ARTIFICIAL INTELLIGENCE IN EMERGING MARKETS

Opportunities, Trends, and Emerging Business Models

IFC | **International Finance Corporation**
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Creating Markets, Creating Opportunities

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Abbreviations and Acronyms

ACO	Ant Colony Optimizer	**ICT**	Information and Communications Technology
AI	Artificial Intelligence	**IOT**	Internet of Things
AGI	Artificial General Intelligence	**KYC**	Know Your Customer
AIS	Artificial Immune System	**LPI**	Logistics Performance Index
ANI	Artificial Narrow Intelligence	**LTE-A**	Long-Term Evolution-A
ANN	Artificial Neural Network	**MIMO**	Multiple-Input and Multiple-Output
AV	Autonomous Vehicle	**ML**	Machine Learning
BCO	Bee Colony Optimizer	**M2M**	Machine-to-Machine
CAD	Computer Aided Design	**OECD**	Organisation for Economic Co-operation and Development
CAGR	Compound Annual Growth Rate		
CPU	Central Processing Unit	**QOS**	Quality of Service
DAAS	Data as a Service	**SDG**	Sustainable Development Goal
DAO	Decentralized Autonomous Organization	**SISO**	Single-Input and Single-Output
DLT	Distributed Ledger Technology	**SON**	Self-Organizing Network
DFI	Development Finance Institution	**SPC**	Statistical Process Control
EC	European Commission	**SVM**	Support Vector Machine
EDGE	Excellence in Design for Greater Efficiences	**TPM**	Total Predictive Maintenance
		TQM	Total Quality Management
EIU	Economist Intelligence Unit	**UN**	United Nations
ESG	Environmental, Social, and Corporate Governance	**US$**	United States Dollar
		VAT	Value-Added Tax
GDP	Gross Domestic Product	**VC**	Venture Capital
GDPR	General Data Protection Regulation	**V2V**	Vehicle-to-Vehicle
GPT	General Purpose Technology	**WBG**	World Bank Group
GPU	Graphic Processing Unit		
IFC	International Finance Corporation		

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

FOREWORD

WILLIAM SONNEBORN
Senior Director, Disruptive
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IFC

The use of artificial intelligence, or AI, has grown exponentially in recent years and shows no sign of slowing down. Breakthroughs in computing power and algorithmic capabilities have brought AI technology—the science of making machines act in rational, intelligent ways—into almost **every facet of our lives**. AI has already been applied to optimize production and service delivery in healthcare, education, agriculture, manufacturing, e-commerce, finance, and more.

Most recently, AI applications are providing new solutions to the complex challenges posed by **the COVID-19 pandemic**. Organizations around the world are exploring new ways to tap into big data and AI analytics to **flatten the curve and preserve public health**. Meanwhile, traditional bricks-and-mortar enterprises are pivoting toward AI and technology-based business models and platforms to provide products and services in new, contactless ways.

Although the pandemic is taking a heavy toll on many sectors of the economy, **the tech industry and its AI applications are experiencing a boost** that offers a bright spot for the growth prospects of emerging markets. Traditionally, building major sectors of the economy required complex and expensive infrastructure. Today, innovative digital solutions allow developing countries to overcome existing infrastructure gaps more quickly and efficiently. In some sectors, AI offers new ways to gradually increase productivity; in others, it allows countries to completely **leapfrog traditional development models,** skipping the need to build expensive infrastructure—or, at least, making it much less capital intensive.

For example, in the financial sector, **M-Shwari** allows customers in remote and underserved regions to apply for loans online. Instead of bearing the logistical difficulty of maintaining a large network of offices and credit agents, the company uses AI to review applications and predict the probability of default. This approach works—by the end of 2017, M-Shwari had provided small loans to 21 million Kenyans.

In healthcare, companies like **Clinicas de Azucar** in Mexico are using AI to analyze data and improve health outcomes for thousands of at-risk diabetic patients. In Rwanda, **Zipline** launched the world's first commercial drone delivery service of blood and medical supplies to remote locations that are difficult to reach over land.

The list of new AI applications grows every day, and with it new opportunities for developing countries to leapfrog development challenges.

However, **innovation comes with the need for regulation**. Using AI to automate tasks can sometimes threaten to replace workers, including in industries that drive economic development. There are also privacy concerns, as some companies can harvest and sell consumer data for profit. And there are increasing questions about how big data will impact equity across markets and affect the digital divide.

To generate trust, we need safeguards, such as industry standards and regulatory frameworks, that can guide the exponential growth of the tech sector. With its extensive experience in AI applications in emerging markets, **IFC can leverage its resources, draw on its knowledge, and apply lessons learned to help the private sector navigate the AI revolution** and realize its full potential.

The data and examples in this report show that AI is helping developing countries overcome infrastructure gaps and solve pressing challenges in critical sectors like energy, transport, agriculture, manufacturing, and financial services. I hope it sheds light on how governments, companies, and investors can harness AI to maximize its benefits while minimizing its risks—when managed effectively and with safeguards in place, AI can facilitate private investment to reduce poverty and improve lives at a pace inconceivable only a decade ago.

EXECUTIVE SUMMARY

Artificial Intelligence, or AI, is changing business and society in ways that would have been unimaginable only a few years ago. Its full potential has yet to be realized—the way we gather information, make products, interact with businesses, and access products and services are all evolving. In emerging markets, AI offers an opportunity to reach the underserved by lowering costs and barriers to entry for entrepreneurs and businesses, creating innovative business models, and leapfrogging traditional technologies. Private sector solutions lie at the heart of ending poverty and boosting shared prosperity, and AI is and will remain an integral part of that process.

But much more can be done. This report explores the role of AI in emerging markets and developing countries—both across and within key sectors—both today and in the future. It also examines the issue of gender bias, and how Big Data can advance, rather than impede, equality. If managed well, AI solutions will expand opportunities and contribute to the achievement of the Sustainable Development Goals.

Artificial Intelligence Across Sectors

CHAPTER 1. The Role of Artificial Intelligence in Supporting Development in Emerging Markets

The adoption of AI has significantly accelerated over the past five years, driven by breakthroughs in algorithmic capabilities, greater computing power, and the availability of richer data. In emerging markets, AI offers an opportunity to lower costs and barriers to entry for businesses and deliver innovative business models that can leapfrog traditional solutions and reach the underserved. As a result, the goals of ending poverty and boosting shared prosperity may become dependent on harnessing the power of AI. For AI to expand and increase its role in emerging markets, practitioners must identify innovative approaches to expanding the opportunities it presents, managing the risks it poses, and supporting private sector-led solutions.

CHAPTER 2. Artificial Intelligence: Investment Trends and Selected Industry Uses

Commercial uses for AI are expanding in both developed and emerging markets—fueling a race to fund, develop, and acquire artificial intelligence technologies and start-ups. AI is being used in virtually every sector, for example, to optimize power transmission, improve health diagnoses, improve learning outcomes in education, design manufactured goods of higher quality at lower cost, expand access to credit and financial services, and improve the entire logistics chain. While China and the United States lead AI investments, most emerging markets have received a limited share of global investment in this critical technology.

CHAPTER 3. Artificial Intelligence and 5G Mobile Technology Can Drive Investment Opportunities in Emerging Markets

Key emerging markets sectors such as telecommunications, agribusiness, healthcare, and education will be transformed by the combination of AI and 5G, which will offer a level of productivity and efficiency that humans cannot match. Applications of AI in earlier mobile generations will likely find more relevance in low-income and fragile contexts. But challenges remain—while most emerging markets are still recouping investments from previous mobile technology generations, the development of 5G infrastructure remains largely an expensive endeavor without clear business models in low-technology contexts. Furthermore, AI creates an urgent need to address security issues and upgrade the skills of the labor force to prepare for the job displacement that these technologies will bring.

CHAPTER 4. Bridging the Trust Gap: Blockchain's Potential to Restore Trust in Artificial Intelligence in Support of New Business Models

Artificial intelligence, blockchain, and the Internet of Things are becoming potent technologies, particularly

when they work together. Thanks to increasing computer power, data generation, and traceability capabilities, they offer significant potential benefits for economic growth and development—particularly in the context of faltering global supply chains. But these innovative technologies face multiple obstacles to implementation, including a mounting fear of the potential implications for individuals and society as a whole. A possible solution may be found in a system of distributed data governance, where the origin and use of data can be independently verified. The integrated implementation of AI and blockchain technologies could help users trust in AI and blockchain applications, resulting in new business models that deliver data security, privacy, efficiency, and inclusion.

CHAPTER 5. Developing AI Sustainably: Toward a Practical Code of Conduct for Disruptive Technologies

Artificial intelligence and other disruptive technologies are playing an important role in market creation and growth. What role can development finance institutions play to align these promising technologies with the Sustainable Development Goals? The authors propose the adoption of a Technology Code of Conduct that reflects IFC's proven Performance Standards. It is supported by a set of practical tools for its operationalization to help clients working on technology-intensive projects. The principles in the Code

define responsibilities for managing environmental, social, and governance risks and suggest a practical roadmap to the sustainable adoption of advanced technologies across markets.

Artificial Intelligence in Specific Sectors

CHAPTER 6. Artificial Intelligence in the Power Sector

Growing demand, changing supply and demand patterns, and efficiency issues present challenges to the global power sector. These problems are acute in emerging markets, where the prevalence of illegal connections to the grid means a large amount of power is neither measured nor billed, resulting in losses and greater CO_2 emissions. Better management of the sector is also constrained by a lack of analytics. Artificial intelligence and related technologies that allow communication between smart grids, smart meters, and Internet of Things devices can help improve power management, efficiency, and transparency, and increase the use of renewable energy sources.

CHAPTER 7. How Artificial Intelligence is Making Transport Safer, Cleaner, and More Reliable and Efficient in Emerging Markets

The demand for transport in emerging markets is growing rapidly due to increasing populations,

urbanization, and in some regions, rising prosperity—which leads to more vehicle traffic and higher freight volumes. This has created new challenges, such as shortages of infrastructure, deteriorating quality of existing infrastructure, and rising pollution. Artificial intelligence offers new solutions to these problems. From scanning traffic patterns to optimizing sailing routes to minimize emissions, AI is creating opportunities to make transport safer, more reliable, more efficient, and cleaner. It also enables private sector investment, which creates markets and allows countries to reach underserved populations.

CHAPTER 8. Artificial Intelligence and the Future for Smart Homes

Population growth and urbanization in emerging markets are leading to bigger cities and rising demand for new urban housing. These trends offer an enormous opportunity to design, build, and operate the homes of tomorrow in intelligent ways that minimize energy consumption and carbon emissions, lower building and homeowner costs, and raise home values. Artificial intelligence will play a pivotal role in this effort by using grid data, smart meter data, weather data, and energy-use information to study and improve building performance, optimize resource consumption, and increase comfort and cost-efficiency for residents.

CHAPTER 9. Artificial Intelligence in Agribusiness is Growing in Emerging Markets

Artificial intelligence can spur progress toward meeting Sustainable Development Goal #2—to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. The challenge is severe, with 820 million people across the globe suffering from chronic hunger today. Food systems must become more efficient if we are to meet the projected doubling of global food demand by 2050 (from 2009). Applications for artificial intelligence in agribusiness will proliferate as access to the Internet and the adoption of smart devices increases among farmers in low-income countries.

CHAPTER 10. Artificial Intelligence Innovation in Financial Services

Artificial intelligence in emerging markets is helping financial services providers improve efficiencies, lower costs, and serve rural and low-income customers. The technology enables them to automate their business processes, leverage big data sources, and help underserved clients establish customer identity and creditworthiness. Advances in data storage, computing power, energy reliability, and analytic techniques have made it cost-effective for businesses to analyze this wealth of real-time and alternative data. As a result, it is now increasingly commercially viable for emerging market financial services providers to begin integrating AI technologies into their service offerings.

CHAPTER 11. AI Investments Allow Emerging Markets to Develop and Expand Sophisticated Manufacturing Capabilities

Artificial intelligence is an integral tool of modern manufacturing and is becoming increasingly important to the industry's future. Already, advances in machine learning, computer vision, and robotics are helping manufacturers improve their processes and produce new and more complex products. By combining large volumes of data with the computing power to simulate human cognitive ability, AI is transforming the efficiency, capacity, and complexity of global manufacturing. This, in turn, helps companies produce an expansive range of sophisticated products and develop dynamic relationships with regional and global value chains.

