4.5 million Kenyans. Similarly, there are numerous examples of mobile insurance platforms, such as Microensure, Bima, and Togo's Freemium.

How to Encourage the Adoption of FinTech

The pace of adoption of FinTech—which is a key determinant of how fast the financial inclusion gap can be closed—has varied across countries. Although FinTech has largely grown out of the mobile telephony revolution and the existence of traditional well-functioning payment systems, the pace of the adoption of FinTech has varied from country to country. There are a number of foundational elements that shape FinTech's broad applicability and have determined the pace of adoption.

First is universal, affordable, and secure mobile connectivity. Building the connectivity infrastructure

capable of connecting almost all the population and delivering high-quality, high-speed, and secure data-transfer broadens the appeal and reach of FinTech solutions.

Second, operators must agree to technical standards that support interoperability, which allows users to interact and transact with one another even though they may be using different systems and networks.

Third, regulators need to adopt new frameworks that 1) cover the use of agent-banking as distributors, 2) establish know-your-customer requirements, 3) enable non-bank e-money issuers, and 4) implement consumer protection that addresses data-privacy issues and cyber-security.

Fourth, users must be able to identify themselves online reliably and securely.

Regulatory sandboxes and pro-active regulations can assist in the adoption of FinTech. Regulatory sandboxes have proven useful in allowing FinTech start-ups to experiment with products and processes in protected environments. For example, Singapore's regulatory sandbox allows for experimentation with innovative FinTech solutions where actual products or services are provided to customers in a controlled environment, under a regulator's supervision.

The sandbox provides appropriate safeguards to ensure that the participating companies comply with legal and regulatory requirements, and if a company fails, the overall financial system is not affected. This helps to provide a supportive environment for safe FinTech experiments and allows the regulator to experiment with regulatory changes as the sector rapidly evolves. Proactive regulations are also important in supporting the adoption of FinTech. For example, in Mexico, the requirement to digitize all invoices and tax filings has allowed companies such as Konfio, an online start-up FinTech lender, to offer working capital loans to SMEs using an assessment of the information in the SMEs' filings as a proxy for a credit rating.

As India's digital ID, Aadhaar, and the India Stack illustrate, FinTech adoption is also stimulated by the ability of individuals and businesses to identify themselves online and, as a result, transact securely. India's biometric-based digital identification (ID)

system, **Aadhaar**, has provided digital access to over 1.2 billion people and is the foundation of the India Stack. The latter is a set of applications that allows governments, businesses, startups, and developers to utilize a unique digital infrastructure to interact and transact with one another on a presence-less, paperless, and cashless basis. The presence-less layer is the **Aadhaar** digital ID system, a universal biometric digital identity that allows people to participate in any digital service from anywhere in the country.

The paperless layer is the Digital Locker, which provides online storage of digital records associated with an individual's digital identity, eliminating the need for collecting and storing massive amounts of paper. It also has a digital signature function that allows documents to be executed electronically.

The cashless layer is the Unified Payment Interface that links all the country's bank accounts and wallets, providing seamless digital payments transfers across systems and networks. The consent layer is a system that allows users to digitally share their data with service providers in exchange for easier access to credit, insurance, and other services. When fully operational, the Unified Payment Interface could bring about a major change to the way businesses, individuals, service providers, and others use digital data in their day-to-day operations.

The India Stack has built on the rapid increase in connectivity in India. By the end of 2017, the number of mobile subscribers had increased from 475 million in 2009 to over 1.2 billion, or 93 percent of India's population. **Aadhaar** has seeded 850 million bank accounts, after these bank accounts were linked by their owners with **Aadhaar**'s 12-digit biometric-based digital ID system, and it authenticates 64 million transactions each day. The development of the India Stack has led to the creation of over 80 alternative online lending companies, savings of \$83 billion flowing into online mutual savings products, and a ninefold increase in the data that are driving new products and new applications.

What about data privacy and cyber-security? IFC has led the work on developing the first global “Guidelines for Investing in Responsible Digital Finance” in consultation with more than 40 leading investment

organizations. These guidelines strive to proactively implement the evolving standards of the G20 High Level Principles for Digital Financial Inclusion, and include investor commitments to promote fair and transparent pricing, prevent over-indebtedness, strengthen digital literacy, enhance customer services for problem resolution, and ensure data privacy and security. The launch of the Investor Guidelines took place in June 2018.

Key Lessons and Remaining Challenges

IFC's experience over the past 10 years shows that FinTech is growing worldwide and will play an important role in almost all developing markets. Although the pace of change is rapid, and the sector will continue to evolve quickly, important lessons are already apparent.

Good infrastructure and a good enabling environment are key requirements. The mobile telephony boom in emerging markets in the 2000s happened because mobile networks provided network coverage and affordable access that addressed a huge unmet demand for communication. FinTech and digital finance services hold the same potential to address the unmet demand for finance and financial services.

Realizing potential requires several things, including continual investment in upgrading networks to 3G+ to make networks high-speed in data transfer capacity, universal in coverage, and affordable to use; enabling individuals and businesses to identify themselves securely online—for a transaction to occur, both sides must know with whom they are transacting; more system interoperability and openness, allowing users on one network to interact with users on another network (as the Global System for Mobile Communications Association [GSMA] recently reported, open systems are becoming platforms that drive scale and application integration); and more efficient agent and merchant networks—as the mobile money sector matures, the cost of these networks consume more than 50 percent of revenues.

Regulations are still under development, and can quickly change the dynamics of a sector. In China, for example, person-to-person or peer-to-peer (P2P) lending

grew very quickly from 2010 to 2015, when over 10,000 P2P lending platforms were offering loans online.

China's banking regulator let the sector grow and did not introduce new regulations until 2014, when clear signs began to emerge of an unsustainable bubble in P2P lending, and cases of fraudulent practices arose. China then introduced new regulations in 2015 that reduced the number of lenders to the 3,500 that had achieved some scale and financial sustainability. A second set of stricter regulations was introduced in 2017 that could reduce the number of online lenders to fewer than 100.

Beyond standard consumer protection measures, data driven business models are particularly challenging for regulators. When zero-cost per transaction payment systems are underwritten by the monetization of data, there are many important implications for data protection and privacy, data-offshoring, and competition policy.

The ability to adapt quickly to changing technology and move fast is the difference between success and failure. What is today a company with a first mover's advantage, may be overtaken tomorrow by a younger start-up with better technology or a more innovative business model. For example, IFC made a few early investments in companies that connect small stores into payment networks where consumers without bank accounts could pay utility bills, transfer money, and receive welfare payments. IFC assumed these companies would become the points for the conversion of cash to electronic money in the future electronic payment ecosystem. But as smartphone adoption rates increased, later-generation mobile payment companies did not need these networks, and replaced their services with apps that put payment services onto mobile phones (mobile wallets).

Innovation is as likely to come from the developing world as from the developed world. While Silicon Valley and China have dominated e-commerce, social media and big-tech innovation in FinTech have come from many places—a result of the potential to address huge unmet demands, the parochial nature of financial services regulation, and the leap-frogging experience of many developing countries due to mobile connectivity.

Countries as diverse as Cambodia and Kenya have become leaders in mobile payment transactions and

the model has been replicated in many developing countries. As discussed above, India offers an alternative government platform-driven model that brings ID systems and government services online, and uses a unified payment system to digitally link 800 million bank accounts. In many other countries, including India and China, state banks have been crucial in providing the basic analogue infrastructure for access to bank accounts and financial services, on top of which a digital financial services infrastructure could be built.

Addressing data-privacy and cyber-security is critical. As more data are generated, transmitted, used, and stored, governments and regulators will need to build regulatory frameworks and monitoring capacity to ensure that data are protected. Financial service providers also need to build robust interface and back-office systems to ensure customer data are protected and to minimize the risk of fraudulent digital transactions. While central ledgers have generated trust in the traditional banking sector, emerging technologies such as blockchain, which decentralize verification, have potential to strengthen the security of digital financial services.

Looking to the Future

There are four technology trends that will continue to drive the shift toward digital financial services. First, the cost of smartphones, which will steadily replace cellphones as the main point of mobile connectivity, will continue to fall. The devices will become affordable for most people in most countries. Second, digital financial service providers will have access to an exponentially increasing amount of data that will help them identify customer needs and assess repayment risk profiles. Third, the development and adoption of artificial intelligence will help digital finance services assess data and make better decisions, as well as spot trends and risks early. And fourth, technologies such as blockchain will drive a continued disintermediation of financial services, allowing borrowers, lenders, service providers, and customers to interact with less need for a financial intermediary.

Cryptocurrencies have had a major impact in some parts of the world. This is particularly so in Southeast Asia where there are numerous FinTech companies

using cryptocurrency to solve operational issues or to raise funding via initial coin offerings (ICO). Although these technologies are still in their infancy, and applications are still speculative in many cases, we expect that, over time, blockchain and other cryptocurrency infrastructure, which is currently under development, could become a part of the infrastructure for digital financial services.

How regulators respond to the rise of FinTech is critical. In some markets, financial payments are restricted to licensed banks, which allow the traditional banking sector to maintain its hold on financial services and retard the growth of FinTech. Even in the most progressive markets, regulators will struggle to keep up with the pace of development and find the right balance between allowing FinTech to serve an ever-growing market and protecting consumers from financial fraud and breaches of privacy.

FinTech is disrupting traditional banking models by fostering disintermediation and the unbundling of banks. Banks in most countries recognize the disruptive forces that FinTech is bringing to the traditional banking model. As a result, most banks in developed countries, and an increasing number of banks in developing countries, are adopting FinTech business models as part of their broader digital financial services offerings. However, banks are also encumbered with the legacy of traditional banking—high fixed-cost branch networks, outdated IT systems, and legacy products and processes that slow the adoption of new FinTech products and processes. For these reasons, as technology continues to evolve quickly, banks are likely to be adopters and adapters, while innovation and disruption will come from FinTech.