CHAPTER 12. Leveraging Big Data to Advance Gender Equality

Achieving gender equality requires significant amounts of accurate data about the circumstances and struggles of women and girls. These include many complex issues, including discrimination, violence, education, employment, economic resources, and technology. But globally, data that is disaggregated by sex is lacking. This gap often renders women's societal, cultural, and economic contributions practically invisible. Big data can be a part of the solution. When used effectively, it can provide the information needed to portray women and their situations accurately, which in turn can inform the creation of evidence-based solutions to gender issues. ■

ARTIFICIAL INTELLIGENCE ACROSS SECTORS
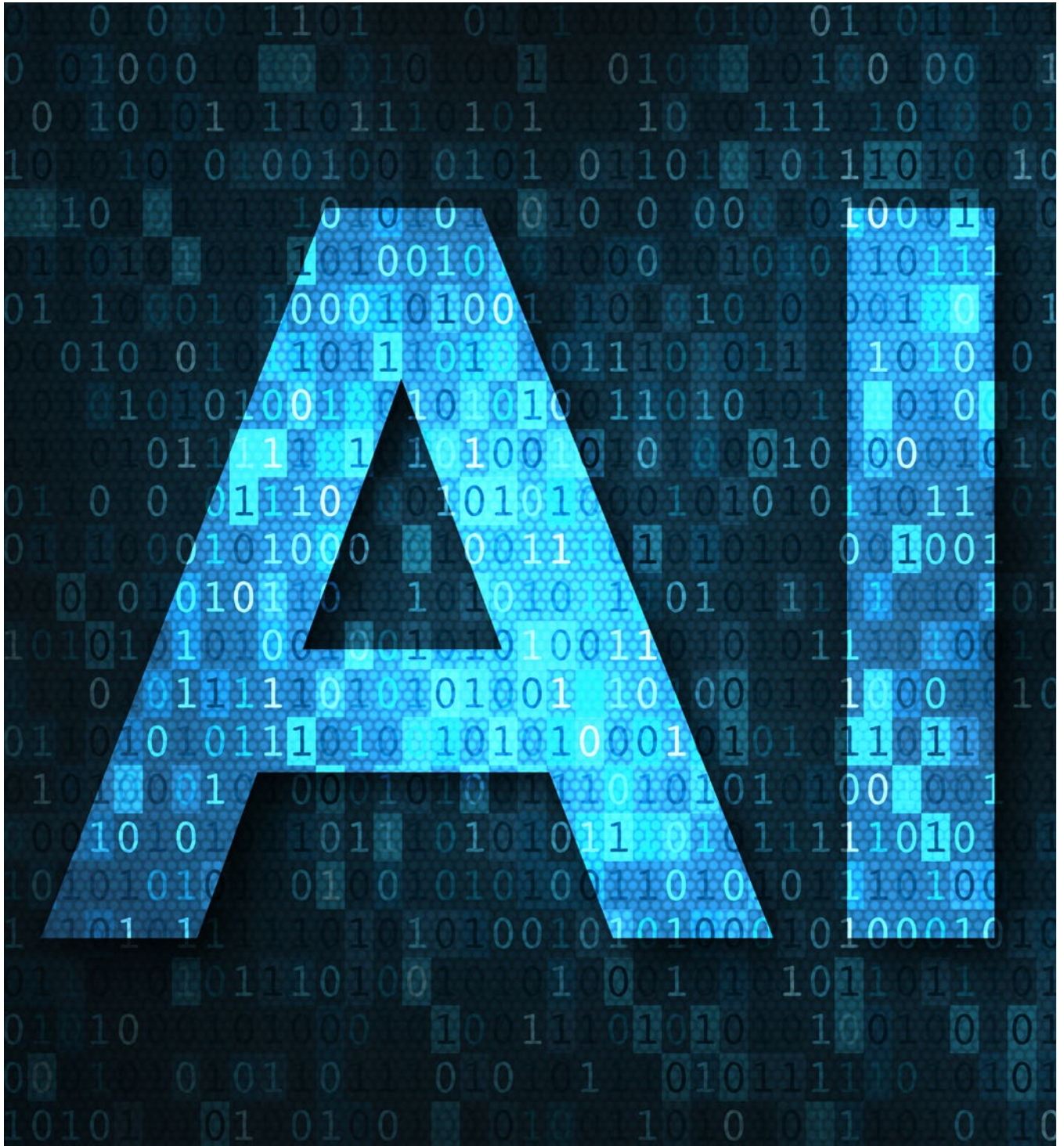
The Role of Artificial Intelligence in Supporting Development in Emerging Markets

By Davide Strusani and Georges Vivien Houngbonon

Artificial Intelligence has enormous potential to augment human intelligence and to radically alter how we access products and services, gather information, make products, and interact. In emerging markets, AI offers an opportunity to lower costs and barriers to entry for businesses and deliver innovative business models that can leapfrog traditional solutions and reach the underserved. With technology-based solutions increasingly important to economic development in many nations, the goals of ending poverty and boosting shared prosperity may become dependent on harnessing the power of AI. While emerging markets are already using basic AI technologies to solve critical development challenges, much more can be done, and private sector solutions will be critical to scaling new business models, developing new ways of delivering services, and increasing local markets' competitiveness. All of these solutions require innovative approaches to expand opportunities and mitigate risks associated with this new technology.

Artificial intelligence (AI) designates "the science and engineering of making machines intelligent, especially intelligent computer programs,"[1] with intelligence defined by the AI100 Panel at Stanford University as "that quality that enables an entity to function appropriately and with foresight in its environment."[2] Other experts define AI as a computerized system that can think and act like humans. More comprehensive definitions consider AI to mean all computer systems that can continuously scan their environment, learn from it, and take action in response to what they sense, as well as to human-defined objectives.[3]

AI combines large volumes of data with computing power to simulate human cognitive abilities such as reasoning, language, perception, vision, and spatial processing. Three types of AI applications can be identified based on which cognitive abilities are simulated and automated:

Basic AI imbeds cognitive abilities such as memory, attention, and language, as well as some executive functions like anticipation and decision-making with limited reference to the past. It is typically used to enhance the performance of business analytics solutions and to improve the functioning of digital platforms. Examples include credit scoring, online matching, chatbots, and smart speakers. In emerging markets, existing services include AI-enabled credit scoring in Madagascar (M-Kajy), Kenya (M-Shwari), Egypt (ValU, Fawry Plus), and India (Aye Finance).

Advanced AI goes further in the simulation of human cognitive abilities such as perception, vision, and spatial processing. It closely mimics the human mind and enables the analysis of unstructured data such as texts, images, and audio data. Immediate application domains include facial and speech recognition, medical diagnoses, transportation, and urban planning, as well as logistics, security, and safety. Outside of China, advanced AI applications are not yet widely adopted in emerging markets. In China, Yitu Technology, a startup founded in 2012 and valued at $1 billion in 2017, provides facial recognition technology. Infervision uses AI to provide medical diagnosis solutions to more than 280 hospitals, 20 of which are outside China. In the transportation and automotive industry, NIO develops autonomous vehicle solutions.

Autonomous AI is expected to become self-aware with the ability to interact with human beings and learn on its own, thereby augmenting humans at home, outside the home, or in work environments. Autonomous AI is still far from widespread commercial use due to limitations in handling irregular objects, biased decision-making involving

value judgment, and an inability to learn from a few examples. Prototypes from Fetch Robotics, Boston Dynamics, and Hanson Robotics are early examples of autonomous AI.

AI performance has been enhanced by a new generation of algorithms labelled machine learning, or ML. Unlike standard rules-based approaches, ML algorithms are automatically built from data, and the richer the dataset, the better they perform. Rules-based approaches tell the algorithm what to do in each state of the world. As a result, they are limited to predictable outcomes and perform poorly when outside of sample. ML, by contrast, involves the use of algorithms to parse data, learn from it, and make a determination or prediction as a result. By learning patterns from the data—including unpredictable ones—ML algorithms generally outperform rules-based approaches. They can be classified into two

broad categories according to the number of stages involved in the learning process:

Basic learning algorithms involve only one stage of learning and are suitable for analyzing structured data like price, quantity, or time; for predicting an outcome given a set of inputs; or for clustering items according to their characteristics. Examples include the prediction of a customer's churn, probability of default (credit scoring), and fraud detection in financial transactions. **Deep learning algorithms**, on the contrary, involve several learning stages organized similar to the structure of the brain. They are suitable for analyzing unstructured data such as images, audio recordings, or texts, and can be useful for face recognition, speech-to-text transcription, or text reconstitution. Unlike basic learning algorithms, deep learning algorithms radically open new avenues for data-driven decision-making, as few alternative methodologies exist to process unstructured data.

BOX 1.1 Differences Between AI and Other Disruptive Technologies

Standard inference and data mining techniques differ greatly from AI and machine learning. For instance, to predict whether a customer is likely to churn, a statistical approach would assemble data on the characteristics of all customers, including whether they have churn or not, specify a statistical relationship between customers' statuses and their characteristics, estimate parameters, and use this relationship to infer the probability that a customer will churn given his or her characteristics. An ML approach would first train an algorithm linking customers' churning statuses with their characteristics on a subset of data (training dataset), use another subset of data to validate the construction of the algorithm (validation dataset), and further test the predicting power of the final algorithm on another subset of data (testing dataset), all before predicting the probability of churn. Deep learning algorithms involve several iterations of this process after partitioning the unstructured dataset.

Cloud Computing, the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer, is often used to implement AI, but it remains distinct. Cloud computing can be used for non-AI related purposes such as data sharing and securing. Likewise, **Blockchain,** a decentralized data sharing architecture, can also be used to store and process data, but does not include an automated and data-driven learning process like AI. In addition, while several **digital platforms** imbed AI technology into their functioning, others do not. Digital platforms that match users from different sides of the platform, recommend contents, or use targeted advertising typically use an AI technology. However, peer-to-peer platforms or job boards, for instance, do not use AI, although they could eventually upgrade.

Opportunities	Risks
• New products and business models—including leapfrogging solutions, solutions for bottom-of-pyramid individuals, and easier access to credit • Automation of core business processes—leading to lower product costs • Human capital development • Innovation in government services	• Obsolescence of traditional export-led path to economic growth • Increased digital and technological divide • Transformation of job requirements and disruption of traditional job functions • Privacy, security, and public trust

TABLE 1.1 Selected Development Opportunities and Risks from AI in Emerging Markets
Source: IFC.

Why is AI Gaining Prominence Now?

Adoption of AI has significantly accelerated over the last five years due the diffusion of digital technologies and major breakthroughs in algorithmic capabilities, access to richer data, and increasing computing power. According to a Gartner global survey, 14 percent of large companies used AI in 2019, up from 3 percent in 2018, and that is expected to increase to 23 percent in 2020. The most popular AI applications include chatbots, process optimization, and fraud analysis on transactional data. Emerging applications include consumer and market segmentation, computer-assisted diagnostics, call center virtual assistants, sentiment analysis and opinion mining, face detection and recognition, and human resources applications such as resume screening. These applications are most common in insurance, software and IT services, telecom, and retail. AI companies tend to have higher valuations and raised more investment rounds than equivalent non-AI startups since 2015.[4]

Companies and users are now creating an unprecedented amount of data. In 2017, the amount of digital data created was more than eight times that of 2009. Progress in telecommunications networks, the ongoing deployment of the Internet of Things, and the upcoming large-scale deployment of 5G networks will all enable even greater data generation. In 2022, Internet data traffic is projected to be three times that of 2017, and the share of licensed IoT devices is predicted to rise from 13 percent in 2018 to 28 percent in 2025. Because AI needs data to learn, these trends are set to supercharge the development of more powerful AI technologies.

Vast improvements in computing power and capacity to store data have supported this growth in data. For example, in 2018 Google introduced its Tensor Processing Unit, which has a processing power of 15 to 30 times that of a Graphical Processing Unit, a key computer element that was central to the implementation of deep learning algorithms.

The rising importance of AI is also driven by demand-side effects such as **the deployment of digital platforms and the emergence of other disruptive applications such as blockchain and cloud computing**. The digital platform business model hinges on the successful targeting of users for marketing purposes and the provision of personalized Internet content to catalyze usage. These functions are essential to the ability of digital platforms to reach the minimum number of users necessary for profitability. Thus, online platforms like Google and Amazon rely on AI to attract both users and advertisers.

Furthermore, the wide range of sectors that AI can transform has attracted **significant venture capital investment**. AI-related venture capital (VC) deals rose from 150 in 2012 to 698 in 2017, with 90 percent annual growth in the volume of investment, from just $0.6 billion in 2012 to $14 billion in 2017.[5]

Reducing Poverty and Boosting Shared Prosperity

Traditional pathways to a country's economic development are increasingly subject to technology-based disruptions. AI is highly disruptive in that it can result in a step change in the cost of, or access to, products or services, or can dramatically change how we gather information, make products, or interact. As development challenges become more and more intertwined with technology-based disruptions, the twin goals of ending poverty and boosting shared prosperity become critically dependent on harnessing the power of technologies such as AI, while at the same time seeking to limit the associated risks.[6]

Emerging markets, including some of the world's poorest countries, are already using basic AI to solve critical development challenges, particularly in the provision of financial services to unserved and underserved populations. Early progress in basic machine learning algorithms, combined with the limited burden of legacy technologies and a growing mass of technology users, have enabled emerging markets to implement basic AI solutions such as credit scoring and targeted advertising. Ant Financial in East Asia, M-Shwari in East Africa, M-Kajy in Madagascar, and MoMo Kash in Cote d'Ivoire are early examples of AI delivering financial services to the poorest. M-Shwari uses machine learning to predict the probability of default of potential borrowers, which allowed it to deliver small loans to 21 million Kenyans by the end of 2017.

AI applications have the potential to address challenges faced by individuals at the bottom of the income distribution, particularly the bottom 40 percent. While these individuals lack the means to purchase AI-technologies or AI-enabled equipment, they can benefit from AI-as-a-service solutions through their mobile devices. Recent examples include a machine learning app, Nuru, that has been used on farms in Kenya, Mozambique, and Tanzania to identify leaf damage in photos taken by farmers and to send information to authorities to help monitor the presence of an invasive pest that threatens farm revenue and food security across East Africa.

Data generated through mobile phones can be highly correlated with financial status, educational attainment, and health status and therefore can enable mobile AI apps to deliver microlending, personalized tutoring, health diagnoses, and medication advice. In addition, AI's speech recognition and speech-to-text functionalities remove literacy barriers typically encountered by the poorest individuals when accessing text-based applications. And image recognition can be used to assess microinsurance claims of farmers in distant rural communities.

AI technologies can enable new approaches to the monitoring and evaluation of development interventions to target those most in need.[7] Emerging countries often lack the data necessary to fine-tune development interventions. AI's ability to tackle unstructured data such as text, images, and audio can be useful for extracting the information needed to improve development outcomes. For instance, an experiment in rural India relies on textual transcription of village assemblies to identify the topics discussed and how the flow of conversation varies with the gender and status of the speaker, thereby shedding light on the functioning of these deliberative bodies—an important aspect of political accountability.[8] Other experiments include the use of machine learning on VAT tax data in India to better target firms for audits and to predict travel demand patterns after hurricanes[9] as well as where food insecurity will occur to help target aid interventions.[10]

Despite the potential risks of AI, failing to take advantage of the opportunities it offers could be even more costly. The economic and societal transformations brought about by disruptive technologies can be accelerated with AI and can dramatically speed up progress toward the Sustainable Development Goals and the World Bank Group's twin goals of poverty reduction and shared prosperity. Yet if countries cannot compete in the future global economy, they will be left behind. To harness the potential of new business models, new ways of delivering services, and shifting sources of competitiveness, countries and companies in the private sector will need to implement innovative approaches to expand AI's opportunities and mitigate its risks.