More fundamentally though, FinTech threatens the traditional banking business model by unbundling products and services. While banks will continue to retain the advantage of cross-subsidizing and bundling products and services, consumers are increasingly aware of FinTech offerings that allow them to compare products and services on a standalone basis. In spite of these developments, banks still remain the main depositories for money and financial data. Because they are regulated, banks also have exclusive access to inter-bank clearing systems and other infrastructure.

New regulations in some countries—notably in the European Union—will require banks to make data and some services available to other financial service providers (called Open Banking in the new Payment Services Directive II of the European Union). This could help FinTech companies compete with banks by giving consumers control over their data—enabling them to decide whether to make it accessible to the FinTech companies they wish to use. Some banks have embraced the role of back-end financial-services providers and have started to offer Open Banking platforms that make various services available through a set of electronic interfaces. For example, the Spanish bank BBVA offers a platform called API-Market that allows other providers to easily and digitally connect to the services BBVA offers to other financial institutions, namely in credit-card issuing and other payment services.

The World Bank Group has a key role to play in promoting open-banking regulation and aiding central banks and regulators with the transition. We are already seeing FinTech companies offering open-banking solutions. In Colombia, for example, such companies are building an open-banking platform that can be used by different banks and will pool banking services such as access to the local clearing house, card processing, and direct debits—all on one open platform. So far, banks in Colombia have been reluctant to engage with open banking, and only a few smaller institutions have signed up. But regulatory pressure may force larger banks to either offer their own open platforms or work with a third-party provider.

Building their own platforms will be a major undertaking for banks because they must create interfaces not only to the services that they run on segregated systems, but also to their core banking infrastructure. They must offer APIs that work seamlessly enough to be attractive to FinTech companies with more modern IT infrastructure.

The rise of big-data in the context of FinTech is a major trend to watch. The large social media, e-commerce, and messaging platforms (“big-data platforms”) will become global forces driving the digitalization of everything, including financial services. They will likely be at the center of the development of FinTech for the foreseeable future.

The concentration of users and data makes it possible to engage with large parts of the population in a very efficient manner. Therefore, Big Data is a powerful tool to accelerate the expansion of financial inclusion. Thus, the ability to sell through platforms and marketplaces will become a critical success factor for financial service providers—banks and FinTech companies alike.

The dominance of the big-tech players highlights the importance of addressing issues such as data-privacy and cyber-security, as breaches could quickly have systemic implications. While big-tech has been the major platform for innovation and disrupting traditional business models, its increasing dominance raises new questions about monopolization and data-dominance.

Is FinTech disrupting capital markets? Until recently, FinTech was mainly focused on the payment, remittance, peer-to-peer lending, and equity crowdfunding sectors. While FinTech in retail financial services has often competed with traditional players by disintermediating them and taking market share, the higher barriers to entry in capital markets mean the rules of engagement are likely to be different. Nevertheless, the role of FinTech in capital markets is increasing, particularly in addressing complex front-, middle-, and back-office problems. These solutions are using technological advances such as artificial intelligence, robotic process automation, distributed ledgers, and cloud technologies, among others, to deliver innovation that was previously hard to achieve.

Wholesale digital solutions are coming of age in capital markets and will help managers focus on delivering superior performance for their firms, clients, and counterparts. Whether FinTech solutions help the front office make better investment decisions through advanced analytics or reduce costs through improved post-trade processing platforms, the opportunities appear vast.⁹² ■

BOX 10.1 How Does FinTech Differ from TechFin, RegTech, and SupTech?

TechFins are established big-data tech firms entering the world of finance, based on their ability to leverage data. TechFins are using Big Data to gain a better understanding of customer needs and behaviors, which allows them to provide tailored financial services.

RegTech is a contraction of “regulatory technology” that was created to address regulatory challenges in the financial services sector. It improves regulated entities’ efficiency in meeting their regulatory compliance requirements. RegTech can also support the regulated entity remaining in compliance by monitoring its financial services operations. For the regulator, RegTech improves the efficiency of data collection, and expands the scope of the data points that could be monitored.

SupTech is a contraction of “supervisory technology” and is the application of digital technology such as software and hardware to improve the efficiency, effectiveness, and scope of financial supervision. These solutions enhance the ability of regulators to capture, process, store, manage, analyze, and distribute data, and act in order to meet their risk and conduct goals.



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Ein Musikinstrument

REINVENTING BUSINESS IN SELECTED THEMES THROUGH DISRUPTIVE TECHNOLOGIES

CHAPTER 11

Disrupting the Gender Gap: How Technology Can Create Opportunities for Women

By Alexa Roscoe

Women have more to gain—and lose—from disruptive technologies and business models.

Because disruptive technologies can offer new pathways to jobs and asset accumulation, women have more to gain from them than men. Properly leveraged, disruptive technologies can help women workers enter male-dominated fields or work on their own terms. They can also help women entrepreneurs close the gender financing gap and gain access to global markets. Conversely, women may be more at risk from these technologies if gender gaps remain unaddressed, and new technologies merely exacerbate the gaps and increase the difficulties that women already face in seizing emerging economic opportunities.

Currently, women face substantial gaps in access to, and use of, enabling technologies. For women to leverage disruptive technologies, they must overcome a substantial digital divide in access to the basic tools of the emerging digital economy. This includes a 10 percent gap in mobile phone ownership and a 26 percent gap in mobile Internet access in low- and middle-income countries, with gaps of up to 70 percent in South Asia.⁹³ Widespread adoption of technologies does not guarantee equal access or usage for women: the World Bank Group Findex database recently found that digital financial services have not closed the gap between men and women with regard to having a bank account. Indeed, old biases are already reemerging in the digital economy.⁹⁴ When women do go online, they are less

likely than men to speak out or use the Internet to look for work.⁹⁵ *The New York Times* reported that women account for only 4 to 6 percent of blockchain investors.⁹⁶

However, when women do gain access to technology, they can overcome longstanding gender gaps.

Once initial barriers are overcome, technology mitigates many of the obstacles to equitable economic participation that women encounter. For example, the proportion of women on online platforms tends to be higher than in comparative employment.⁹⁷ For its publication, *World Development Report 2016: Digital Dividends*, the World Bank Group conducted a survey on microworkers.com, which found that 27 percent of respondents viewed the ability to work at home and to have flexible hours as the primary advantages of working online.⁹⁸ For women in particular, these advantages ranked above earning extra income. This survey finding emphasizes a key potential benefit of disruptive technologies: they can help women work online when their household responsibilities require them to stay at home. Technology can be an equalizer in other ways as well. BCG and Microsoft found that “technology leaders with female founders... achieved average revenues that mostly match or surpass those of male-founded companies.”⁹⁹

Disruptive technologies can have markedly different impacts on men and women.

Technology is not gender neutral. A study on the facial recognition tools of three top firms found that accuracy dropped for

BOX 11.1 Social Media Help Women Entrepreneurs Build Networks in the West Bank and Gaza

In fragile and conflict-affected situations, restricted mobility increases the obstacles that women entrepreneurs already face. Networking and skills building—both critical to the growth of any small business—require mobility. However, when mobility is a challenge, women tend to have smaller business networks and greater need for flexible schedules. IFC has found that disruptive technology can help to address both these issues.

With IFC support, the Bank of Palestine (BOP) implemented a six-month “mini-MBA” business skills development program for women entrepreneurs in West Bank and Gaza, using social media platforms such as Facebook to generate awareness, recruit participants, and share information. More than half of the participants learned of the program through Facebook, which indicates the important role that social media can play in reaching women.

During the program, BOP provided participants with training materials and other online resources on Facebook and the BOP website, as well as other platforms. To address the travel restrictions

between the West Bank and Gaza, BOP conducted video conferences that provided both locations with access to experts.

Facebook and WhatsApp were the two main mediums of communication used by the BOP team, trainers, and the women participants. In their private Facebook group, participants shared business and personal information, queries, business contacts, and recommendations among themselves, and with the bank. Although the training ended in April 2016, the Facebook group remains active, with the women and the BOP continuing to share information and business updates. By the end of 2018, the posted content had received more than 78,000 likes, demonstrating its continuing usefulness to women.

Overall, the program had promising results. On average, participants have accessed 37 new customers, doubled their revenue and profits, and created new jobs. The BOP, in turn, achieved greater recognition of its brand, and an increase in the sale of its financial products.

both people of color and women, with error rates rising to nearly 35 percent for women of color, compared with an error rate of about 1 percent for white men.¹⁰⁰ Gender differences are likely to be reflected both in specific technologies and broader trends of economic disruption.

In an analysis focusing on OECD countries, the International Monetary Fund (IMF) found that women’s jobs are at higher risk of being automated than men’s due to women’s concentration in routine or codifiable tasks—roles that have a 70 percent likelihood of being automated.¹⁰¹ Other research has found that women will be disproportionately impacted in the near future, but more men will be more impacted over the long term as jobs requiring higher levels of analytical skills become automated.¹⁰² However, gender-differentiated impacts are not necessarily negative: IFC’s research on the ride-hailing industry found that women experience both distinct opportunities and challenges from engagement in the sharing economy (see case study below).

Closing gender gaps could spur business and development impacts. According to a 2018 report of the GSMA, an international organization of mobile network operators, closing gaps between men and women’s mobile phone ownership in low- and middle-income countries alone would generate an estimated \$15 billion in additional revenue for the mobile phone industry.¹⁰³ Multiplied across industries and geographies, the opportunity for stronger and more inclusive growth is substantial. Intel estimated that enabling Internet access for an additional 150 million women could contribute an estimated \$13 billion to \$18 billion to the annual GDP of 144 developing countries.¹⁰⁴ This is a fraction of the estimated economic benefit that would result from gender equality. A 2018 World Bank report found that if women earned as much as men, it would result in an additional \$160 trillion in human capital, worldwide.¹⁰⁵

BOX 11.2 Women Entrepreneurs Light the Way

Across the world in emerging economies, lack of electricity takes up a great deal of women's time (for example, gathering firewood for cooking, making fires, and buying kerosene for lamps and maintaining them). Women's lighting and cooking fuel-related chores reduce the time they can spend earning income, and cooking fires and kerosene lamps damage family health, and especially women's health. Consequently, as IFC's experience in India and Africa shows, women entrepreneurs can be a key part of the ecosystem that spurs the adoption of off-grid solar products.