AI Benefits	Economic Drivers	Economic Impact
Human capital development	Productivity growth	Increased output
Automation of core business processes	Lower barriers to entry for businesses	Increased consumption due to income growth
Easier access to credit	Market expansion	
New products and business models—including leapfrogging solutions		
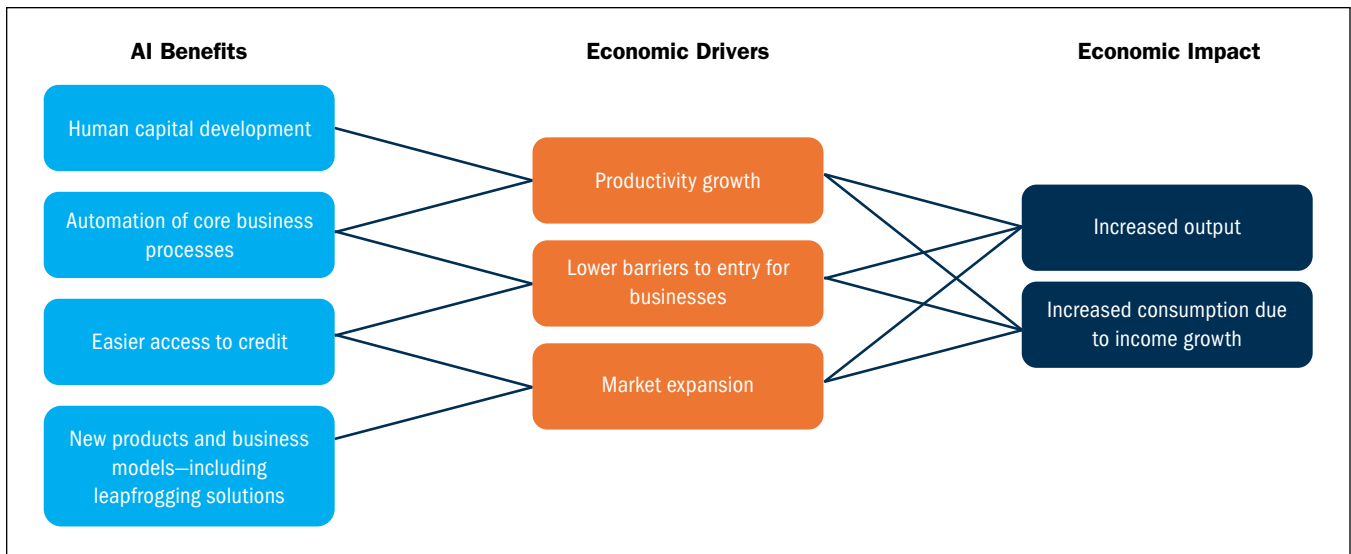
FIGURE 1.1 Channels to Economic Development Supported by AI Technologies

Source: IFC.

Identifying the Development Opportunities of AI

AI can expand and increase development opportunities in emerging markets in several ways. **Improved business productivity** stemming from automation of core business processes and human capital development can significantly lower production costs. These improvements are already used by many companies in developed markets. AI-enabled productivity growth directly raises output and employment, and does so indirectly through increased consumption.

Cost reductions stemming from automation of certain functions can combine with increased access to credit to reduce overall business costs—a critical advantage AI technologies are already delivering. This can increase both the volume of bankable business opportunities and the level of competition within markets and industries. AI solutions can also help overcome the lack of infrastructure and large information asymmetries in emerging markets by supporting product innovation in the form of new business models and leapfrogging solutions tailored to serve previously unserved and underserved populations.

AI has the potential to deliver significant productivity gains for businesses. This includes the combination of the accelerated pace of technology diffusion,

the convergence of multiple technologies, and the emergence of digital platforms. Through automation, AI is set to bring significant cost reductions across all core business functions, including human resources management, marketing, accounting, and inventory. For instance, employee recruitment often involves the costly review of dozens of candidate profiles, a process that can be automated using AI solutions. Automation of the recruitment process typically cuts time-to-hire from 10 weeks to 2 weeks, and the time to shortlist candidates from 2–3 weeks to almost nothing. Also, repetitive human review of accounting documents or inventory can instead be performed by AI, generating significant cost savings. For instance, automation of accounting services in Brazil is set to reduce the bureaucratic costs incurred by medium-sized enterprises—for example, in filing taxes. These improvements are likely to drive the growth of informal businesses, which make up to two-thirds of GDP in some lower-income countries.[11]

Productivity improvements also stem from more efficient investment in human capital thanks to automation. AI can reshape high-quality education and learning through precisely targeted and individually customized human capital investments. The integration of online courses with AI offers the opportunity to improve access to affordable education and raise learning and employment

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in emerging markets. Edtech companies like Coursera, Andela, and Udemy are generating data on student performance across emerging markets and are poised to leverage this data to deliver upskilling recommendations. In India, UpGrad has enrolled 2,000 students in entrepreneurship, digital marketing, data analytics, and product management courses, whereas Edutel uses two-way satellite technology to deliver live lessons by specialist teachers in science, math, and English to about 2,000 primary and secondary schools in the southern state of Karnataka. Other companies are combining data from online education and job platforms to deliver automatic upskilling recommendations with the goal of improving employability. Examples include 51job.com in China and Revelo in Brazil.

AI is driving innovation in financial services through better data processing, increasing access to credit. By relying on nontraditional data such as mobile phone call records, mobile-money transaction data, text messages, and address books, AI can reduce information asymmetry in contexts where borrowers lack credit history, enabling access to financial services for first-time borrowers and the unbanked. AI has the potential to make financial services more affordable thanks to the automation of credit scoring, a process that requires human resources in traditional financial institutions. Machine learning algorithms can parse large amount of mobile phone data to deliver instantaneous credit scores to users in developing countries. Once a user is offered a loan, the scoring algorithm continues to improve by absorbing credit history data. An example of this approach is Branch, a fintech company that offers microloans to first-time borrowers and customers without bank accounts in Africa (Kenya and Nigeria), India, and Mexico.

AI's capacity to handle unstructured data has the potential to enable product innovation in sectors such as pharmaceuticals, transportation, and logistics. Because of limited statistical capacity, emerging markets often lack the structured data needed to power business analytics solutions. AI, however, can handle unstructured data such as audio recordings or videos largely available in emerging markets to discover new ways of servicing customers and providing new drugs and new predictive healthcare solutions. Drug

discovery, for instance, involves searching through an almost infinite set of molecular combinations, a task for which AI is far more efficient than medicinal chemists. AI is also driving innovations in business models through automation that delivers more affordable services, thereby expanding the market to underserved consumers. For instance, TaxiJet, a ride-hailing company with a business model similar to Uber, uses AI to match users with taxi drivers in Cote d'Ivoire at lower cost than traditional taxis.

AI can also alleviate constraints from poor infrastructure in emerging markets by providing alternatives and cost-effective solutions to deliver social services to those who need them most, including remote communities. Taking advantage of the widespread coverage of mobile networks, AI is being used in telemedicine for early diagnosis of disease, which can reduce costs associated with maintaining an extensive network of community health workers. Likewise, education resources planning often fails to account for the geographical distribution of learning outcomes due to poor data, which leads to an unequal distribution of resources. Automated processing of student performance can help target areas with the greatest challenges. AI-enabled matching of students with teachers can also improve access to higher quality education.

Productivity growth, lower barriers to entry, and market creation and expansion have the potential to raise consumption and ultimately output. Creating and expanding markets can help create jobs and raise consumption, to the benefit of the wider economy. For instance, across Africa, online marketplaces that rely on AI solutions are expected to create around 3 million jobs by 2025 by expanding the supply of goods and services, making assets more productive, and unlocking demand in remote locations.[12] Productivity growth of informal businesses and market expansion are more critical in emerging markets, suggesting a higher economic potential for AI in these countries than in developed markets. China offers an example of the size of the opportunities AI holds for emerging markets: it is estimated that AI could boost China's GDP by 26 percent by 2030, compared with 14 percent in the United States.[13]

These gains could be further reinforced by AI-driven efficiencies in the delivery of public services. Governments in emerging markets could benefit from AI due to potentially significant cost-savings, improved delivery of social services, and better risk management. While few studies have investigated the gains from automation for governments in emerging economies, estimates from advanced economies suggest that it could be substantial. In the United States, estimates suggest that the federal government could save up to $41 billion through AI-enabled automation.[14] Potential government services that could be automated include data entry with automated handwriting recognition, planning and optimization algorithms, and customer service using speech recognition and natural language processing. For instance, electronic document discovery locates 95 percent of relevant documents in the discovery phase of legal cases, compared to an average of 50 percent for humans, and in a fraction of the time.[15]

Other opportunities include risk management—disease prevention, natural disaster management, humanitarian crisis management—and citizen engagement through automated and real-time analysis of online activities, including social network and telecommunications metadata.

Managing the Risks that AI Poses

Disruptive technologies including AI pose new risks to economic and societal inclusion. Technologies are reshaping the nature of work and could exacerbate inequality within countries.[16] Shifts in the demand for labor and the skills that complement technology can reward those with access to new technologies and skills—at the expense of those who lack them. With advances in AI and ML, highly skilled routine tasks may be disrupted. There will thus be a premium on skills that complement technology—not only technical skills but also socio-behavioral and creative skills for greater adaptability and lifelong learning.

One concern is whether AI will disrupt the potential for emerging economies to catch up through traditional export-led manufacturing. Emerging countries have been able to take advantage of abundant skilled, but low-wage, labor to attract foreign manufacturing

firms and outsourced services and gain global competitiveness in export-oriented sectors. Countries like China today, or South Korea and Japan in recent decades, have succeeded by relying on this model. However, AI, more than other disruptive technologies, embeds the cognitive abilities mobilized by this labor force, which might make it more difficult for emerging countries to exploit this important traditional development ladder.

For instance, advanced AI applications such as natural language processing could replace outsourced customer care services, an industry that employs thousands of workers in countries like Vietnam, South Africa, and Morocco. Likewise, autonomous AI, enabling robots to sew, could replace hundreds of thousands of workers in Bangladesh and Ethiopia. Job displacement, accentuated by the decreasing importance of cross-country labor cost arbitrage and combined with slower output growth, could further widen the gap between advanced and emerging countries, as well as increase inequality within countries, and thereby limit upside opportunities for nascent middle classes. This risk is more acute in the medium term for countries that have already developed these types of jobs, while for the poorest countries these jobs may not be there to lose.

AI may challenge existing local businesses that fail to catch up with the latest technologies. A key element of AI performance is access to large volumes of data, and this tends to increase the initial advantage of a successful first mover. Such a trend has the potential to create "winner take all" outcomes. Successful AI-enabled businesses are more competitive and therefore attract more customers and accumulate more data, which further improves their AI algorithm and reinforces their initial competitive advantage. This is often the case with mobile operators that offer electronic financial services and employ AI to optimize their distribution networks. If the enabling environment to be competitive does not adapt, firms will not be able to pursue new opportunities, widening productivity differences, creating larger first-mover advantages, and fostering growth accelerations only in certain sectors and locations.

Acute societal challenges include privacy, security, public trust, algorithmic biases, and ethical use of

AI type	Cognitive abilities simulated	Selected examples of sectors impacted	Impact on output	Impact on jobs
BASIC AI	Attention (sustained concentration on an object, action, or thought, and ability to manage competing demands) Memory Language (translate sounds into words and generate verbal output) Executive functions (anticipation, decision-making)	Outsourced services (accounting, HR, customer care) Business analytics (customer care, digital assistants, smart speakers, content creation in the media) Marketplaces: e-commerce, recruitment (online chatbots, search and recommendations) Financial services: increased access to credit (credit scoring, fraud detection) Innovation in access to energy for the poor (particularly in rural areas, smart metering) Innovation in social sectors (new business models to deliver personalized and low-cost education and healthcare to the poor, epidemic prevention and disease containment)	*Re-shoring of business functions in home countries* Income generating opportunities through financial inclusion Increased productivity in the informal sector through modernization of business processes Creation of market demand through access to previously un(der) served populations Increase in human capital, yielding productivity gains	*Job destruction in routine tasks.* *Job losses for the emerging middle class* Employment for low-income workers Jobs induced by financial inclusion and by productivity gains (overall lower employment multiplier due to lower labor intensity of AI)
ADVANCED AI	Perception (recognition and interpretation of sensory stimuli) Visual and spatial processing (ability to process incoming visual stimuli, to understand spatial relationships between objects, and to visualize images and scenarios)	Agribusiness (optimizing seed planting, fertilization, irrigation, spraying, and harvesting - Abundant Robotics does automatic apple harvest) Health (diagnosis, drug discovery and monitoring) Transportation (autonomous vehicles, including drones) Smart cities (urban planning with AI-enabled IoT) Security & Safety (face and speech recognition)	Increased productivity of agricultural production Increased productivity of firms due to improved efficiency of urban infrastructure	*Potential displacement of rural/farm workers*
AUTONOMOUS AI	All the above plus human awareness and the ability to learn	Manufacturing (robotics in industrial plants and warehouses— e.g., Fetch Robotics) Logistics	*Limited delocalization of manufacturing activities from top emerging countries like China* Increase productivity of established manufacturing industries and in the logistics sector	*Lost opportunity to take advantage of abundant low-cost labor* *Job losses for manufacturing and logistics workers*

TABLE 1.2 Selected Development Opportunities and Risks from AI in Emerging Markets

Source: IFC.

AI. Survey results suggest that these issues are more severe in emerging markets. For instance, only 20 to 21 percent of businesses leaders in the Asia-Pacific, Europe, the Middle East, and Africa regions provide their boards with adequate reporting metrics for cyber and privacy risk management, compared to 35 percent in North America.[17] Because they are often trained on imperfect data, AI applications in real world settings like job screening, insurance approval, and policing tend to reproduce social biases typically related to gender and race. Policy makers are taking steps to mitigate these risks, with member states of the OECD and some emerging countries like Brazil and Peru having recently endorsed a set of principles to promote responsible stewardship of AI.

On top of these challenges, there are **risks that AI may widen gaps between countries, reinforcing the current digital divide.**[18] AI leaders (mostly in developed countries) could increase their lead in AI adoption over developing countries. Many developed countries may have no choice but to develop their local AI industry to capture higher productivity growth as their GDP growth momentum slows, a phenomenon often related to aging populations. Moreover, wage rates in these economies are high, providing more incentive than in low-wage developing countries to substitute labor with machines.

Developing countries tend to have other ways to improve their productivity, including catching up with best practices and restructuring their industries, and may therefore have less incentive to develop the local AI industry. This does not mean that developed economies will reap the biggest gains from AI and that developing economies are destined to lose the AI race. Countries can choose to strengthen their digital economy foundations and develop the supporting capabilities needed to reap the potential of AI. While China has become the second largest AI powerhouse, paths remain open to other economies, and support from the private sector will be critical to accelerating adoption and dissemination.

Supporting Private Sector-led AI Solutions in EMs

The private sector is well positioned to harness the opportunities AI offers in emerging markets because of the significant need for innovation and the potential gains in productivity, market expansion, and business opportunities in the public sector. However, aside from China, private sector involvement in the diffusion of AI in emerging markets has been limited so far. India, the second largest emerging market nation, remains a significant laggard, with just 152 AI startups as of 2018, compared with 1011 in China.[19]

Most private sector initiatives are focused on microlending and use machine learning algorithms in conjunction with mobile phone data to predict the probability of default by potential borrowers, with fintech companies and mobile operators leading the race. AI applications in promising sectors such as transportation, education, health, and agribusiness are rarely available in emerging markets.

Critical constraints to the adoption of AI solutions include the lack of a developed digital economy and a supporting entrepreneurial ecosystem capable of driving innovation and attracting financing; a scarcity of local AI expertise; and a lack of government support in key areas such as open access to data, system interoperability, trust, and acceptance of trial and error.

While basic AI applications such as credit scoring and online platforms (mobile-based or fixed) can rely on traditional connectivity like 2G, advanced AI applications such as facial and speech recognition require broadband connection to transmit bandwidth-consuming files such as images and audio. Likewise, the smooth functioning of autonomous vehicles requires a web of connected objects and a network architecture closer to 5G.[20] Data centers are critical infrastructure for data storage and high-speed computation and

parallel computing, yet they remain deficient in many emerging markets, particularly in Africa.

In terms of entrepreneurial ecosystems, few emerging markets have AI startups. As of 2018, 20 countries hosted 95 percent of worldwide AI enterprises, and only three of them are emerging markets. China is second with 1011 AI enterprises, India is 5th with 152, and Russia is 20th with 17.[21] A lack of access to expertise and data often discourages private investors from pursuing AI projects in emerging markets. Scarce AI expertise in low-income countries increases the cost of implementing any AI projects. Recent initiatives tackling this issue in Africa include Andela (Nigeria, Kenya, Rwanda, and Uganda), a Google AI Lab in Accra (Ghana) and the creation of a Master's Degree in Machine Intelligence at the African Institute of Mathematical Science in Kigali (Rwanda).

Looking Forward

Development finance institutions, including IFC are pursuing a broad range of strategies to help private companies and governments across emerging markets implement AI solutions.[22] VC investment as well as investment in funds is enabling the growth of AI startups. Further investment in online educational platforms that offer machine learning and programming courses are building local expertise across emerging markets. However, private sector investment in AI projects in emerging markets remains limited to a few countries, partly due to uncertainty about consumer interest in AI products.

The private sector alone cannot make AI succeed in emerging markets. Governments must level the playing field by providing open access to big data; by catalyzing network effects through standards setting and interoperability enforcement; and by supporting trial-and-error phases, including potentially through public subsidies to AI incubators. ■

Artificial Intelligence: Investment Trends and Selected Industry Uses

By Xiaomin Mou

The global race to fund, develop, and acquire artificial intelligence technologies and start-ups is intensifying, with commercial uses for AI proliferating in advanced and emerging economies alike. AI could increase GDP growth in both advanced countries and emerging markets. In energy, AI can optimize power transmission. In healthcare, diagnosis and drug discovery will benefit enormously from AI. In education it can improve learning environments and learning outcomes and can better prepare youth for transition to the workplace. In manufacturing, AI can help design better products in terms of functionality, quality, and cost, and improve predictive maintenance. AI can help extend credit and financial services to those who lack them. The potential impact of AI on transportation and logistics goes far beyond automation and road safety to span the entire logistics chain. Yet with the exceptions of China and India, emerging markets have received only a modest share of global investment in this advanced technology, despite the fact that they may benefit more from AI implementation than advanced economies.

Artificial intelligence, or AI, has the potential to imitate the human brain, which makes it unique among technologies in that it can learn and solve problems that would normally require human intelligence. In general, AI includes natural language and processing, visual perception and pattern recognition, and decision making. These processes in combination give AI enormous potential in multiple disciplines and across many economic sectors.[23] And they may help address persistent development challenges such as a lack of infrastructure or underdeveloped healthcare or financial sectors, which can leave many individuals underserved.

Despite its revolutionary potential, AI—at least in its most basic form—has existed for decades. First-generation AI-equipped computers played chess, solved puzzles, and performed other relatively straightforward tasks.

Yet the sophistication level of AI has evolved dramatically in recent decades, and the technology is now prevalent in many areas of everyday life. Google Maps uses AI to dynamically learn traffic patterns and create efficient routes; smartphones use AI to recognize faces and verbal commands; AI enables efficient spam filters in email programs, smart assistants such as Alexa, and recommendation engines. These are a small sample of familiar technologies that leverage AI's capabilities. AI applications can be found in virtually every industry today, from marketing to healthcare and finance.

Of course, the development and implementation of AI is not without its share of controversy, and the debate about the risks and rewards of this unique and revolutionary technology tends toward extremes, with many observers predicting that AI will destroy jobs and even eventually threaten humans. Some scenario analyses[24] suggest a potentially positive impact of AI on GDP growth, but virtually all of these are focused on developed economies. In general, the aggregate impact is predicted to hinge on several factors including skills, availability of open source data, and technological progress, with some countries expected to gain more than others. The impact on jobs is much more uncertain, as it depends on the particular economic sector and the skill composition of the labor force.

Controversial or not, the race to develop AI proceeds apace. Because the distribution of venture capital (VC) investment into AI-specific technologies closely tracks the flow of overall VC flows, the latter can be used as a proxy for interest in AI by country. And it is clear from the data that the United States and China lead in AI investment, with China dominating global AI funding.

Chinese AI companies raised a total of $31.7 billion in the first half of 2018, almost 75 percent of the global total of $43.5 billion. China looks poised to lead the AI space in several sectors including healthcare and autonomous driving. China's progress with AI is largely the result of strong and direct government support for the technology, leadership from Chinese tech industry giants, and a robust venture capital community.

With the exceptions of China and India, emerging markets have received a modest share of global investment in advanced technologies. Total VC flows to emerging markets between 2008–2017 excluding China and India were just $24 billion, compared with global flows to the United States over the same period of $694 billion (Figure 2.1).

AI development in China has important implications for other emerging markets, too. A microlending algorithm developed using the credit scoring of Chinese consumers can be much more readily applied in another emerging market than one developed using credit reports of American consumers. That is due to the fact that, unlike borrowers in advanced economies, borrowers in China and other emerging markets often do not have credit cards or traditional mortgages. In China, companies like AntFinancial and Tencent have credit scoring solutions that leverage e-commerce data, as well as payment platforms that provide insight to credit-based decision making. These technologies, much like those in agribusiness and other sectors, have enormous

potential to be applied to other emerging markets such as Sub-Saharan Africa.

Machine learning, in which machines are inspired by biological processes and learn from observation and experience, is the most invested category of AI. The AI industry is moving toward consolidation, with large corporates and industrial players making frequent acquisitions of start-ups, a phenomenon that tends to drive up valuations and limit opportunities for VC investors.

The Evolution of AI

Artificial intelligence can be categorized into three basic stages of development.

- **Basic AI or Artificial Narrow Intelligence** (ANI) is limited in scope and restricted to just one functional area. AlphaGo, a computer program that plays the board game Go, is an example.

- **Advanced AI or Artificial General Intelligence** (AGI) is advanced and usually covers more than one field, such as power of reasoning, abstract thinking, or problem solving on par with human adults.

FIGURE 2.1 Global VC Investment 2008–17

Source: Pitchbook 2019.
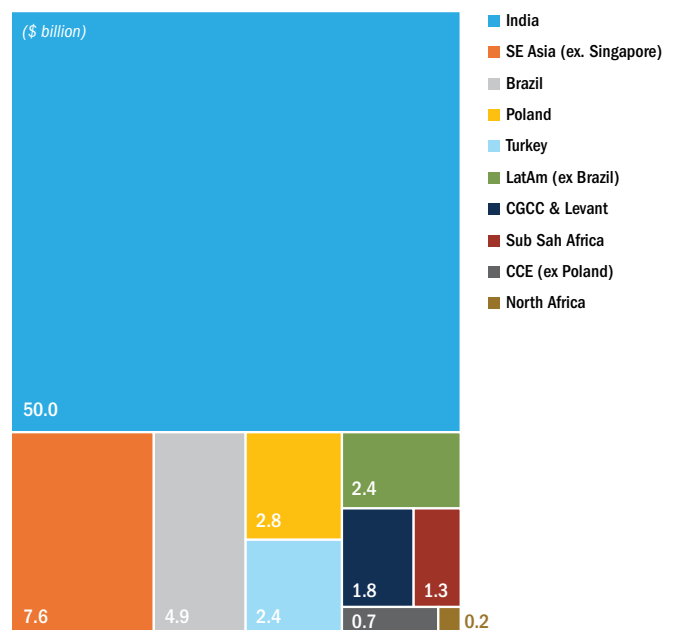
FIGURE 2.2 EM VC Investment 2008–17 (ex-China)

Source: Pitchbook 2019.

- **Autonomous AI or Artificial Super Intelligence (ASI)** is the final stage of intelligence expansion in which AI surpasses human intelligence across all fields. This stage of AI is not expected to be fully developed for several decades.

The Rapid Growth of Data

Today, advances in other technologies are creating an environment conducive to the rapid acceleration of AI technology. Massive amounts of data that are being created by increasingly ubiquitous connected devices, machines, and global systems—including the Internet of Things, or IoT—are becoming increasingly helpful in training learning systems to make them more realistic and humanlike in their behaviors.

For example, electric vehicle carmaker Tesla aggregated some 780,000,000 miles by the close of 2016—a rate of one million miles every ten minutes—through its connected cars. The data generated by those miles can be instrumental for AI applications.

The more data available, the better the AI algorithms become. In addition, significantly faster computers allow for much more rapid processing of the data. Lower-cost computing power, particularly through cloud services and new models of neural networks, have dramatically increased the speed and power of AI. Graphic processing units (GPUs), repurposed to work on data, allow for faster training of machine learning systems compared with more traditional central processing units (CPUs). While CPUs load and process data sequentially, GPUs can "parallel" process data, which allows AI to manipulate vectors and matrices in parallel. By repurposing these graphics chips, networks can iterate faster, leading to more accurate training in shorter time periods. GPUs can also replace expensive high-performance hardware. The effect of these chips has been described as allowing processing speeds to "jump ahead" seven years, relative to what Moore's Law would have allowed.[25]

New Approaches to AI

Beyond data generation and computing power, new approaches to artificial intelligence are driving the technology forward. The first such approach involves modelling the human brain. This includes physically building an electronic model of the brain, as well as using logical approaches like neural networks that mimic the way neurons in the brain interact.

Alternative approaches involve sophisticated logical rules. These include logical programming to code human reasoning into software; evolutionary computational intelligence that allows for some degree of derived action beyond explicit coding; and statistical analysis that mimics the results of human reasoning without having to "understand" that reasoning. Natural language processing uses this latter approach with a departure from grammar building to use statistical rules.

Also, as AI becomes more widely adopted, its basic toolsets and functionality will become available as commercial services from large tech platforms. Examples include Amazon Machine Learning Services, Google DeepMind and TensorFlow, IBM Watson, and Microsoft Cortana Intelligence Suite, among others. Platform operators will offer an AI layer to add stickiness to existing offerings, and with this horizontal toolset available, start-ups will be able to scale AI more quickly and cheaply.

Funding Trends in AI

As commercial uses for artificial intelligence proliferate, the race to acquire AI technologies and start-ups is intensifying. Big corporations in every industry, from retail to agriculture, are attempting to integrate machine learning into their products.

Perhaps as a result, machine learning leads AI technology investments. Machine learning, as opposed to learning according to rules and logic, occurs through observation and experience. Instead of a programmer writing the commands to solve a problem, the program generates its own algorithm based on example data and a desired output. Essentially, the machine programs itself.

As of January 2019, Venture Scanner, an emerging technology research firm, analyzed over 2000 AI start-ups and classified them into 13 functional

categories that collectively raised $48 billion in funding since 2011. Start-ups developing machine learning applications make up half of this funding. These companies utilize computer algorithms to automatically optimize some part of their operations. Examples include CustomerMatrix, Ayasdi, Drive. ai, and Cylance. Many other AI categories include pioneers and display enormous potential for growth and development.

Market intelligence firm CBInsights has identified 100 of the most promising private companies applying AI algorithms across more than 25 industries, from healthcare to cyber security. These start-ups have collectively raised $11.7 billion across 367 deals.

Perhaps due to this rapid growth in the AI space, there is now an acute shortage of AI talent in many workforces. And this is accelerating the race to acquire early-stage AI companies with promising technologies and personnel. Notable acquisitions include Amazon's purchase of AI cybersecurity start-up Sqrrl and Oracle's acquisition of cybersecurity firm Zenedge. While tech giants continue to hunt for AI technology and talent, traditional insurance, retail, and healthcare incumbents are also on the chase. The largest deals in AI history include the 2018 Roche Holdings acquisition of New York-based Flatiron Health for $1.9 billion, and Ford Motor's acquisition of auto tech start-up Argo AI for over $1 billion in 2017. Google is the top acquirer of AI start-ups, with 14 acquisitions under its belt.

The growth of VC funding since 2012 has followed a similar path. In 2017 AI attracted $12 billion of investment from VC firms, which is double the volume of 2016, according to KPMG. Around 42 percent of AI companies acquired since 2013 had VC backing.

AI Acquisitions and Funding are Scaling Rapidly

According to ABI Research, AI start-ups in the United States raised $4.4 billion from 155 investments, while Chinese start-ups raised $4.9 billion from 19 investments,[26] as they tend to focus more on mature AI applications. The most vibrant AI hubs worldwide are California's Silicon Valley, New York City, Beijing, Boston, London, and Shenzhen. These

hubs benefit not only from the creation of highly skilled and highly paid jobs, but also knowledge and innovation spillovers. Employees at AI firms tend to become AI entrepreneurs, AI workers switch between AI companies, and innovative AI products can be developed for and deployed in local markets, exposing even more people to the technology.