In India, 100 million people have no access at all to grid electricity, and an equally large number still rely on inefficient fuels as their main source of lighting. Despite its vast potential, the market for off-grid solar products in India is severely underdeveloped, with at best a 10 percent penetration rate. This is mostly due to the difficulties of building demand among last-mile customers and ensuring delivery to them. These potential customers typically have low incomes, limited access to information and networks, and are more expensive to serve due to their remoteness.

Lighting Asia/India, part of IFC's Lighting Global program, overcame the challenges associated with last-mile sales by building a market for off-grid solar lighting through focusing on women as distributors and customers. The program partnered with Frontier Markets, a clean-energy-products company, to develop a network of Solar Sahelis made up of self-employed women. These women-run alliances provide access to funds and technical assistance to help village women to improve their lives by starting businesses that sell solar lighting systems.

In 2016, at the end of the 18-month partnership between IFC and Frontier Markets, the Solar Sahelis network accounted for 30 percent of all sales. By the end of 2018, Frontier Markets had sold 115,000 solar lamps and torches and 12,000 solar home-lighting systems—bringing clean, safe, and affordable light to the homes of approximately 630,000 people.¹⁰⁸

The situation in Africa is similar. Over 70 percent of Sub-Saharan Africans living in rural areas have little or no access to grid electricity, and rely instead on solar, biomass, and kerosene for their energy needs.

To improve the power situation, the World Bank and IFC launched the Lighting Africa program to provide modern lighting and energy products to 250 million off-grid people by 2030. As women can serve an important role in achieving this goal, the program engaged an NGO to design an innovative business model that includes women in the solar energy value chain, both as consumers and as entrepreneurs.

Kenya's energy shortfall mirrors that of the rest of Africa, and women disproportionately suffer adverse health effects from it (approximately four million Kenyans die each year from household air pollution). Women also bear the unpaid burden of gathering energy resources, spending up to 20 hours per week fetching firewood.¹⁰⁹

A survey of women in Kenya using off-grid solar products in regions covered by Lighting Africa found that women save about \$10 a month, which they invest in their microbusinesses, and also use to pay off their debts from purchasing solar lanterns and other products.¹¹⁰

In India and Kenya, as women energy entrepreneurs earn more income, they are able to create better lives for themselves and their families.

Case study: Women, ride-hailing, and the sharing economy

Harnessing disruptive trends for development means thinking about disruptive technologies—but also disruptive business models. In “Driving Toward Equality: Women, Ride-Hailing, and the Sharing Economy,” IFC combined data from the ride-hailing firm Uber Technologies with surveys of over

11,000 drivers and riders across six countries, most of whom were in emerging markets.¹⁰⁶ The findings were striking:

- **Women as drivers:** Women drivers faced substantial challenges related to social norms and access to finance and, as a result, they were only a small portion of the total population of drivers. However, they also saw greater boosts in their incomes than

men once they registered on the Uber app. Attracting and retaining more women drivers means addressing safety and security: 64 percent of women drivers cited security as the reason why more women do not sign up to drive. Overcoming these challenges would help grow the ride-hailing market, both due to the increase in available drivers and being able to better meet riders' demands for more women drivers.

- **Women as riders:** On average, across the six countries surveyed by IFC, women represented over 40 percent of riders. Yet women and men had markedly different usage patterns—for example, women used low-cost ride-hailing options such as UberPool more than men, and they took more, but shorter trips to a greater variety of destinations. Importantly, women were also more likely to benefit from increased mobility; for example, just under 25 percent of the women riders surveyed said that ride-

hailing helps them feel more independent, compared with only 18 percent of men. Approximately the same percentage of women said that ride-hailing allowed them to reach locations that were previously out of reach for them. Women riders were also more likely to value the price transparency that comes with ride-hailing.

Opportunities and barriers to ride-hailing varied substantially across markets. In Mexico, for example, where women make up the highest percentage of drivers in the markets IFC studied, there is relatively good support for women drivers. By contrast, in Indonesia, over half of male drivers said they would be unhappy if a woman in the family wanted to drive for Uber. These and other report findings reaffirm the importance of understanding specifically how disruptive technologies and business models impact women, as knowledge is critical to making the case for investing in women.¹⁰⁷ ■

CHAPTER 12

A Technology-first Approach to Climate-Smart Cities

By Prashant Kapoor and Rebecca Menes

According to the United Nations, cities consume 78 percent of the world's energy and produce more than 60 percent of all carbon dioxide. Today, every second person on the planet lives in a city, but by 2050 cities will be home to 70 percent of the world's population, with most of this growth in emerging markets.¹¹¹ The development and mass adoption of climate-smart technologies that are affordable and practical to implement will be essential to making our urban environment smarter, more livable, and more productive. Cities will need to feed, water, energize, mobilize, digitalize, and clean up after themselves in increasingly circular metabolisms. For cities to flourish in independent and sustainable ways, it will take the commitment and creativity of the public and private sectors, as well as local communities.

How do We Define Climate-Smart Technology Disruption in Cities?

Disruptive technologies that dramatically reduce resource consumption and improve air quality will shatter the status quo and lead to rapid societal and economic advances. These new technologies will interconnect people, buildings, and the natural environment in surprising ways, making cutting-edge cities more competitive locations to live and work. Tomorrow's climate-centric cities will value and incentivize technologies that help them meet science-based targets of lower carbon emissions and achieve their commitments to the Paris Agreement. As cities capture data and become more "smart," they will report on their achievements with greater precision, producing ever higher standards for what truly constitutes a climate-smart city.

Which Technologies are Disrupting Climate-Smart Cities?

Producing and Storing Energy. Cities of the future will largely power themselves. Distributed renewable

generation and electricity storage will transform the energy landscape, making dependence on the grid redundant. Widely useable, emerging technologies such as see-through solar cells¹¹² and adaptive solar facades¹¹³ will work particularly well in dense urban settings with limited sun exposure area. Domestic batteries such as Tesla's Powerwall¹¹⁴ will store excess energy so homes rely completely on their own power generation. Blockchain technology¹¹⁵ will support the development of autonomous microgrids that offer "prosumers" the opportunity to sell their surplus energy through peer-to-peer transactional platforms.

Older cities can be retrofitted with fuel cell-powered cogeneration systems¹¹⁶ that generate electricity and repurpose waste heat at the district level. By using high-efficiency, triple-effect absorption chillers, waste heat can be supplied to buildings for space heating and water heating, or to generate chilled water for air conditioning. Buildings that receive their energy supply from district cogeneration systems will not require their own heating, ventilation, and air conditioning¹¹⁷ (HVAC) systems or boilers, resulting in efficiencies of up to 40 percent.

Rooftop, Hydroponic, and Vertical Farming. In the United States, food now travels between 1,500 and 2,500 miles from farm to table.¹¹⁸ In emerging markets, urban farms can help consumers to reduce their "foodprint" by providing them with the opportunity to purchase food grown within their communities. These farms also cut down on the significant fossil fuel consumption necessary for transport.

With hydroponic farming, food can be grown with nutrient-rich water as opposed to soil. This practice ensures higher quality produce with fewer fertilizers, requiring just 10 percent of the water that a conventional farm uses. Vertical farming techniques, where hydroponic farms are stacked inside skyscrapers, are already being used in Singapore.¹¹⁹

Bus Rapid Transport and the Mushrooming of New Mobility Trends. By adopting new technologies and business models, highly congested cities in emerging markets have the potential to leapfrog the transit paradigms established in previous centuries.¹²⁰ Bus rapid transport (BRT), or modern bus systems with dedicated traffic lanes, is a starting point for cities to inexpensively develop mass transit infrastructure. In Brazil, because of its extensive BRT system, the city of Curitiba has roughly three and a half times less car travel per person than a car-dependent city such as Brasilia. Cheaper batteries will allow electric buses to provide efficient, green, and quiet public transportation. And urban planners can reduce parking spaces and use other disincentives to driving, while enabling bike, scooter, and car-sharing programs to sprout, providing a competitive array of accessible options for moving around a city.

Green Urban Communities Connected to Transit. Planning and policy innovation will be critical for green urban communities to take shape and prosper, particularly with regard to the integration of transportation and urban land use planning. In Barcelona, “super blocks” have been designed that combine city spaces into pedestrian-friendly, car-free mini grids.¹²¹ Copenhagen has used a “finger plan” to guide growth along five well-defined, linear corridors separated by “green wedges” with open spaces, water sheds, and ecological preserves. Only compact, mixed-use developments (called transit-oriented developments) have been permitted around train stations to ensure a sustainable urban form.

Attractive, green urban communities located at public transit nodes that combine office, residential, and retail use can be designed anywhere in the world. These mixed-use developments match density to transit capacity, rewarding city-dwellers with less expensive and more environmentally-friendly options, while improving their quality of life.

Efficiency and the Art of Designing, Constructing and Managing Buildings. High-density urban areas that are built using green methods pollute less and are more energy-efficient. Technology already exists to manage the entire lifecycle of buildings, from design to construction to ongoing management. IFC’s free

EDGE software provides building professionals in more than 1,300 cities with an estimate of the extra cost to design a resource-efficient building, showing the payback period through reduced utility bills.¹²² Cities can use EDGE to aim for zero net carbon buildings that optimize passive design features for a particular climate.¹²³ These include natural ventilation, ceiling fans and super-insulated façades, with low-energy heating and cooling systems powered by renewables.