Silicon Valley is the top global hub for start-ups (12,700 to 15,600 active start-ups) and tech workers (two million). It is the global leader for VC investment and the headquarters for many top technology firms.

New York is the leading hub for the financial and media industries; it has an AI talent pipeline from universities; and it has a strong funding ecosystem—the world's second largest after Silicon Valley in terms of the absolute number of early-stage investments.

Beijing leads the volume of academic research output in AI, which comes from Tsinghua, Beihang, and Peking Universities; it has extensive involvement of tech leaders, especially Baidu; and the Chinese government considers AI to be of strategic importance.

China and AI

AI pushed total VC funds flowing to China to a record $40 billion in 2017, up 15 percent from the previous year. The Chinese government is actively promoting the AI industry and initiatives; its stated goal is to develop an AI sector worth $150 billion by 2030. The Chinese private sector is also active in the space. Internet firm Baidu has actively pursued an "AI first" agenda since launching the Institute for Deep Learning in 2013 and establishing the Silicon Valley AI Lab the following year. In January 2018 the Beijing Frontier International AI Research Institute was established under the leadership of Kai-Fu Lee of Sinovation Ventures.

There are also local AI initiatives in China with multiple cities—Beijing, Shanghai, Hangzhou, Zhejiang, and Tianjin among them—developing plans and policies for AI. For example, Shanghai plans to establish a special fund to invest in AI development, while Hangzhou has launched its own AI industrial park along with a fund that will invest approximately $1.5 billion in it.

Legend:
- B2B Services
- Lifestyle & Consumption
- Transportation & Automobiles
- Health
- Fintech
- Education
- Security
- Tools & Software
- Manufacturing
- Logistics
- E-Commerce

Pie chart values: 32%, 17%, 13%, 11%, 10%, 5%, 3%, 3%, 3%, 3%, 2%, 1%
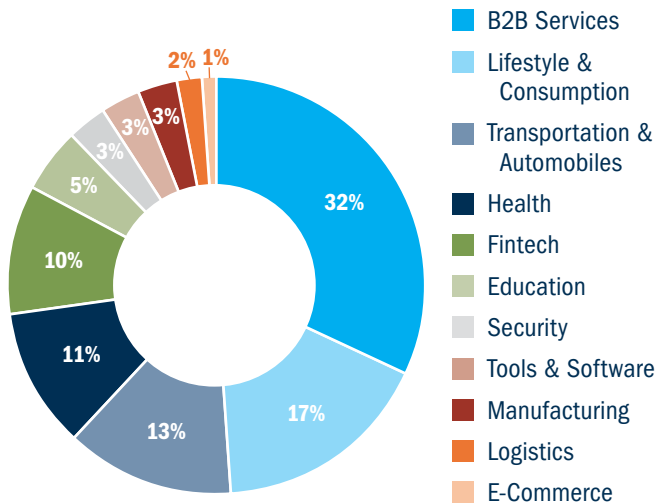
FIGURE 2.3 China AI Investment by Subsector (# of deals)

Source: ITJuzi.

PricewaterhouseCoopers predicts China's GDP will reach $38 trillion by 2030, with $7 trillion of that coming from AI through new business creation in fields such as autonomous driving and precision medicine, as well as existing business upgrades in terms of improved efficiencies and reduced costs. From 2010 through Q3 2017, a total of 704 AI deals were made in China, representing $6.67 billion.[27]

Do the Rewards of AI Outweigh its Risks?

New technologies come with risks, and there is much uncertainty around advances in AI and machine learning, particularly with regard to the technology's impact on society and the economy. AI's potential to imitate human behavior has given rise to concerns that the technology poses a significant threat to jobs, privacy, and the nature of human society itself.

Concerns about AI-driven job losses assume that humans won't be needed to manage and monitor AI machines and regulate inputs and outputs. Yet a study by the Economist Intelligence Unit (EIU) that looked at the manufacturing, healthcare, energy, and transportation sectors found that AI would boost

GDP by 1 percent under all scenarios it examined, with even more significant gains in developing Asian nations.[28] The EIU study also projects that employment in the manufacturing sector will remain relatively steady after AI technology penetration. The study does predict that certain job categories would be eliminated by AI, though there will be offsetting job creation among higher-skilled job categories. Still, job losses have historically been associated with the introduction of revolutionary technologies, especially in manufacturing.

Bias in AI

As AI technologies have emerged and spread, a phenomenon known as AI bias has been noticed. It occurs when an algorithm produces results that are prejudiced due to erroneous assumptions in the machine learning process. And it can lead to and perpetuate biases in hiring, lending, and security, among other areas. Bias can creep in at many stages of the learning process,[29] including (1) setting what the model should achieve (potential predatory behavior to maximize profit); (2) collecting data that reflects prejudices (selecting one gender over another, for example) or is not representative of reality; and (3) preparing the data and selecting which attributes the algorithm should consider or ignore. Mitigating these biases can be challenging, but there is a strong movement within the AI community to do so, and researchers are working on algorithms that help detect and mitigate hidden biases in training data and models, processes that hold the users of these models accountable for fairer outcomes and defining fairness in different contexts.

AI in Energy

AI's potential in the energy industry mostly leverages the technology's ability to analyze highly complex systems in real time and optimize them in ways not possible with conventional information technology.

The timing is particularly fortuitous, as the energy grid is changing from constant baseload systems to intermittent renewable generation, a shift that greatly increases system complexity. For example, AI could be used to optimize distributed energy resources

such as rooftop solar photovoltaic and batteries to match load and capacity. Electricity meter data can be disaggregated with heuristics machine learning, generating insights for additional energy savings. And renewable energy sales and deployment can be accelerated with AI.

AI can deliver increased energy efficiencies at the grid level by reducing standby reserves of thermal base load generation by allowing the grid to follow load and renewables more closely. This directly reduces the use of coal, oil, and gas, and thereby reduces greenhouse gases. Also, through its greater level of flexibility, AI can increase renewables generation by lifting the ceiling on the amount of renewables that can be accommodated.

At the building level, AI can increase efficiency by using machine learning to predict building heating and cooling loads based on weather, time of day, weekday, etc. And AI can empower consumers through better disaggregation of electricity meter data, allowing for resource conservation through behavior modification.

AI in Healthcare

There are many uses for AI technology in the healthcare sector. These technologies are maturing rapidly and are already being used in a number of applications—from aiding diagnosis to improving operational healthcare workflow efficiencies. The goal of many of these applications is to do what humans do but faster, more accurately, and more reliably. That makes them potentially beneficial in resource-constrained environments with limited access to doctors and other health professionals, as well as in cost-containment constraints. Top uses include:

1. AI-enhanced medical imaging and diagnostics is designed to improve the speed and reliability of analysis and can be particularly beneficial in contexts where there is a lack of trained doctors, radiologists, etc.

2. AI-triage plugs into tele-health platforms and provides a pre-consult triage, even flagging potential diagnosis, to save physicians time.

3. Patient data and risk analytics. AI promises data analytics and machine learning on patient data such

as electronic health records, facilitating predictive diagnostics, and ultimately improving outcomes.

4. Drug discovery. Deep learning techniques using convolutional neural networks[30] are very effective in predicting which molecular structures could result in effective drugs. Applications are being developed by both in-house research and development departments as well as by independent start-ups that are focused on vertical systems and are expected to accelerate drug discovery. AI also supports personalized medicine, or the targeting of medicines based on individual genetics and other genomic analysis.

5. Pharmaceutical supply chain. Using AI to process real-time data and make predictive recommendations is expected to drive data-driven supply chains, improving efficiency and cost management.

AI can increase access to quality healthcare through AI-enabled triage, leveraging the time of scarce doctors and facilitating diagnoses. It can deliver more affordable care through increased productivity, allowing available healthcare professionals to focus more closely on patient care and human-interaction. It can lower costs through better data management and more efficient drug discovery mechanisms.

AI in Education

Artificial intelligence technologies can dramatically enhance the way students learn both within and outside of the classroom, as well as help expand access, relevance, and efficiency of education, although the use of this technology in the sector is still at a nascent stage of development. Machine learning can customize learning content by providing teachers and faculty with actionable insights from student performance to better understand and serve student needs. AI can improve online tutoring, help teachers automate routine tasks such as grading, and fill gaps in their curricula, and can give students immediate feedback to help them better understand concepts at their own pace and with a greater degree of individualization.

The use of AI in education can not only improve learning environments and learning outcomes, it can also save teachers and faculty time and allow them to

focus on learners with special needs, and can make curricula more relevant to the needs of employers and industry. It also has the potential to democratize education by providing quality teaching in non-traditional learning environments. And AI can give parents a greater role in their children's education through new tools and platforms, and can decentralize education to reduce school, campus, and class sizes.

All of these applications are useful not only for academia, but also for making on-the-job training programs more efficient. AI applications also have the potential to better prepare youth transition to the workplace through specialized work readiness programs, while helping working adults remain competitive in the workplace through customized reskilling/upskilling offerings. Experts predict great potential for AI in assessments, intelligent tutoring, the development of global classrooms, language learning, and matchmaking between the demand for and supply of skills.

AI in Manufacturing

Manufacturing offers multiple opportunities for AI technologies, with innovations encompassing both hardware and software. The top uses are:

1. Product and process engineering. This includes the use of AI in CAD (Computer Aided Design) systems to design better products in terms of function, quality, or cost. This area is by far the most promising for the manufacturing sector because of the scalability of CAD software solutions. Thus, Generative Design, which uses a mix of large databases of designs and an input of the critical parameters and functions of a given product, can automatically create a product optimized in its function, cost, and manufacturability.

2. Intelligent CAD systems can also be interfaced with process simulation tools to seek the best ways to manufacture a given product (for instance, deciding between 3D-printing or traditional molding for plastic parts). As we have already seen with traditional CAD systems, where the cost has fallen to 1 percent of what it was 20 years ago, such tools could quickly become affordable and therefore widespread—even in emerging markets.

3. Production management. AI-enhanced predictive maintenance is aimed at improving asset productivity by using data to anticipate machine breakdowns, particularly in cases when traditional statistical analysis tools have already been fully deployed and costs and benefits justify adding AI to them.

   In addition, collaborative and context-aware robots can recognize their environments, enabling them to alter their actions based on what is needed of them. And functions can be altered in real time.

4. Yield enhancements are a consequence of root cause analysis of defective products and improved manufacturing processes in real time to boost output. AI can help in the cases when traditional statistical analysis has already been fully deployed and if costs/benefits justify it. Some AI applications are being developed both in-house and by start-ups focused on the industry whenever costs and benefits analysis can justify them. As with other AI applications, access to large data sets and the involvement of data scientists, who are also technical experts in the specific application targeted, are critical to successfully deploying AI in manufacturing.

It has been proven over decades that Total Predictive Maintenance (TPM) programs can significantly reduce factory or assembly line downtime and maintenance costs. Automated, sensor-based inspection of critical parameters coupled with Statistical Process Control (SPC) is also proven to reduce online rejects significantly. In specific cases, when scale is large enough and maintenance or quality issues cannot be solved with traditional TPM or Total Quality Management (TQM) tools, AI tools could be considered. Similarly, collaborative and context-aware robots could improve productivity in specific cases.

AI in Financial Services

AI is likely to have a game-changing impact in the financial services industry in six major areas.

1. Gaining insights that can accurately predict customer behavior. An example is using AI to look at a potential borrower's past behavior and

accurately predict his or her creditworthiness. IBM Watson is just one of hundreds of applications here.

2. Early detection and prevention of cybersecurity threats. Generative Adversarial Networks can generate real and fake data sets and learn over time, increasing accuracy of identification and verification.

3. Supporting financial institutions in complying with Know Your Customer/Anti-Money Laundering (KYC/AML) regulations as AI can learn, remember, and comply with all applicable laws. This can significantly reduce operating costs in an increasingly complex regulatory world.

4. Visual identification and verification can be used to identify customers and documents, streamlining processes such as account creation and loan and insurance origination. For example, Irisguard supports customer identification.

5. Humanlike chatbots, similar to the popular Siri application, can intelligently interact with customers, answer questions, and reduce loads for customer service departments. NextIt is an example of a chatbot provider.

6. Using AI technology and data analytics to support consumer access to mortgage financing, especially for those who are informally employed and applicants with weak documentation. Aavas, a specialized housing finance company in India, relies on data analytics and AI tools to assess the creditworthiness and willingness of households with undocumented and documented incomes to repay loans received.

AI can significantly lower the cost of asset management, making it available to average investors and not just high-net-worth individuals. AI-enabled fraud detection can allow banks to accurately predict if an account is at risk. And AI can help eliminate human error from compliance processes, a challenging area for many financial institutions. From extending investment opportunities to the underbanked and the average investor, to detecting fraud and mitigating investment risks, AI has the potential to improve the financial health of people and institutions globally.

AI in Transport

Autonomous vehicles tend to dominate the discussion of AI in transportation, but the effects of AI on transportation and logistics extend far beyond AVs and even roads. An entire spectrum of transportation modes is expected to go driverless or crewless, including railways, ships, and various delivery vehicles, all of which are potentially viable in the short-to-medium term.

AI technologies have enormous potential to address challenges in transportation, particularly with regard to safety, reliability and predictability, efficiency, and environmental issues such as pollution. AI can provide innovations in traffic management for solutions to more effectively route cars and avoid accidents, crashes, and fatalities, as well assist law enforcement. Routes can be optimized to reduce traffic and increase reliability, while optimal transit networks for communities can be designed with smarter traffic signals and other transport infrastructure. Delivery routes for trucks and motorcycles in intra-city deliveries can be altered for quicker delivery times, while commute times can be reduced for individuals. All of these solutions impact pollution, as route optimization reduces fuel use and emissions for all types of transportation, including ships, trucks, and cars, among others.

The effects of AI on transportation and logistics go beyond automation and road safety management to span the entire logistics chain—from origin to final destination of cargo and goods. AI can offer shippers faster delivery times and increased reliability at lower costs to get products sent by sea from factories to land distribution centers. AI can also enable much more accurate predictions of arrival times for container ships and can spot trends and risks in shipping lanes and ports. Machine learning can help analyze historical shipping data by considering factors such as weather patterns and busy or slow shipping seasons, which can highlight inefficiencies, errors, and duplications. AI can also help provide digital chartering marketplaces for the bulk maritime industry (VesselBot already does this).