Construction software like PlanGrid¹²⁴ and Procore¹²⁵ enable construction workers to document and assign punch list items to team members through hand-held devices, essentially eliminating paper onsite. Schneider Electric, with its EcoStruxure Building platform, uses sensor-based technologies and the Internet of Things to empower building engineers to connect, automate, and manage their energy environments.¹²⁶

The Possibilities of Sensor Networks and 5G Cellular Technology. Urban innovators now have the possibility to embrace sensor technologies for everything from traffic flows to air and water quality detection and energy management. The price of equipping a city with sensors has fallen from thousands of dollars per sensor a decade ago, to as little as \$100 today, making the technology immediately applicable. For example, as cities convert streetlights to LED lighting, they can add sensors to streetlights.

5G cellular networks can help cities benefit more from sensor technologies by opening higher frequencies in the millimeter wave spectrum (24-86GHz) for high speed wireless communications. Compared to the current 4G network, 5G improves performance along all parameters of mobile networks, including coverage, bandwidth, latency, and cost. 5G networks will have a smaller footprint compared to traditional cellular base stations, shrinking from a full-size switching cabinet to one the size of a pizza box. As cellular operators look for numerous sites to host their small cells, cities can monetize access to preferred locations such as billboards, streetlights, and public WiFi sites.

Data Sharing that Leads to New Urban Insights. The flow of data generated by sensors and other means will revolutionize how policy makers gain insights and make decisions about city services. A vast amount of anonymized data are now available from geospatial

tools such as Google maps, online ride sharing programs, and various software applications.

- Uber is sharing its data through its new digital platform, Movement, which lets cities understand and react to traffic patterns based on raw data from billions of trips.¹²⁷
- Google's Sidewalk Labs uses technology to tackle such urban growth issues as efficient transportation and the high cost of living.¹²⁸
- The World Bank Group's CURB (Climate Action for Urban Sustainability) is a free, interactive scenario planning tool that helps cities improve air quality and reduce congestion.¹²⁹
- Ho Chi Minh City is using artificial intelligence to enforce zoning governance through the use of mobile apps with geospatial data.¹³⁰

Sensors, Sorting, and Smart Bins to Manage Waste. The smart waste collection market is brimming with new technologies that can prevent landfills from bursting at the seams. Ideally, all waste generated by a city should be contained in its borders with the goal of zero output, and reprocessed rather than buried.

Perhaps the most significant opportunity is in state-of-the-art-based sensor sorting, which moves trash through a machine that sorts out as many as 30 types of waste.¹³¹ Other technologies such as pneumatic tube systems that suck trash through high-tech chutes are still expensive for widespread use in emerging markets. Creating liquid fuel products (such as ethanol and diesel fuel) by converting waste to energy has also not yet proven to be profitable. The game changer may be gasification—the conversion of municipal solid waste into energy through combustion or incineration, using the resulting steam to generate electricity. This works on a small scale, reducing transportation costs and

generating byproducts that can be used to create a more circular economy.

Capturing, Storing, and Treating Water. With water becoming increasingly precious, cities will need to take advantage of every opportunity to capture, store it, and return treated greywater to district systems. The wastewater chain can produce energy, heat, and resources as raw materials are extracted.¹³² New technologies can also minimize losses from stressed city water systems, including through sensors and by leak detection robots.¹³³ Parks and plazas can double as runoff collectors for large amounts of water, a practice put in place in Copenhagen.¹³⁴ In hotter climates, green areas and water surfaces can cool an urban area by 10 degrees Celsius compared to a concrete counterpart.¹³⁵

Looking to the Future

Climate-Smart Cities as Living Laboratories.

With all of the technologies available in the future, cities will need to experiment, cross-pollinate, and be entrepreneurial in order to become living laboratories of data-driven design. Decision-makers must ascertain the best solutions that will stand the test of time, and respond with a policy-driven yet entrepreneurial approach that encompasses every major area: energy, water, transit, farming, waste, telecommunications, and green buildings.

As technologies are woven into a single, more densely-knit fabric, climate-smart cities will perpetuate themselves and become the norm. But new technologies by themselves will not be enough. Disruption will be dependent upon the eagerness of urbanites to shed old habits and embrace the possibilities of a world that is more efficient, clean-tech oriented, and viable for all. ■

CHAPTER 13

Leveraging Technology to Disrupt the Microfinance Industry

By Margarete Biallas and Matthew Gabriel Brown

Disruptive technologies and new entrants are radically altering the financial services industry in emerging markets, forcing traditional microfinance business models to adapt, while changing the economics of delivery to benefit the unserved and underserved. This new reality presents both threats and opportunities for the microfinance industry. It also challenges IFC to increase its support for innovative solutions and partnerships that can enable microfinance institutions (MFIs) and banks to reach the underserved at scale. And it necessitates greater coordination with the World Bank Group to foster regulatory environments that encourage innovation and financial stability.

How Do We Define Disruption in Microfinance?

The early years of this century (2007–2010) saw a strong focus on mobile money and payments as mobile phones became more accessible. As the mobile money

industry grew, there was a shift from payments to banking. Accordingly, IFC focused on supporting the development of business strategies that use technology to deliver financial services to the poor, as well as optimize distribution through agents and branchless banking.

Since 2014, there has been significant technological progress and growth of data and analytical capacities in financial services, driving diversification in products ranging from savings, payments, and loans to crop insurance, among others. In addition, there is a greater focus on efficiency, customer service, and customer experience, especially through technological innovation. As a result of technological evolution, digitalization is happening in all aspects of life, from government to the private sector, and is rapidly changing the world:

- Governments are increasingly focusing on digital financial services (DFS) by supporting digital identifications (IDs), and making government payments as well as collections electronically;

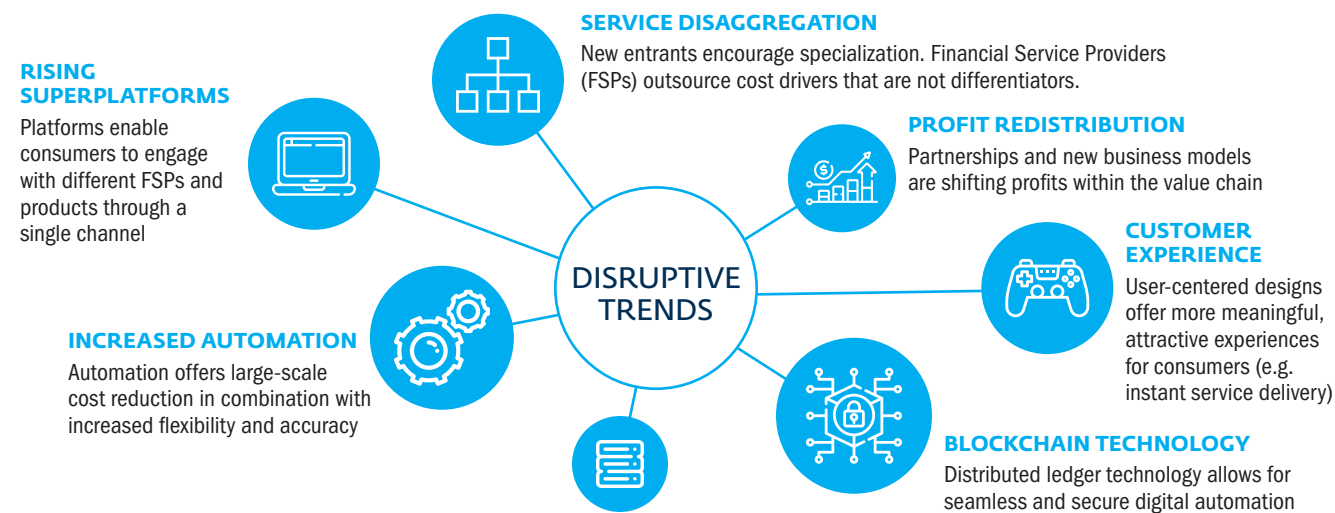


FIGURE 13.1 Technologies Disrupting Microfinance—Several Trends in Technology are Accelerating the Pace of Innovation and Disrupting the Traditional Provision of Financial Services.

Source: IFC

- Banks, insurance companies, and other financial services incumbents are investing in digital platforms, payment technology, and alternative delivery channels, as well as Big Data assessments;
- Different entities and consortia are developing distributed ledgers that utilize blockchain technology.

The microfinance industry is facing disruptive challenges to its model and markets, which are similar to the challenges faced by the broader financial services industry. However, given their cost structure, MFIs tend to be far more vulnerable to such challenges, though they also have greater opportunities to use technology to reduce costs.

Digital inclusion is rapidly expanding, and more people in emerging markets now have access to mobile devices and the Internet than to traditional bank accounts. Digitalization of government-to-person and person-to-government payments presents opportunities for deepening financial inclusion. There is also a demographic shift as members of the millennial generation are digital natives, hyperconnected through social media, and comfortable with simplified and on-

demand services like Grab, an Asian rideshare provider. The shift in demographics, along with economic drivers such as low interest rates and the desire for simplified, intuitive, on-demand, and mostly free customer service, are leading millennials to explore options beyond traditional banking. This too is a trend that can benefit the microfinance industry.

Which Technologies and Policies are Driving Disruption?

Digitalization has the power to transform the financial services industry. Through the disaggregation of financial services, new opportunities and business models are being created.

A radically changing financial services landscape is emerging. Specialized financial service providers or challenger banks are operating with lean structures and without legacy systems, optimizing the use of technology, and focusing on a single service such as lending or remittances—all of which make these services highly efficient. This is most apparent in Asia, where China is leading the digital age and is the most competitive market. With the emergence of superplatforms, or TechFins as they are known, the market is experiencing significant disruption. For example, ANT Financial is now the largest consumer lender in China and is rapidly expanding globally with investments in India, Thailand, the Philippines, Indonesia, and Bangladesh—all in the past 12 months, and putting significant pressure on microlending.