AI technologies are also being used to mimic human perception and cognitive abilities such as seeing, hearing, reading, and interpreting sensor data, and this

has benefits for user interfaces aboard ships, including speech recognition programs that directly control equipment.

Looking Forward

Recent breakthroughs in deep learning have produced AI systems that match or surpass human intelligence in certain key functions and economic sectors. The United States and China are leading the race in AI. While the capital flowing to AI start-ups is similar in the two countries, in China the average dollar amount per investment is much higher, reflecting the reality that in China, AI applications are the main focus, rather than fundamental AI development.

AI development will force societies to confront the possibility of job losses, yet studies suggest that AI will add to GDP, with emerging markets standing to benefit even more than developed countries. We expect emerging markets such as China to become adopters rather than just developers of AI, with AI applications poised to proliferate in and have a significant impact on major economic sectors. These developments will capture significant gains across the value chain, with cost savings stemming from more accurate demand forecasting and tailored and targeted user experiences. Along with the promises of AI comes the challenge of AI bias, though a growing contingent of researchers are devoted to mitigating this bias to ensure fairness in AI systems across the spectrum. ◼

Artificial Intelligence and 5G Mobile Technology Can Drive Investment Opportunities in Emerging Markets

By Peter Mockel and Baloko Makala

The intersection of artificial intelligence and 5G mobile technology has enormous potential to deliver dramatic improvements in productivity, efficiency, and cost across business sectors and broader society, delivering innovative products and services not previously possible. Although mainstream applications that combine AI and 5G have yet to be developed, key emerging markets sectors such as agribusiness, healthcare, and education will be transformed by the combination of AI and 5G. While many mobile operators remain focused on recouping their investments in previous network standards, there is a growing interest in 5G networks globally.

Artificial intelligence (AI) refers to a growing body of computational techniques relating to computer systems capable of performing tasks that would otherwise require human intelligence. Examples include the diagnosis of diseases, solving complex mathematical equations, and analyzing electronic circuits.[31]

For the purpose of this chapter, we follow the definition and description of basic, advanced, and autonomous artificial intelligence put forward in in the first two chapters of this report.[32] Essentially, AI is the science and engineering of making machines intelligent, especially intelligent computer programs.[33] This also means that AI is not one type of machine or robot, but a series of approaches, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve specific objectives.

While AI alone offers innovations, it is the combination of AI and other technologies such as 5G that has the potential to profoundly transform society as we know it. Although a majority of emerging markets have not

yet rolled out 5G networks, they can still reap some of the benefits of AI and cellular communication technology. Even with a 2G cellular network, various successful business models have developed across emerging markets.[34]

What is 5G Cellular Technology?

The mobile communication industry is on the verge of yet another technological revolution: the fifth cellular technology generation, commonly referred to as 5G. Unlike previous generations, 5G is expected to provide optimized support for a variety of different services, different traffic loads, and different end-user communities. 5G networks are anticipated to impact virtually all processes of everyday life and will be treated as critical national infrastructure.[35]

Higher spectral efficiency means that 5G networks can transmit more bits of data per second and per hertz of spectrum than previous cellular generations. This is significant because spectrum is both scarce and expensive. Higher spectral efficiency means more concurrent users can be served at lower cost.

Another key difference between 5G and earlier mobile network generations is the higher priority of Internet of Things, or IoT, applications. Earlier generations served the IoT market through mobile modems that provided full-service access for machine-to-machine applications. That provided an adequate but expensive solution for high-value use cases, for example, home alarms or industrial machinery monitoring. 5G introduces new network services dedicated to IoT that can be tailored to lower-cost and lower-bandwidth IoT applications, allowing efficient and low-cost blanket coverage of large fleets of IoT objects.
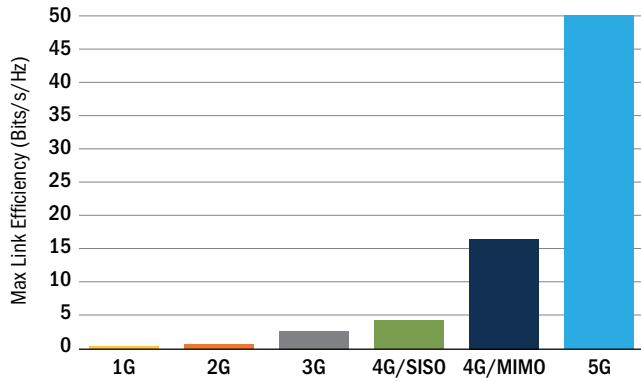
FIGURE 3.1 Spectral Efficiency of Mobile Systems

Source: Ortenga; Ortenga Blog at ortenga.com/2016-2/.
Note: SISO = single-input and single-output; MIMO = multiple-input and multiple-output.

Industrial IoT, in particular, will be an important factor in economic competitiveness. There will be a direct link between the availability of 5G network services and economic development. Economies that lack 5G technology will find themselves at a clear disadvantage. With the expansion of 5G in urban core networks around the world, consumers are already experiencing a significant increase in their data rates

as high as 1 Gigabit per second (Gbps) over the air. Below is a map of the roll-outs of 5G networks in cities around the world. Nonetheless, it is important to mention that in real-world transformation, 5G will continue to coexist with previous technologies for many years.[36]

The transition between network generations is less sharp than it seems. As existing 4th generation networks are pushed to their limit in what is referred to as 4G LTE-A (Long Term Evolution—Advanced), the step change to the first 5G networks is more gradual.

Indeed, the adoption of 5G in emerging markets will take time. In Sub-Saharan Africa, for example, 5G adoption is not imminent.[37] Mobile operators are still recouping their investment in previous technology standards. Thus, it is expected that there will not be any large-scale 5G deployment before 2025, although 5G pilot testing is already underway in many markets.[38] In Egypt, it was reported that 5G would be used during the African Cup of Nations.[39] Cellular provider Rain South Africa launched the country's first 5G network in September 2019.[40]

FIGURE 3.2 5G Deployments in Cities Around the World

Source: Ookla Interactive 5G Map. www.speedtest.net/ookla-5g-map. Note: Red indicates commercial availability, i.e., a 5G network is present and devices are available for consumers to purchase and use; purple indicates limited availability, i.e., a 5G network is present but devices are limited to select consumers; pink indicates pre-release, i.e., 5G network hardware is in place but is currently in testing and/or not yet accessible to consumers; dark blue dots indicate the number of multiple networks of any combination of red, purple, or pink that are revealed when zooming in the interactive map showing, for example, the high number of such networks in Kuwait and in and around Kuwait City.

Generation	2G EDGE	3G HSPA	3G HPSA+	4G LTE Cat 4	4G+ LTE-A Cat 6–16	5G
Maximal Speed	0.3 Mbps	7.2 Mbps	41 Mbps	150 Mbps	300 Mbps–1 Gbps	1–10 Gbps
Average Speed	0.1 Mbps	1.5 Mbps	4 Mbps	15 Mbps	30–90 Mbps	150–200 Mbps
Latency in Seconds	0.5	0.1		0.05		0.001

TABLE 3.1 Comparing Speeds of Different Generations from 2G to 5G

Source: Authors.
Note: Mbps = Megabit per second; Gbps = Gigabit per second; HPSA = high speed packet access; LTE-A = Long Term Evolution - Advanced; Cat = Category. For detailed and accessible explanations see: https://kenstechtips.com/index.php/download-speeds-2g-3g-and-4g-actual-meaning.

Across the Latin America region, as of August 2019, 18 5G trials were underway.[41] However, it is anticipated that Latin America will trail the rest of the world in terms of 5G adoption with an 8 percent adoption rate by 2025. The future of 5G in the region is dependent on macroeconomic stability, government policies, and the use of 4G.[42]

In the Asia-Pacific region, on the other hand, the lack of clear business cases and lack of demand were identified as the main impediments to 5G adoption.[43] To illustrate this, multi-party video calls are just about

practical with the current 4G networks, and they will also be one of the initial key applications for 5G, albeit with improved quality.

Beyond that, the first set of applications that are firmly outside the performance envelope of even the best 4G networks, and therefore require 5G, include autonomous driving, augmented reality, and online gaming with low latency.

Potential of AI and 5G in Emerging Markets

The world is embracing a new era characterized by breakthroughs in emerging technologies, the rise of artificial intelligence, and faster data rates, the combination of which is set to transform virtually all facets of everyday life through automation and machine-enabled decision making.

Undoubtedly, AI and 5G are set to become the engines of this new technological revolution. However, the majority of use cases that have been proposed for 5G involving AI cannot be considered true 5G use cases as they do not necessarily require a generational change. What will truly make the difference are applications that would leverage an improvement in latency reduction, that is, response times of less than 1 millisecond.

The AI and 5G journey in emerging markets will most likely involve enhancing existing use cases[44] and the development of new ones that are yet to be addressed by current technologies. There are many applications that can be made possible as a result of the combination of AI and faster data rates supported by 5G networks. These include:

BOX 3.1 5G and Latency

In networks, latency describes the time it takes for a corresponding server to reply when a packet of data is sent. It is therefore different from the speed of downloading data packets. Why does reduced latency matter? Take an example of an automobile travelling at a speed of 50 mph using 4G LTE Cat 4 with a latency of 0.05 seconds. At this speed the vehicle would travel another 1 meter before the corresponding server would respond (the distance traveled in 0.05 seconds). With 5G, that latency would be reduced by 98 percent, to just one millisecond (0.001 seconds). During this reduced time the car would only travel 2 centimeters before the server responds. It can be argued that the reduced latency is at least as powerful as the increased speed of downloading in opening up new applications, as counterparts are reached faster and can reply faster.

Enhanced Mobile Communication Network and Services. The provision of mobile communication services is becoming increasingly complex. The roll-out of 5G networks is much more challenging than previous generations as it requires upgrades in radio, edge, transport, core, and cloud infrastructure that would ideally be optimally managed with AI to address the complexity associated with 5G networks and the billions of IoT devices these networks can support.

In addition, the combination of 5G and AI will bring about a host of new or improved technology applications and services. Entertainment is expected to become richer and more social thanks to high-speed connectivity capable of delivering holograms, augmented reality, and other virtual applications.

AI and 5G represent a symbiotic combination and enable each other. 5G relies on automated optimization based on AI algorithms. 5G is too complex to work with the static, manual planning optimization of earlier mobile network generations. 5G networks change their topology dynamically, responding to changes in traffic. The better the optimization works, the more efficiently the network will perform in terms of spectrum and energy use. For example, 5G relies on Self-Organizing Network (SON) technology. SON measures radio

parameters such as path loss and throughput constantly for different frequencies, drawing conclusions about optimal performance and automatically adapting network settings.

As a result, mobile network operators are currently testing AI due to increased network complexity that requires an intelligent and automated approach.[45] It is expected that more than half of mobile operators will incorporate AI into their networks by the end of 2020.[46] According to the key findings of a study conducted by Ericsson, with 132 service providers globally as respondents,[47] AI is already being incorporated into cellular networks primarily because of a potential reduction in capital expenditures. Service providers testing AI are focused on several areas for potential improvements. These include cost reductions, network optimization, and increased revenue streams, which stand at 48 percent, 35 percent, and 41 percent improvement, respectively.[48]

Globally, Sub-Saharan Africa is the region with the highest mobile subscription growth rate. Between 2017 and 2023, subscription rates in the region are expected to grow at a compound annual growth rate (CAGR) of 5 percent, to over 900 million subscriptions. That will lead to a penetration rate of 105 percent,[49]
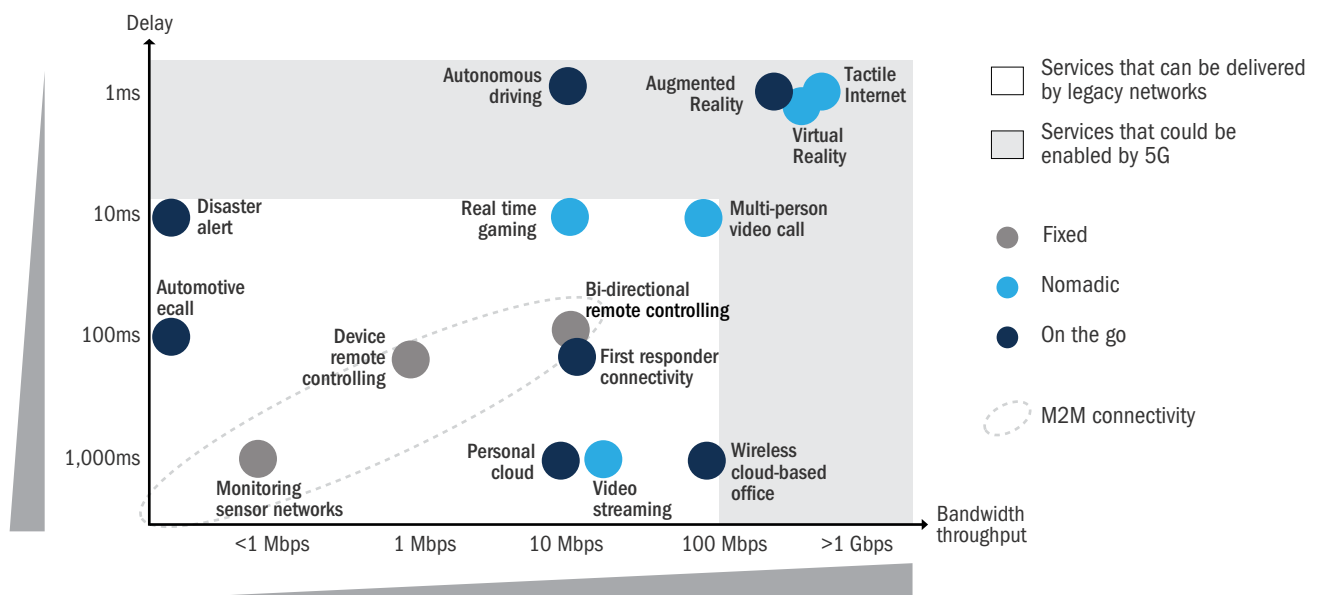
FIGURE 3.3 Bandwidth and Latency Requirements of Potential 5G Use Cases

Source: GSMA.

which indicates availability on average of more than one mobile phone per user. Digitalization is rising across the region and represents $10.5 billion in potential revenue by 2026 across key industries in Africa.[50] Affordability remains an important factor in the adoption of AI and 5G-enabled services in emerging markets. Most of the potential applications for these technologies in emerging markets hinge on the development of affordable network technologies in industries such as agriculture, education, health, mining, and others.[51]

Other examples for the pivotal role of AI in 5G network operations include:[52]

- Support Vector Machines (SVM) for path loss prediction models in urban environments.