We are seeing similar moves by PayPal, which holds a banking license in Luxemburg and is providing small business loans in Europe, leveraging its data, and offering banking services to selected clients in the United States in partnership with licensed banks. Facebook, through its messaging service, WhatsApp, has already entered financial services and is significantly growing its market share. Facebook provides financial services in India, while also collecting significant amounts of data that could be leveraged to develop lending products for the base of the pyramid—a segment typically served by microfinance institutions.

The rapid evolution of data processing capacity has facilitated new lenders and new asset classes. As a

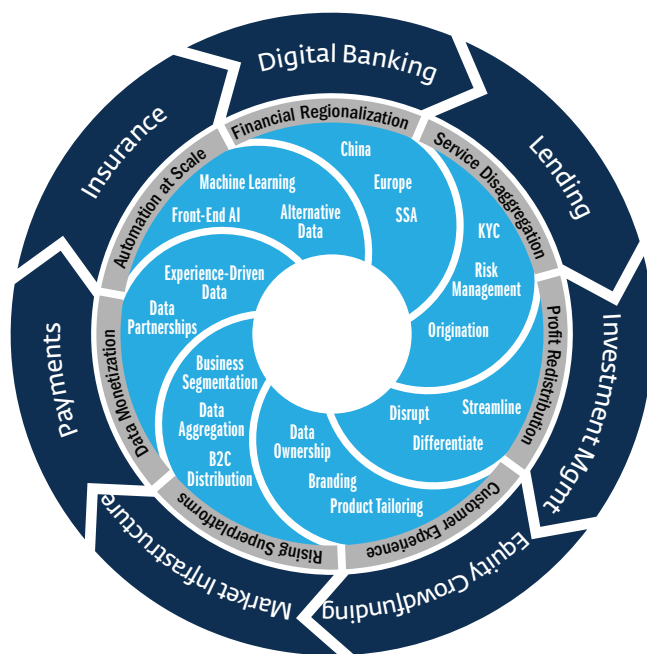


FIGURE 13.2 Financial Services Disaggregation

Source: IFC

result, small loans are much easier to access than just a few years ago, which could displace microfinance lending to the base of the pyramid.

Products and margins will continue to come under pressure, with the most lucrative products targeted first. And while financial service providers have chosen different routes in reacting to increased competition, their common emphasis has been on improving customers' experiences and leveraging partnerships to expand the services they offer. With MFIs and banks increasingly under pressure to stop conducting business as usual, finding good partners is ever more important for them. And in this regard, IFC advisory services and investments are playing an important role in brokering the partnerships that enable financial institutions to digitalize. As technological evolution continues to impact financial services, albeit with a time lag, the time from technological development to proof of concept and implementation is rapidly decreasing.

The key technologies disrupting microfinance are similar to those upending the broader financial services industry:

- Data analytics
- Artificial intelligence
- Internet of Things
- Machine learning
- Digital lending
- Process digitalization
- Digital transformation of financial institutions.

In some markets, additional challenges result from the regulatory environment. In Bangladesh, for example, there are regulatory limitations on the establishment of specialized mobile financial service providers (MFSPs), a situation that has led to protection of one mobile operator whose significant growth is putting pressure on traditional MFIs and banks. Similarly, regulations relating to agents in Kenya initially resulted in an uneven playing field for financial institutions and MFSPs, as the requirements for agents and the use of agents were far more onerous for financial institutions than for mobile network operators. The World Bank Group can assist regulators in understanding as well as fairly regulating emerging services.

How is the Disruption of Microfinance Achieving Scale and True Development Outcomes?

IFC can help MFIs benefit from digitalization in two ways—through partnerships and automation. IFC can leverage its client network to facilitate partnerships between traditional financial service providers and new entrants. This allows financial service providers that are beginning the digitalization process to implement new technology in low-risk and low-cost ways, while providing new entrants with established client bases and operational capacity. IFC can also help its clients to develop their data analysis capacity to automate decision making on loans.

Partnerships. There are several types of partnerships that MFIs can pursue. In general, these partnerships have three key objectives: 1) expansion of the MFI's product offering; 2) broadening of the MFI's reach; and 3) growth of the MFI's assets.

MFIs often expand their product offerings by partnering with specialized financial service providers or FinTechs. This allows MFIs to offer products that they might not otherwise carry such as crop insurance. By partnering with agent networks or providers of mobile financial services, MFIs can expand their reach without expanding costly branch infrastructure. Finally, partnerships with data-rich companies such as fast-moving consumer goods companies can enable MFIs to significantly grow their assets by leveraging the data they have on the creditworthiness of their customers.

Product Expansion. In Papua New Guinea, the MFI MiBank has partnered with BIMA to offer life and health insurance services to its clients. While MiBank distributes these policies, BIMA carries the underwriting risk.

Leveraging MNO Infrastructure. Mobile network operators (MNOs) present a partnership opportunity for MFIs, particularly in fragile and conflict-affected situations and low-income countries. MNOs can often provide the “rails,” or infrastructure that MFIs need to provide more cost efficient services. For example, Musoni, a Kenyan MFI, has reduced the time required to complete a loan application by approximately 80 percent.¹³⁶ Research also shows that if MFI clients have

the ability to repay their loans anytime, anywhere, the quality of the MFI's portfolio can improve by as much as 10 percent.¹³⁷

By partnering with a specialized agent network manager, Caja Sullana in Peru has managed to reduce the operating cost of an outlet from \$5,000 per month to \$500. As the cost for an in-house agent network is just 38 percent of the cost for a branch, and the cost for an outsourced network is 65 percent of the cost of a branch, this has resulted in a 50 percent reduction in transaction costs, and a 40 percent increase in transaction volume.¹³⁸

Automated Lending. It is estimated that approximately 2.5 quintillion bytes of data are produced in the world every day—an amount that exceeds 10 billion high-definition DVDs.¹³⁹ Most of these data are new—90 percent of the world's current data were created in the last two years. This digital data revolution includes the developing world: in 2016 there were 7.8 billion mobile phone subscriptions in the world, with three-quarters of them in developing nations. And far more data are expected in future. As the cost of smartphones falls, mobile Internet access is set to rise from 44 percent of the population in 2015 to 60 percent in 2020. In Sub-Saharan Africa, smartphone use is predicted to rise from 25 percent in 2015 to 50 percent of all connections by 2020.

Everyday objects are also increasingly able to send and receive data, connecting and communicating directly with one another, and through user interfaces in smartphone applications (the Internet of Things, or IoT). While the latter is primarily a developed country phenomenon, there are also examples from emerging markets. In East Africa, for example, there are solar devices that produce information about the unit's usage and repayments made by the owner.

Microfinance institutions can draw from an ever-expanding array of data sources: transactional data, mobile call records, call center recordings, customer and agent registrations, airtime purchase patterns, credit bureau information, social media posts, geospatial data, and more. These emerging sources of data have the capacity to positively impact financial inclusion. Data collection and analytics can improve the business processes of microfinance institutions that serve low-

income households by allowing them to identify and engage new customers more efficiently—especially those previously excluded from the financial system. An example of an MFI utilizing data to grow its loan book is MicroCred Senegal (Baobab), which launched a nano-credit product leveraging data from Orange's mobile phone usage. This helped Baobab grow its loan portfolio by 100 percent over a six-month period.

Key Lessons and Remaining Challenges

It has become clear that going digital is essential for MFIs' survival. The fast pace of technological progress, a growing millennial generation customer base, and emerging FinTech companies looking to enter the microfinance market are just a few of the reasons MFIs must adopt a digital strategy.

However, what does it really mean to go digital? What exactly is a digital MFI? With so many buzzwords thrown around—including blockchain, Big Data, artificial intelligence, and machine learning—it is increasingly difficult to identify the long-term and sustainable assets that can help an MFI remain relevant in the future and continue competing in the financial sector. The two critical elements MFIs should focus on are:

Customer Experience. The importance of customer experience is growing, and only those financial institutions able to understand their customers' thinking will succeed as distributors of their own products. At the same time, there must be an emphasis on digital delivery rather than on extensive branch networks. The focus should be on customer experience and gaining a comprehensive view of customers, which will not only enable MFIs to reduce their costs, but also use customer data to develop suitable products.

Automation at Scale. As new technologies such as AI continue to emerge, financial institutions will need to manage their employees as well as machine-based solutions. The digital revolution presents a great opportunity for MFIs; unlike FinTechs, MFIs are more than a “one trick pony” as they can offer multiple products. Partnerships will likely become a critical success factor; however, to maximize efficiencies in distribution, the infrastructure or “rails” need to be in place.

Looking to the Future

Several key trends in microfinance are expected to continue. These include:

Service disaggregation. Specialized financial service providers such as digital lenders, offering a single product, will continue to expand, leveraging technology to minimize costs. As they face increasing pressure to reduce costs, MFIs are embracing new technologies, working with competitors, and engaging new entrants to both outsource cost drivers that do not provide competitive differentiation and to acquire critical infrastructure.

Profit redistribution. Due to technology and new partnerships, MFIs are bypassing traditional value chains and shifting profits within, and across, the value chain.

Rising super-platforms. These offer the ability to engage with different financial institutions from a single channel, and may become the dominant model for the delivery of financial services in some markets.

Data Monetization. Data are becoming increasingly important for differentiation, so to gain customer insights, MFIs will need to use a combination of strategies to collect the right depth and breadth of data.

Financial regionalization. Diverging regulatory priorities and customer needs are leading financial services in different regions down distinctly different paths.

Banking as a Service (BaaS). For MFIs and banks to survive in the new digitalized market, they will need to reshape their value proposition. BaaS is emerging as a new, efficient business model that can enable MFIs/banks to compete successfully. It represents a shift from building and managing financial solutions to assembling client-driven financial management tools

and related offerings, allowing MFIs to compete in this fast-changing market. BaaS can enable MFIs/banks to shorten their time-to-market and rapidly meet the needs and expectations of their digital consumers. This will require financial institutions to unlock their data and application services to partners, including FinTechs and other third-party developers, through standardized and open-application programming interfaces, as well as plug-and-play applications. Within these new emerging platforms MFIs/banks will not be the actual owners of the customer experience and relationship, which is a radical departure from their traditional business model.