- Machine learning for dynamic frequency and bandwidth allocation in self-organizing dense small cell deployments.

- Unsupervised learning for cooperative spectrum sensing.

And AI applications are also dependent on 5G technology, requiring its ubiquitous, high-bandwidth, low-latency connectivity. While 5G improves on bandwidth, the technology's ability to cut response times represents a qualitative improvement for AI applications: lower latency is not just a qualitative improvement for AI applications but a qualitative step change. In addition to radically reducing latency, 5G makes latency definable as a quality of service (QoS) parameter. That is, the network can guarantee response times, whereas earlier network generations delivered on a best-effort basis.

Taken together, higher bandwidth, ubiquitous availability, and guaranteed latency performance make it possible to run critical AI applications in real time. For example, vehicle-to-vehicle communication (V2V) for accident avoidance requires communication between fast-moving cars at guaranteed maximum latency.

If one car warns another car of an obstacle on the road, the system needs to rely on the message not being delayed by the network. In general, any application that requires acquisition of continuous high-volume data (for example, video) and the real-time control of assets, based on their analysis, will require a 5G network.

Furthermore, AI is deemed to be vital for improved customer service and enhanced customer experience. Because of AI, service providers anticipate recouping their investments in 5G.

Potential 5G and AI Uses

From crisis-related challenges such as responses to natural or man-made catastrophes, or using drone capability for economic empowerment through use of low-altitude sensors to improve farming yields, AI-powered applications could leverage 5G networks and by doing so deliver real societal benefits and impact.[53]

Other potential and impactful uses include:

The automotive industry, which is betting big on 5G connectivity and its potential when combined with AI. Today, virtually every major car manufacturer has developed its own autonomous vehicle. Manufacturers such as Tesla and Toyota are testing self-driving vehicles. These vehicles rely on sensors to continuously detect their surroundings, first by identifying and classifying the information (perception), followed by acting on the information through autonomous control of the vehicle. The success of this new transportation business model will depend on the availability of network coverage, low latency, and fast connection speeds.

However, one of the most promising aspects of 5G is when it is used in combination with industrial IoT. That is, IoT used in a non-manufacturing environment, for example, from windows and doors to air conditioning control hub units, and almost all objects and tools we use on a daily basis. Although 4G LTE could deliver on some of these requirements, only 5G can offer them all.

Drones are another important application. They represent a $100 billion market and have multiple applications, in particular public safety through information gathering and inspection in remote regions.[54] Drones also have been used across emerging markets to address different transport and logistical challenges.

In Argentina, for example, drones have been used in forest management to offer cost-effective, high-resolution imagery.[55] The World Economic Forum highlighted how Africa helped the drone industry get
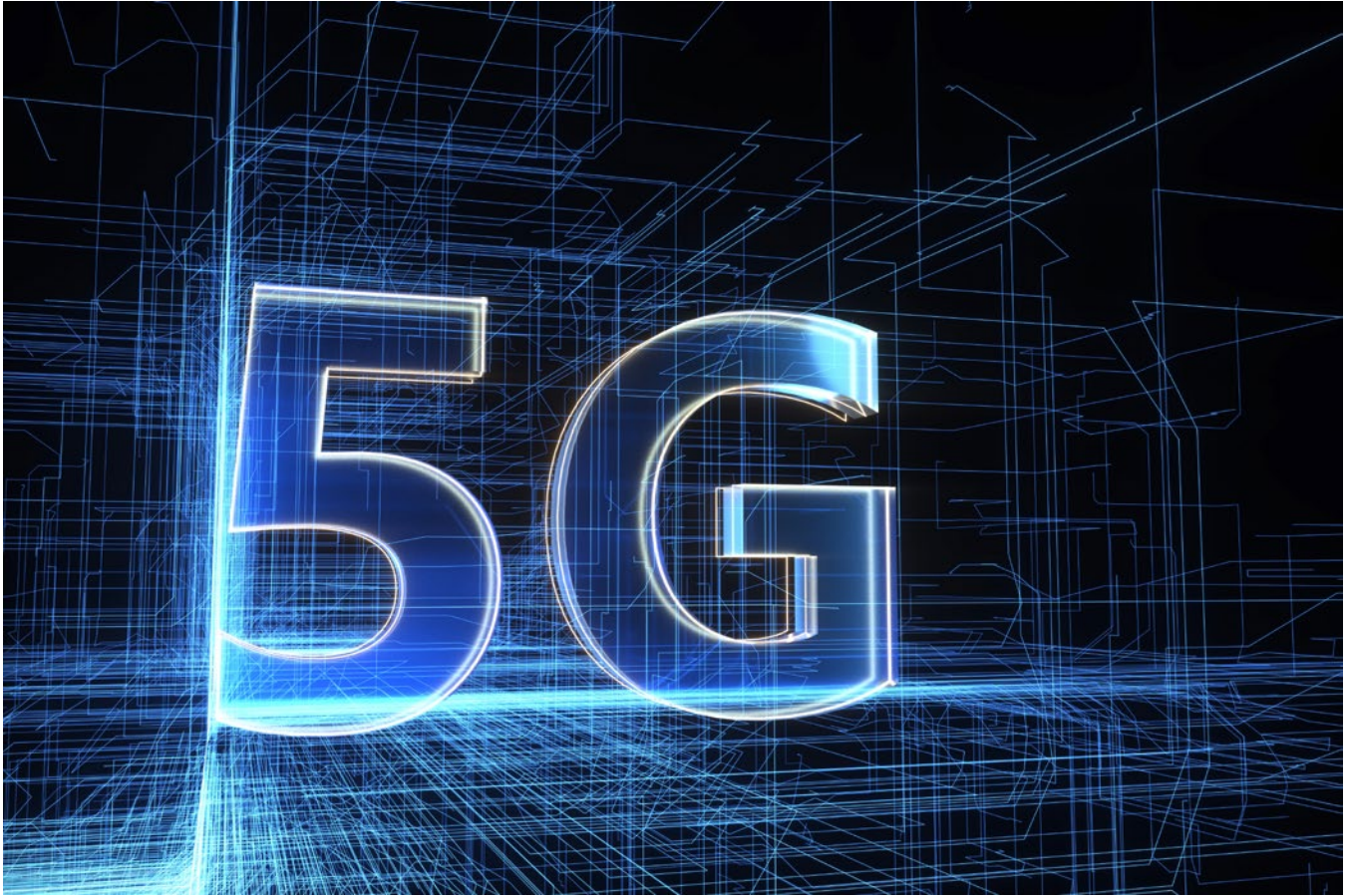
off the ground as the continent is experiencing a drone revolution, with pioneers using drones to address various challenges.[56] For example, the U.S. startup Zipline, in partnership with the Rwandan government, made headlines with the first delivery of blood supplies to remote medical facilities.

Drones require high-speed connectivity in order to perform command and control, media sharing, and autonomous flying. 5G networks are well placed to provide machine-to-machine connectivity, while meeting stringent requirements of latency, throughput, capacity, and availability.[57]

HAWK 30 drone, an Alphabet-backed project developed at the University of Hawaii, is a solar-powered drone beaming a 5G signal that can fly non-stop for six months at a time. The project is currently in testing phase.[58]

In South Korea, drone manufacturer Percepto developed drone-in-a-box systems that are designed for industrial and enterprise applications in areas such as security

optimization or business operations using aerial visual insights while reducing risk and operational costs. Percepto recently demonstrated autonomous drones using SK Telecom's 5G trial network.[59]

Public safety and security will benefit from the proliferation of IoT devices. The main impediments to the emergence of a "smart city" have been speed and bandwidth. The combination of IoT devices and 5G through advances in analytics and AI could enable applications related to public transit law enforcement. In 2017, U.S. fire and police agencies acquired drones for proactive policing. In China, at the 2019 "5G is ON" summit, the China Mobile Industrial Research Institute project, which supports firefighting with 5G drones, won a Mobile Internet Innovation Pioneer award.

Utilities and Energy. Smart meters are already commonplace in many households around the world. The modernization of smart grids is becoming imperative to reduce hydropower generation inefficiencies, predict faults, make decisions, prevent

theft, and balance power loads. Data communication has been critical to efficient power generation and consumption. AI is expected to be an important component in this effort, as the increasing use of sensors means a constant demand for faster data speeds. This could be a possible application for AI and 5G, although the energy sector appears to be following a modest adoption of 5G because of the reluctance of utilities to test new technologies.[60]

In **agriculture**, smart farming is not an option, it is a necessity if the industry is to keep pace with a growing world population, particularly at a time when crop yields are being affected by climate change. Sensor technology is already being used in agriculture through IoT devices that allow farmers to better measure critical factors such as moisture, fertilization, and weather patterns. Global technology company XAG develops drones, IoT, AI, and other digital tools to help farmers effectively grow high-quality produce without excessive pressure on the environment.[61] High speed connectivity in rural areas remains a challenge, however, which is an obstacle for 5G to address.

AI in **healthcare** offers new avenues to solve health challenges. For example, Ada Health has developed a chatbot in Swahili that helps patients and doctors diagnose diseases ranging from malaria to diabetes.[62] The combination of fast data speeds and AI could bolster healthcare quality, particularly when AI is already used in the detection of diseases or in the reduction of costs. Other applications in healthcare that would require high-speed connectivity include remote-control surgery, as well as downloading large data files. The healthcare industry generates massive amounts of data daily, including heavy imagery such as MRI, CAT, and PET scans. The resulting data, in turn, could be processed using AI for faster diagnosis and treatment. Real-time remote monitoring and sensor innovation aimed at developing do-it-yourself innovations would place medical devices in the hands of patients who would be able to monitor their health at home.[63]

The global market for AI in **education** is expected to reach $2 billion globally by 2023, which represents a 38 percent annual growth rate from 2018 to 2023. While emerging markets constitute just a fraction of this market, they are seeing growth, too. In Africa,

for example, the market for eLearning is expanding rapidly, from $530 million in 2017, it is expected to reach $1.4 billion by 2022. The use of AI is limited in this sector, but there is considerable potential.

The combination of AI and 5G can help make immersive education methods such as virtual reality possible, as many such methods require high bandwidth and low latency to perform optimally. With 5G, download speeds could be reduced to seconds, freeing teachers to use their time in other areas. In addition, IoT devices can be used to automate administrative tasks.[64]

Challenges and Next Steps

AI and 5G represent a powerful combination of technologies that will be the engine of the Fourth Industrial Revolution. However, applications that truly combine AI and 5G, and would trigger massive adoption, have yet to emerge. Also, the adoption of both technologies has associated challenges.

Artificial intelligence is already having a profound impact on business and industrial processes where machines are taking over tasks previously performed by humans. Setting aside the ongoing ethical debate around AI, it is now urgent to reskill the current labor force, and prepare the future labor force for the job displacement that will result from the intersection of AI and 5G, as together they offer a level of productivity and efficiency that humans cannot match. Therefore, the focus of retraining and reskilling should be on human skills that machines cannot model.

5G is part of a succession of cellular technology standards that have transformed the way we communicate—and indeed the way we live. Each of these generations of technology has brought about a key differentiator that has had a transformative impact on consumers' communication experiences, yet each also exhibited weakness that would be addressed by the following generation. Some of these standards are still relevant today. For example, primary 2G mobile brought digital telephony and messaging. Successful business models were built on the back of this standard. M-Pesa, a Kenyan mobile fintech application, is arguably one of the most successful business

models leveraging 2G cellular technology. However, 2G network data rates are very low and can barely support Internet connectivity. The advent of 3G and 4G connectivity enabled faster data transmission, and both standards will remain dominant in emerging markets until at least 2025, which will delay the development and adoption of 5G in those regions.

Spectrum availability is currently a challenge to the growth of 5G. The power and speed of 5G rest on the frequency used. One way to circumvent spectrum-related challenges is to use frequencies with lower bandwidths that may have advantageous properties. For instance, a frequency of 600 MHz may not lose power quickly and therefore can easily reach 5G phones, while overcoming physical obstacles such as thick walls.

Also, the 5G standard is very expensive to implement. Many mobile operators in Africa and elsewhere have yet to make an investment in infrastructure supporting 5G because of the significant capital costs involved and the lack of a clear business model that would recoup the investment. Operators would need to upgrade base stations, add new base stations, and upgrade the backhaul high-speed, high-capacity mobile access networks (4G, 5G etc.) that are often not available in emerging markets. That renders the investment hurdle even higher, as not only will operators have to implement 5G radio technology, they will also have to upgrade their networks end to end. In contrast, operators in advanced markets will have already made extensive progress.

5G also poses unique security challenges because the role of equipment integrators will be much larger than for previous generations of mobile technologies. The security risks will increase significantly as 5G architecture pushes functionality that was once at the core of networks out to the "edges" where it is more difficult to control and more vulnerable to tampering. With the sheer number of connected devices, the number of unsecured and compromised devices will increase. These could be used for nefarious purposes, for example, in the case of a distributed denial-of-service, or DDoS, attack. In addition, the volume of data generated will increase the difficulty of detecting abnormal or malicious traffic. Aside from these technical concerns, a greater share of the global economic output that would depend on the data generated will be at greater risk.[65]

Currently, AI and 5G are at the center of geopolitical tensions. These tensions have given momentum to a race for technological innovation dominance in a 5G-enabled world. Regardless of who wins that race, there is a call for close collaboration between developers and other actors in the cellular communication ecosystem to come up with solid 5G use cases and appropriate implementation models. Previous network generations will not disappear overnight because of the advent of 5G. It is therefore important for operators to devise a clear strategy toward a 5G-enabled digital ecosystem and paths to maximize returns on investment. ■

Bridging the Trust Gap: Blockchain's Potential to Restore Trust in Artificial Intelligence in Support of New Business Models

By Marina Niforos

Rapid increases in computing power and data generation have turned artificial intelligence, blockchain, and the Internet of Things (IoT) into potent technologies that are rapidly gaining use in many areas of society and commerce, with significant potential benefits for economic growth and development. These innovative technologies face multiple obstacles to implementation and—particularly in the case of AI—a general wariness of their potential implications for human society. Fortunately, an integrated implementation of the three technologies may be a solution that can restore human trust in AI and blockchain applications, resulting in new business models that deliver data security and privacy, efficiency, and inclusion along with their many other benefits.