On the downside, rising debt levels are rapidly becoming a concern. As lending is increasingly digitalized, a key challenge will be to ensure responsible lending, and avoid structural disintermediation. The latter is a phenomenon currently observed in Kenya, which has been the leader in the digital credit ecosystem, with more than 20 digital credit deployments (as of 2018),¹⁴⁰ and more than 4.7 million Kenyans taking digital loans.¹⁴¹ However, many of these borrowers were first introduced to formal borrowing through this digital channel, and they may not have fully understood the terms and conditions of the loans. As a result, some 2.7 million borrowers in the country are now negatively listed with the Credit Reference Bureau.¹⁴² Instead of building positive credit histories, half of the digital borrowers are now characterized as defaulters. IFC, together with likeminded investors, has developed “Guidelines for Responsible Investing in DFS,” as we believe that as investors, we can influence the evolution of the industry and enforce minimum standards related to fair and transparent pricing, as well as informing clients of the terms and conditions of products, and ensuring their data privacy.¹⁴³ ■

CHAPTER 14

Disruptive Technologies Expand Housing Finance in Emerging Markets

By Friedemann Roy and Srijan Kaushik

Mortgage markets in emerging markets are tiny. In most of these markets the mortgage-to-GDP ratios—a measurement of market penetration—are in the single digits, whereas in advanced economies these ratios reach 60 to 70 percent. Growing populations are increasing the demand for housing in emerging markets, and especially so in rapidly urbanizing areas. Within two decades every second person in emerging markets will live in a city.

The households with the greatest demand for housing belong to the low-income (or affordable) segment. Their incomes are a combination of formal and informal sources. In Indonesia, for example, 60 percent of the population has an informal income. Whereas many in this group could afford a housing loan, banks have shied away from providing them as they consider the risks to be too great. Additional impediments include weak titling and enforcement structures.

In India, however, specialized housing finance companies (HFCs) have managed to penetrate the affordable segment by implementing innovative lending models driven by intensive use of technology and data analytics. These are used to assess borrowers' repayment capacities, predict the probabilities of loan default, and optimize operations.

In other emerging markets such as Brazil and South Africa, lenders have implemented FinTech elements into their operations. Creditas, a Brazilian financial technology firm, focuses on secured consumer and mortgage loans and uses innovative credit scoring systems and borrowers' assets to offer loans. It funds loans using capital from investors or through partnerships with other traditional financial institutions. Customers apply for loans through the Creditas website. In December 2017, the loan portfolio amounted to the equivalent of \$100 million. The percentage of loans in default was just 1 percent.¹⁴⁴

South African-based Select Africa relies on technology to enhance overall operations performance. The company operates in six African countries, offering

housing and incremental building loans, and to date it has originated nearly 33,000 loans.¹⁴⁵

How Do We Define Technological Disruption in the Housing Finance Sector?

Mortgage finance for low-income households is a mass business. Besides a thorough understanding of the market dynamics and legal conditions, successful operations rely on the application of information technology and business analytics to achieve operational excellence and cost efficiency.

Operational excellence is defined by a low turnaround time, or TAT (the time to approve a loan application), a high conversion ratio (the number of loan requests approved), and the ability to scale the business model. An institution is cost efficient if transaction costs are minimized by managing the operations, deciding on loan requests, and minimizing delinquent borrowers.

Which Technologies Are Disrupting Housing Finance?

Lenders in emerging markets focus on two areas to disrupt traditional lending models. First is **the use of technology for data collection and management**. Instead of using handwritten applications, a lender's staff collect data through smartphones or tablets, running installed loan software. All documents supporting the application are scanned as images. Thus, loan files only exist in electronic format. Once client data are entered, the loan software performs initial creditworthiness assessments, initiates requests to the credit bureau, and performs identity verifications. Collected data also feed into the lender's own credit scoring systems.

Second is **the use of data analytics to support the underwriting decision or loan approval**. Lenders deploy

their own data models to identify creditworthy clients based on probability-of-default models and minimum approval criteria. The data inputs are converted into a score that indicates an approval, a rejection, or a recommendation for further scrutiny.

How Is the Disruption of Housing Finance Achieving Scale and True Development Outcomes?

Over the last 10 years, HFCs have disrupted the market for low-income housing finance in India by combining traditional microfinance methodologies (for example, on-site visits) with the use of digital tools to allow faster processing of loan applications and better prediction of default probability. HFCs specialize in providing housing loans to individuals, however, some HFCs provide loans to developers and have a license to collect deposits. HFCs finance their operations through credit lines from banks and the National Housing Bank (NHB), a subsidiary of the Reserve Bank of India, as well as bond issuances. The NHB is the regulator, promoter, and financier of the HFCs, which consist of traditional HFCs servicing middle- and upper-income households, and Affordable HFCs (AHFCs) serving low-income, urban, and rural informal customers. The loan book of the AHFCs grew from the equivalent of \$160 million in 2013 to \$4 billion in 2017, facilitating ownership of more than 200,000 homes.¹⁴⁶

The affordable housing market is considered a high growth area in India. According to recent estimates, the segment has the potential to grow to \$600 billion over the next 20 years. As in other emerging markets, the demand for housing and housing finance in India, is driven by population growth, urbanization, and changing housing preferences. According to McKinsey, about 40 percent of India's population will live in urban areas by 2030.¹⁴⁷ This rapid and unplanned urbanization, coupled with a lack of affordable housing, has led to a shortage of 19 million urban and 11 million rural homes. Some 96 percent of this shortfall is in the low-income housing sector. Most households in this sector do not have a verifiable income. In response to the situation, the government of India launched the "Housing for All by 2022" vision aimed at stimulating the supply of 60 million homes

through investments of over \$2 trillion, or about \$250 billion to \$260 billion annually.¹⁴⁸

Mortgage lending has experienced dynamic development in India. By the end of September 2017, housing credit amounted to \$235 billion. The market share of HFCs accounts for about 41 percent. In 2019, a growth of 16 to 18 percent is predicted. In the last few years, HFCs have experienced higher growth rates than banks because of HFCs' superior service levels and focus on the affordable segment.

TABLE 14.1 Comparison of the Performance of Financial Institutions in India (as per 2017)

2017	HFCs	Banks	Small banks	MFIs
TAT in days	25 to 35	7 to 20	10 to 15	10 to 15
Cost-to-income ratio	18.3	40.8	66.3	72.9
ROE	18.40%	5.10%	12.90%	9.80%
NPL ratio	1.15%	9.32%	5.60%	11.05%

Source: Vinod Kothari Consultants (VKC). 2017. "India Housing Finance Report, 2017." See also CEIC. 2018. "India Non-Performing Loans Ratio"; and Motilal Oswal. 2017. "PNB Housing Finance."

Table 14.1 provides an overview of the performance of different financial institutions in India. Whereas HFCs have a longer turnaround time, they record lower cost-to-income ratios and nonperforming loan ratios (NPLs). Additionally, their return on equity (ROE) is the highest in the industry. However, HFCs have managed to decrease their TATs significantly (Table 14.2). On average, the TAT of two HFCs fell by about 30 percent. The market shows a similar trend at other AHFCs. The AHFCs' loan book grew on average by 34 percent in the same period. For example, the HFC Aadhaar grew its loan book from \$14.4 million in 2012 to \$385.6 million in 2017.

TABLE 14.2 TAT of Selected AHFCs (2012–2017)

	2012	2017	% age change
Aadhaar	51	35	-31.4%
MHFC	123	88	-28.5%

Source: "India's home loan GDP ratio only 5%." Livemint.com, Sept 13, 2007.

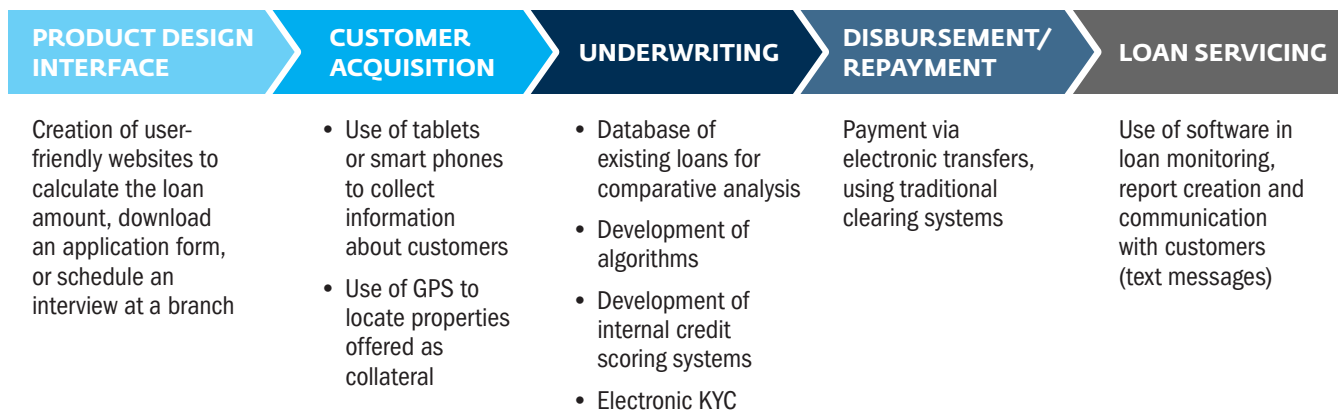


FIGURE 14.1 Typical Areas of Technology and Data Analytics Applied to Support Underwriting and Servicing Processes in Mortgage Lending in Emerging Markets

Source: Friedemann Roy

How Does Housing Technology Differ in Emerging and Advanced Economies?

The trend toward digitalized loan offerings, underwriting, and servicing is at an early stage in the housing finance industry in emerging markets. At present, a fully digitalized mortgage lender such as Rocket Mortgage (operated by Quicken Loans in the United States) does not exist in any emerging market.

Figure 14.1 illustrates areas of technology and data analytics applied to support underwriting and servicing processes in mortgage lending in these countries. To date, lenders have mainly concentrated on underwriting and the overall administrative process. Obstacles to digitalization include incomplete land registries, as well as the personal interviews of applicants needed to determine their likelihood of repayment.

Key Lessons, Remaining Challenges and Binding Constraints

Since the Indian housing and housing finance market has many features similar to other emerging markets (a significant share of informal wage earners, a poor enabling environment, and limited access to long-term funds in local currency), it provides a good example for lenders and regulators in other emerging market countries for disrupting their own housing finance

markets. Critical elements that are relevant to other emerging markets are:

1. **Benign economic conditions and supportive government policies.** India has enjoyed growth rates that expanded its middle class and demand for housing. The Indian government has implemented several measures to improve the enabling environment. Additionally, as expressed by the “Housing for All by 2022” vision, the government is committed to increasing affordable housing. Another supporting factor in India is the NHB, which is a regulator, promoter, and financier of the HFCs.
2. **A focus on the specifics of the informal (affordable) income segment.** The HFCs have brought a product offering and an income assessment methodology to the market, which takes into consideration the needs, capacities, and preferences of low-income households. The income assessment is a combination of the traditional microfinance methodology (such as on-site visits) and reliance on standardized interview techniques to evaluate an applicant’s repayment capacity. Another critical factor has been a considerable level of diligence in the technical and legal reviews of the properties offered as collateral. Technology has contributed to the income assessment methodology by creating tools (such as credit scoring and comparable analysis of income information) that enable rapid deselection of non-creditworthy applicants.

- 3. Reducing the processing time of loan applications and maintaining high levels of customer service.** Short TAT times are critical to competition and are important for processing a greater volume of loan applications. The deployment of technical tools allows for rapid transmission of data and borrower information, as well as deselecting non-creditworthy borrowers as early as possible.
- 4. Managing operational costs.** Once management decides on the market entry strategy and the target market, a rigorous cost management strategy is applied to keep operational costs under control. All HFCs have invested considerable amounts of capital to automate processes, to accelerate the credit appraisal process, and to facilitate loan portfolio monitoring.
- 5. Managing funding costs.** HFCs have focused on regular access to long-term funds at low cost to manage interest and liquidity risk, and offer attractive prices to customers. The involvement of the NHB, with its offer of specific long-term

funding lines, and an interest rate below market, has helped all HFCs to lower their funding costs.

HFCs have decreased their funding costs in a dialogue with investors by emphasizing the robustness of their business models, maintaining multiple bank relationships, and accessing funds from development finance institutions. Another factor has been the issuance of bonds in capital markets, which allow HFCs to obtain a credit rating and attract additional investors.

Looking to the Future

Similar to the housing market in India, there are large unbanked segments in most emerging markets that are not served, or are underserved, by traditional lenders. Indian HFCs, however, have demonstrated that with the support of technology and data analytics in loan operations and credit analysis, a viable and profitable business model exists to successfully tap into the underserved market segment. ■

CHAPTER 15

E-Logistics: The Click of a Button Can Change How Goods are Transported

By Shruti Chandrasekhar

Logistics is an inherent cost of doing business.

It is the backbone for industrial development in emerging markets—as these develop and grow, so does the need for movement of goods. As emerging economies transition and domestic consumption becomes an increasingly important driver of growth, connecting small and medium enterprises to markets beyond urban areas has not kept pace due to a lack of modern logistics.

When logistics is inefficient, costs increase. This spills over to the prices of other goods and services, with economy-wide implications. These inefficiencies are more pronounced in emerging markets. Advanced economies spend around 8 percent of GDP on logistics, while emerging economies spend more than twice that amount.¹⁴⁹ A primary reason for these inefficiencies is that long-haul logistics often account for the largest share of the logistics market—in China, for example, it is 80 percent.¹⁵⁰ And long-haul logistics in emerging markets primarily relies on road transport, which is inefficient, expensive, prone to delays, and vulnerable to various externalities such as traffic, lack of transparency, manipulative intermediaries, less use, and more idle time.

Trucks in China are four times less efficient than those in the United States. Much of this inefficiency results from an extensive set of intermediaries that facilitate connections and transactions between drivers and shippers. In India, trucks are used only 33 percent of the time, as shippers large and small find it challenging to source available trucks without going through several levels of brokers and other intermediaries. This has led to most companies choosing to work with transporters who can aggregate trucks for them. Transporters, in turn, maintain a roster of regional and local brokers to help them access local truck owners and drivers. This has resulted in an inefficient system, with significant value lost through the various layers between shippers and truckers.

Truckers ultimately pay the price for the market inefficiencies

that increase the cost of logistics. In markets as varied as China, India, Brazil, and South Africa, truckers earn very little.

Technology Can Disrupt Logistics

IFC has analyzed potential solutions that can reduce logistics inefficiencies and disrupt complacency in the market. One of the most effective (and relatively simple) solutions is an Uber-like platform that is used in China, India, and Brazil, and is starting to operate in Kenya, Nigeria, and other markets. These digital platforms enable truckers and shippers to find each other and transact directly. With these platforms, shippers can source truckers from a massive network of independent truck owners, and disintermediate the brokers and transporters. With 82 percent of the Chinese population and 53 percent of the Indian population using smartphones, almost all truckers own a phone and can access the platform.¹⁵¹

Case Study

IFC's first investment in this space was made in 2016 in a company called Truck Alliance in China that built an online marketplace. Truckers using this app saw a 35 percent increase in their incomes, while shippers saw a 15 percent decline in their costs. These results were due to the elimination of intermediaries who consumed some 50 percent of truckers' earnings, and a reduction in idle time, which effectively increased utilization and productivity. An added benefit of reducing empty trucks on the road is reducing greenhouse-gas emissions. Since then, Truck Alliance has saved over \$5 billion in gasoline costs and prevented the release of over nine million tons of CO₂. Around 60 percent of the trucks in China were on the Truck Alliance platform before it

merged with its second largest competitor in 2017 and became the “go-to platform” for truckers in China.

In 2017, IFC invested in a similar company in India called Blackbuck, with a business model better suited to the Indian market. Blackbuck provides similar benefits to shippers and truckers as the Truck Alliance platform. And both platforms have expanded

their support features to include discounts on fuel, truck repairs, toll cards, and insurance plans. These innovative technologies have increased productivity, lowered the overall costs of logistics, enhanced truckers’ incomes, reduced greenhouse-gas emissions, and supported many other benefits—all through use of a smartphone.¹⁵² ■



CHAPTER 16

Digital Identification for Development Creates New Business Models for Private Enterprises in Emerging Markets

By Julia Clark, Seth Ayers, and Vyjayanti Desai

In order to participate in many social, economic, and political activities, individuals require some way to prove who they are. Without government-recognized proof of identity, access to education, formal employment, financial tools, social assistance, voting, and many other essential rights and services—which those with identification take for granted—is either impossible or severely inhibited.

Despite the importance of identification, one billion people around the world,¹⁵³ and 38 percent of the eligible population in low-income countries,¹⁵⁴ lack any form of government-recognized identification, and are essentially not persons in the eyes of the law. This gap disproportionately affects the poor, marginalized women, children, rural residents, and individuals in Asia and Sub-Saharan Africa. In Sub-Saharan Africa, roughly 500 million people—or half of the region’s population—cannot prove who they are.¹⁵⁵

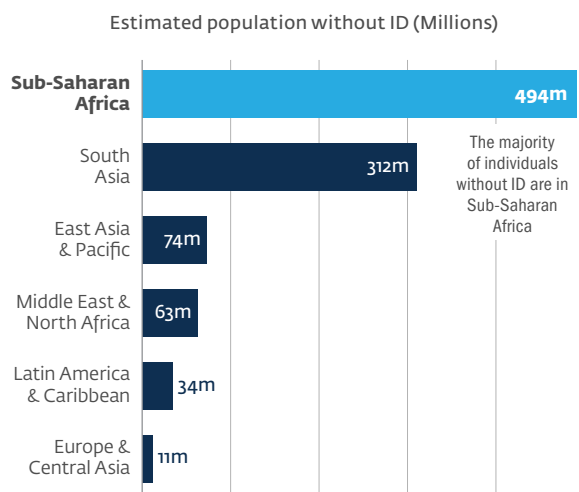


FIGURE 16.1 Identification in Sub-Saharan Africa

Source: World Bank Group - Identification for Development (ID4D). 2018. “Global ID4D Dataset.” World Bank, Washington, DC

Similar to the infrastructure and investment gaps that constrain development in emerging and developing economies, the “identity gap” prevents access to the services and opportunities that would allow people to achieve higher living standards, and so increases their risk of being left behind. For example, some 57 percent of adults in Africa do not have a bank account, and 63 percent of women lack one. In a survey of the unbanked in Africa, over a quarter of respondents indicated that lack of necessary documentation was a barrier to obtaining an account.¹⁵⁶

Improving ID systems should be a primary component of development policies, rather than an afterthought. Governments, the private sector, and donors should work together to provide identification to all,¹⁵⁷ and in the process improve social and economic inclusion, and the efficiency of many programs.¹⁵⁸

For all these reasons, the provision of identification is the aim of Sustainable Development Goal 16.9, endorsed by the United Nations General Assembly in September 2015: “By 2030, provide legal identity for all, including birth registration.” To align with this SDG target, as well as with other SDG targets for which identification can accelerate progress, the World Bank Group has launched the “Identification for Development” (ID4D) initiative to enable all people to exercise their rights and access services.¹⁵⁹

How Do We Define the Disruption of Digital Identification in Emerging Markets?

Identification is more than just a technical problem for a development program to solve. The ability of individuals to prove their identity is a central

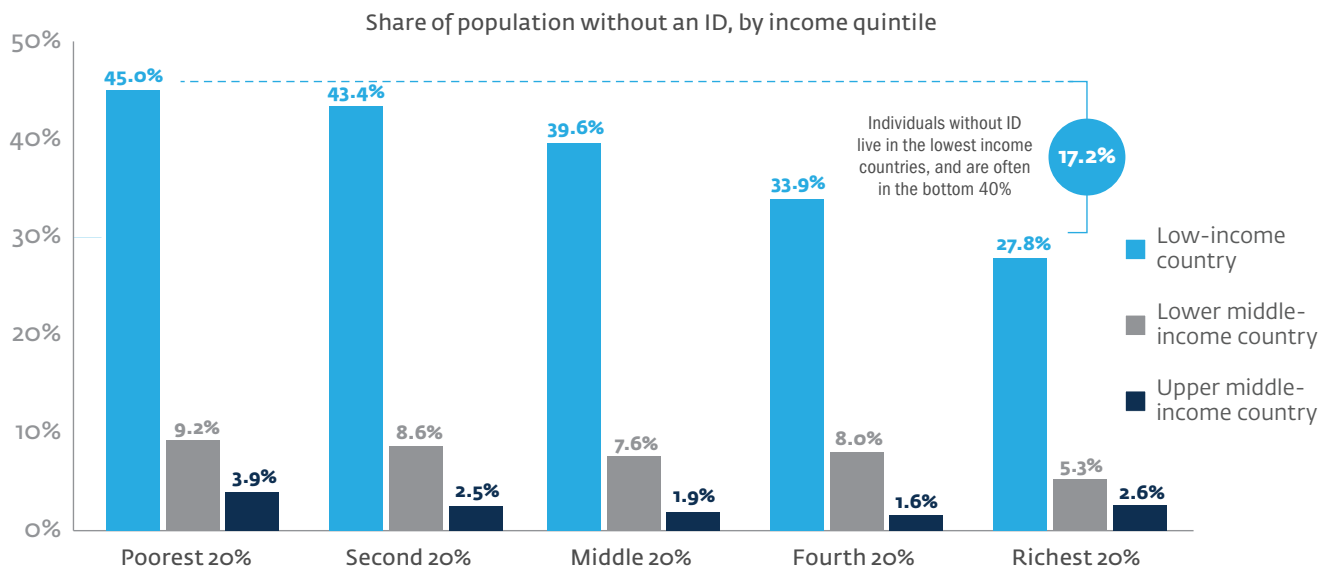


FIGURE 16.2 Individuals without an ID

Source: World Bank Group - Identification for Development (ID4D). 2018; “Global ID Coverage by the Numbers: Insights from the ID4D-Findex Survey.” World Bank, Washington, DC.

component of development policy itself, and will remain so until the majority of individuals in emerging markets can verify their identities.

Whether nations are improving and enhancing existing ID systems or building ID systems from scratch, technology will be central to these efforts. While individuals in advanced economies can rely on a birth certificate, utility bills, or a driver’s license to prove their identity, these systems are often non-existent or limited in emerging economies. However, new technologies such as mobile communications can leapfrog traditional paper-based systems, and quickly roll out and scale up low-cost identification systems, and make proving identity easier, less expensive, and more accurate.

Which Technologies are Disrupting Digital Identification?

There are multiple authentication and credential technologies that could alter, improve, and disrupt the way individuals in emerging and developing nations prove their identity in face-to-face and online contexts. Many of these technologies are available or already in use and are increasing convenience and efficiency.

Biometrics. Biometric recognition uses an individual’s unique physiological or behavioral attributes to establish uniqueness and authenticate his or her identity. Physiological attributes include fingerprint ridges, iris patterns, and facial characteristics; behavioral attributes include gait, signature, keystroke patterns, voice pattern, and even mouse usage.

In the biometric category, fingerprint, face, and iris capture and recognition technologies continue to evolve the most rapidly, though other technologies show promise, too.

Since its launch 2010, India’s Aadhaar program has enrolled 1.2 billion residents and issued them unique identity numbers. The speed by which near-universal coverage was achieved—especially compared to the experiences of other countries—is largely a result of Aadhaar’s simplified design and process. It collects only a few biographic data fields, and does not provide proof of citizenship or legal status. It allows any holder to reliably and quickly authenticate their identity using fingerprints, iris scans, or one-time passwords through SMS text messaging. The ease of authentication through Aadhaar, combined with simplified customer due diligence regulations and expanded banking

agent networks, have helped India increase its level of financial inclusion from 35 percent in 2011 to 80 percent in 2017, with the most significant gains for women and the poor. Aadhaar has also enabled the Indian government to achieve considerable savings by eliminating “ghost” beneficiaries.

Mobile Solutions. Globally, the rapid proliferation of smartphones, fast improving wireless network capabilities, and the adoption of cloud technologies have created new opportunities for the public and private sectors to develop easy-to-provide and easy-to-use mobile identity solutions. For instance, the governments of Estonia and Moldova have partnered with mobile network operators to deliver mobile authentication services to eID cardholders. In each case, the mobile companies issue users a public key infrastructure-enabled SIM, and then charge a per-use fee when they use a digital signature to prove their identities for eGov and other online services. Similarly, Mobile Connect, the Global System for Mobile Communications Association’s solution, leverages the reach and inherent trust in mobile networks to enable customers to create and manage a digital identity via a single log-on on their mobile phone.

Across many developing countries, rapid increases in mobile adoption, falling mobile phone prices, and improvements in mobile connectivity mean that increasing numbers of people can access the mobile Internet and other digital services that allow them to register, prove, and verify their identity. Projects indicate that there will be 4.8 billion biometrically-enabled smart mobile devices by 2020.¹⁶⁰ As these devices become more portable and less expensive, remote populations’ access to digital identity and identity-linked services (such as mobile money, health services, or social protection) are expected to increase. For example, in Tanzania, efforts are underway to use mobile technology to increase birth registration by making it more accessible, affordable, and inclusive.¹⁶¹

Self-managed identity, including blockchain. It is critical that people have full control of their digital identity, including the ability to manage how and when their personal data are shared, and with whom. While such approaches depend on a change in mindset and overall architecture, technologies such as blockchain

are being explored by a wide range of governments and firms around the world as a tool to facilitate self-managed identity. One of the key benefits of blockchain is that there is no reliance on a single intermediary or authority to manage records, and these records are portable and immutable.¹⁶² However, in order to be relied upon for many real-world transactions, any identity on the blockchain still depends on authoritative sources such as government-issued identification. Likewise, blockchain for identity is still unproven at scale, and existing approaches have not yet addressed the challenge of establishing the uniqueness of an individual across a decentralized network, which is often required for many services. Mobile applications and hardware technology such as Fast Identity Online (FIDO) and Mobile Connect are also being leveraged to provide greater control to end users. The World Bank Group’s ID4D will carry out an Innovation Challenge in 2019 to pilot new approaches to provide people in developing countries with greater control over their digital identity, as well as new approaches to achieving “privacy by design.”



FIGURE 16.3 Principles on Identification for Sustainable Development: Toward the Digital Age

Source: World Bank Group. 2018. “Principles on Identification for Sustainable Development: Toward the Digital Age.”

Looking to the Future

Going forward, private firms have a large role to play in offering or utilizing the digital identification systems that are becoming publicly available in emerging markets. In order to transact with customers, companies need to verify and authenticate their customers' identities. Because of anti-money laundering and counter terrorist financing regulations, this is particularly true for mobile network operators and enterprises that offer banking and financial services.¹⁶³

However, while disruptive technologies might deliver significant benefits to emerging economies rolling out identification systems, they may not be economically feasible—or appropriate—in all situations. Contactless smart cards, for example, may be too expensive for some governments and populations to implement, or may not be necessary for certain applications.

Mitigating the risks associated with exclusion and privacy is central to fully realizing the transformational

potential of identification systems. As of September 2018, the World Bank Group's *Principles on Identification for Sustainable Development*, which have been endorsed by 25 international, philanthropic, academic, and private-sector organizations, offer a guiding framework.¹⁶⁴ As digital identification systems become more widely used, it is essential that countries introduce robust legal and regulatory frameworks around data protection and establish independent oversight authorities to enable people to seek redress.

Public- and private-sector cooperation will accelerate progress toward robust and trusted ID systems around the world. As more countries seek to federalize or decentralize their ID systems, and particularly the authentication functions, the private sector has an opportunity to provide such services and to drive innovation that makes the use of digital ID systems more convenient, reliable, and secure. ■

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FURTHER READING

Additional reports about the role of technology in emerging markets, as well as a list of EM Compass Notes published by IFC Thought Leadership: ifc.org/thoughtleadership



Blockchain: Opportunities for Private Enterprises in Emerging Markets

January 2019 (Second and Expanded Edition) – 88 pages

Over the course of two years, IFC worked with key influencers and experts in the worlds of distributed ledgers and digital finance to create a series of nine papers examining the potential and perils of blockchain. An initial report with six chapters was published October 2017. Since then, three additional in-depth notes have been added to broaden and deepen our understanding of this burgeoning technology, its enormous potential, and its many challenges. These documents collectively examine the general contours and technology underlying blockchain and its implications for emerging markets.

Specifically, this report provides an examination of blockchain implementation in financial services and global supply chains; a regional analysis of blockchain developments in emerging markets; and a new focus on blockchain's ability to facilitate low-carbon energy solutions, as well as a discussion of the legal and governance issues associated with the technology's adoption.



How Technology Creates Markets – Trends and Examples for Private Investors in Emerging Markets

April 2018 – 100 pages

Technological progress is often associated with the creation of novel and useful products through innovation and ingenuity. Yet in many emerging markets, including low-income economies, it is often more common to adopt, adapt, and scale technologies that were created elsewhere.

This report focuses on how technology is contributing to market creation and expansion in emerging markets. It includes analysis and examples of increased access to products and services—energy, financial, and other types—that have been unavailable to large population segments. The report also looks at the impact of technology on market participants, ecosystems, and existing players.

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