Artificial Intelligence, or AI, designates "the science and engineering of making machines intelligent, especially intelligent computer programs…enabling an entity to function appropriately and with foresight in its environment."[66] While the technology has existed in some form for almost 60 years, it is the recent combination of deep learning algorithms, greater amounts of data, and enhanced computing power that have transformed it into a disruptive technology with enormous economic and business potential across multiple sectors.[67] The imminent deployment of 5G networks, in combination with the widespread use of IoT devices, will provide the infrastructure for faster and more stable data generation, which in turn will enable the ever more rapid development of AI technologies and spawn new business models, and will radically alter the way entire industries operate.[68]

AI already plays a critical role in optimizing processes and influencing strategic decision-making, and is expected to have enormous economic and social implications in the years ahead. Global consulting firm PwC predicts that AI will increase global GDP by an additional $15.7 trillion by 2030.[69] PwC expects China to reap the greatest economic gains from AI (a 26 percent boost to GDP in 2030), followed by North America (14.5 percent). The two combined are expected to total about $10.7 trillion and account for almost 70 percent of the global economic impact of AI.[70] According to the PwC study, developing countries are projected to see more modest gains from AI due to slower rates of technology adoption,[71] despite the fact that these markets have significant opportunities to use AI technologies to leapfrog traditional development models.[72]

AI thrives on data: the more data that is fed into its algorithms, the more intelligent they become. Yet this massive demand for, and accumulation of, data has made it necessary to find better systems for data storage and processing. Along with cloud computing, distributed ledger technology (DLT)[73] has been put forth as a potential way to store, manage, and process data generated by AI.[74] Blockchain acts as a distributed database,[75] maintained by a peer-to-peer network of users, without a central authority or intermediary, to validate business processes and act on data.[76]

DLT is a fairly new technology that has not yet attained maturity, having come into existence with the birth of bitcoin in 2008. DLTs have been gaining momentum, collecting $5.5 billion in venture capital flow through 2018, and showing equal pace in 2019.[77] Gartner forecasts that blockchain will generate an annual business value of more than $3 trillion by 2030.[78] Blockchains are more than a technical solution to solve the problem of double-spend in digital cash: "they can change the balance of power in networks, markets and even the relationship between the individual and

state."[79] The technology is being tested in cases across multiple sectors to provide secure, digital identification, to manage fraud and ensure transparency in global value chains, and to create greater transparency and efficiency in financial and government services. Yet the technology is also likely to take years and go through several transformations before it becomes mainstream.[80]

Nevertheless, this distributed form of data sharing provides some novel attributes over centralized databases, and these can be essential for addressing some of the challenges of AI, including: (i) enhanced security since there is no central point of attack; (ii) transparency and auditability, as the data is available to all participants in real time; and (iii) immutability and traceability, since its consensus-based verification makes it virtually impossible to tamper with data or obfuscate its origin. If blockchain is able to deliver these advantages at scale, with speed and cost-efficiency, it could provide an efficient and transparent infrastructure for AI data generation and processing.

The ability of blockchain to potentially provide a "trust mechanism" for AI data ecosystems is critical. There is growing mistrust among both businesses and citizens—as well as increasing perceptions of risks regarding governance—about AI data collection and usage. Awareness about the technology's strategic importance raises concerns about its ability to make important decisions in a fair and transparent way, respecting human values that are relevant to the problems being tackled.[81] Concerns about AI-powered automation and its potential threat to employment have only added to wariness about the technology.

As a result, there is a widely held desire for greater transparency and accountability with regard to AI technologies, including a call for agreed ethical guidelines for their implementation.[82] Along those lines, AI data storage systems need to be able to provide more safeguards in terms of reliability, accessibility, scalability, and affordability.[83]

The AI Trust Deficit

The AI trust deficit needs to be resolved if the technology's promises of economic growth and innovation of data marketplaces are to be realized. Fortunately, blockchain-

enabled storage systems are a potential solution, one that may be able to build and maintain trust between human communities and artificial intelligence applications designed to benefit them.

AI and Data: Need for Adapting Governance Rules

Data has been called the "new oil," as its proliferation offers staggering potential to drive economic growth and innovation. Yet unlike oil, data is not an exhaustible resource,[84] and AI algorithms can continually adapt and evolve organically with its availability. Yet as the business community becomes increasingly aware of the massive economic value of AI applications, it is also becoming clear that adapting governance rules for these emerging marketplaces is quite complex. The concept of nonrivalry of data, and the fact that data can be used by many firms simultaneously, imply increasing returns and have important implications for market structure and property rights.[85] Consumers and individual citizens are increasingly aware of the value of their personal data and are demanding greater control over its use and monetization (the focus on privacy protection by policy-makers and the proliferation of privacy laws are evidence of this). In the United States, Facebook recently received a record $5 billion fine and agreed to new layers of oversight to settle privacy violations, in addition to acknowledging it was under investigation from the Federal Trade Commission for antitrust concerns.[86]

Personal Data Marketplace: Protection and Monetization

While the vast majority of data is generated by machines, more than 10 percent of total data is created by people, which represents nearly a quarter of a trillion dollars in economic value each year for the companies able to use it.[87] It has been posited that the recognition of data property rights in favor of the consumers who generate it can be an optimal market allocation mechanism, since consumers are likely to establish a balance between the value from the sale of their data and their privacy.[88]

If data is needed to help AI make better decisions, it is important that the humans providing that data are

aware of how it is handled, where it is stored, and what uses it is put to. This is particularly important in industries like healthcare or financial services, where a high percentage of personal data generated is private and/or sensitive. In fact, customer data and profiling algorithms are already considered business assets and protected through trade secrets provisions. Yet individuals do not seem to be fully aware of the present and future value of their data and, as a result, may be allowing the "appropriation" of their digital identity.[89] Regulations such as the General Data Protection Regulation (GDPR) in Europe provide some fundamental rights over personal data. A similar discourse is taking place in the United States at present, with Senators Mark Warner and Josh Hawley having sponsored legislation in 2019 that would require the big Internet companies to regularly inform users of the personal data they collect and disclose the value of that data.[90]

IoT Data Marketplace

By 2030, the IoT data marketplace is expected to generate $3.6 trillion and 4.8 zettabytes of yearly traded data.[91] While established "data-as-a-service" (DaaS) channels exist for companies to buy and sell data, IoT data streams are much more difficult to handle, as they are less structured and come directly from devices that control critical processes and produce sensitive information, which in turn makes them vulnerable to hackers. This is particularly relevant in an IoT environment with exponential growth of devices.[92] The potential of these machine-to-machine (M2M) data marketplaces will not be fully leveraged without addressing the issues of trust and security, the two obstacles that impact organizations' willingness to sell and buy IoT data.

Blockchain: Addressing AI's Trust Problem?

At present, the majority of machine learning and deep learning methods used by AI rely on a centralized model for training in which a group of servers run a specific model against training and validating datasets. This centralized nature of AI holds some important risks, as it renders it more vulnerable to data tampering and manipulation by hackers, and the data origin and authenticity are not guaranteed.[93] Given this context,

it is critical to establish the traceability of data, and where and how data originated and was processed by AI systems. The perceived lack of transparency and accountability is holding back faster adoption despite recognition of its ability to drive business value creation. A recent report by the IBM Institute of Business Value underlines this ambivalence of the business community: 82 percent of enterprises surveyed are considering AI adoption, attracted by the technology's value creation potential, yet 60 percent of those same companies fear liability issues, and 63 percent say they lack the skills to harness AI's potential.[94]

What Can Blockchain do for AI?

Multiple AI and blockchain shortcomings could be addressed by integrating the two technologies. Blockchain has intrinsic capabilities to address concerns about AI and can unlock the potential of data marketplaces, namely by providing control over access to stakeholders, through cryptographic encryption to secure data, and with real-time auditability of the ledger visible by all participants. Enabled by blockchain, these marketplaces can restore trust and facilitate the exchange of data between buyers and sellers, potentially unlocking more than $3.6 trillion in value by 2030.[95] Conversely, AI can boost blockchain
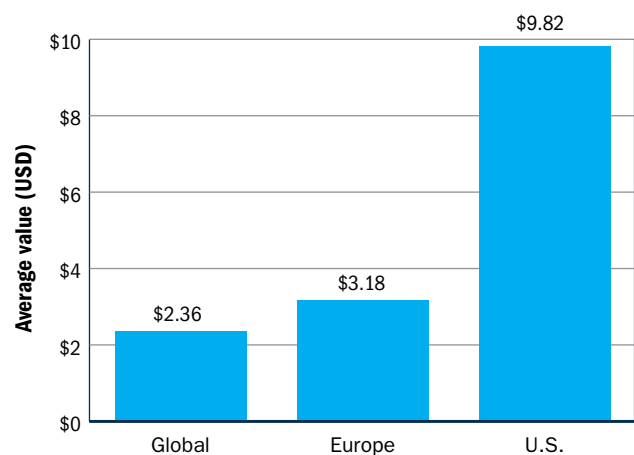
FIGURE 4.1 The Future Value of Data— Estimated Value of Data per Internet User in 2025 per month

Source: IDC's Global Data Sphere, November 2018; Facebook Annual Report 2017; Strategy & Analysis. "Tomorrow's Data Heroes," Strategy + Business. PwC. 2019. "Monetizing and Trusting Data: 2019 is the Year to Seize the Prize."

efficiency and computational power. The convergence in the implementation of AI and blockchain systems can work for their mutual reinforcement and further their respective adoption.

How Can AI Improve Blockchain Ecosystems?

Smart Contracts and Distributed Governance

As discussed in EM Compass Note 41, blockchain's ability to truly transform economic and business ecosystems will require the continuous improvement and evolution of smart contracts, which are still limited in their capability and sophistication.[96] Smart contracts are embedded in code and can receive information and take actions based on predefined rules. They can be used in numerous scenarios, from the transfer of property titles to settlement of financial derivatives, and even to empower the governance of Decentralized Autonomous organizations (DAOs). The use of deep machine learning techniques and AI agents can accelerate the evolutionary process of the algorithmic blockchain-hosted entity. By utilizing the big data acquired by everyday transactions, IoT devices, or stored information on a blockchain, and then feeding them back into the process, it can render smart contracts, encoded statutes, and the overall decision-making process more autonomous, resilient, and "intelligent." AI's massive computational power may also be able to assist with some of the persistent challenges for blockchain, namely providing more energy efficient, scalable platforms, and can even

address issues of security breaches that have occurred due to faults in the code.

Key Benefits of Blockchain Integration with AI

Enhanced Data Security

Cyberthreats are continuously evolving and AI can be a powerful tool in the hands of malicious attackers. A recent report found that adversaries will dwell in a network for an average of 86 days before they are discovered.[97] And a 2019 study by IBM Security and the Ponemon Institute found that a single data breach in the United States cost a corporate victim an average of $3.9 million.[98] The quality of data generated through AI is therefore critical. In a blockchain decentralized storage system there is no central repository of data, "no single point of failure" and once data is "on chain"—data codified on a blockchain—it cannot be altered. Still, blockchain has its technical hurdles: It remains slow and somewhat unwieldy, forcing a trade-off between security and efficiency.

Ensure Data Integrity and Privacy

One of the biggest challenges in data science today is the collection of a proper dataset that can be utilized for training a neural network.[99] The pluralism of data over the Internet is enormous, and even Internet giants such as Facebook and Google often fail to separate "signal from noise"[100]—the proliferation of fake news is evidence of this. Machine learning algorithms cannot

Blockchain	Artificial Intelligence (AI)	Integration Benefits
Decentralized	Centralized	Enhanced data security
Deterministic	Changing	Improved trust on robotic decision
Immutable	Probabilistic	Collective decision-making
Data integrity	Volatile	Decentralized intelligence
Attacks resilient	Data-, knowledge-, and decision-centric	High efficiency

TABLE 4.1 Key Benefits of Blockchain Integration with AI

Source: Salah, Khaled et al. 2019. "Blockchain for AI: Review and Open Research Challenges."

reach their full potential using inaccessible, non-secure, and unreliable data.

The de facto standard in use is a centralized client-server architecture, in which data is collected from the client (the user) and owned by the server (the company). In an IoT environment with exponential growth in the number of devices, greater throughput for machine-to-machine communication and payment channels, and the need to protect increasingly personal data, this model is inefficient, as it increases data duplication and data transfers that congest network traffic. A blockchain data management system that avoids duplication and provides transparency and traceability can permit the structuring and qualification of data that in turn makes it actionable. In addition, blockchain allows participants to have direct control over access of their data through their ID authentication and a public/private key infrastructure, thereby addressing concerns regarding potential abuse of personal data.

A recent paper from the EU Blockchain Observatory suggests that an intelligent application of criteria regarding which information to store on and off the blockchain, coupled with data obfuscation, encryption, and aggregation techniques in order to anonymize data, may help navigate some of these issues. The paper also stresses that "many of the GDPR's requirements are easier and simpler to interpret and implement in private, permissioned blockchain networks than in public, permissionless networks, where privacy can be "designed." Yet public networks are here to stay and represent a vital space of innovation that has the potential to create jobs and thriving companies."[101]

Higher Efficiency and Distributed Governance

AI can provide real-time analysis of data and decision-making on a large scale through a blockchain-enabled data registry. In a multi-stakeholder environment involving individual users, business firms, and governmental organizations, blockchain can provide a more efficient and transparent governance model for automatic and fast validation of data/value/asset transfers among different stakeholders, through the deployment of Distributed Autonomous Organizations (DAOs)[102] and smart contracts that govern the interactions of participants.

Inclusive Data-driven Business Models

Currently, the development and deployment of AI is mainly in the hands of large corporations with massive amounts of data, such as Google, Facebook, Baidu, or Tencent. These firms can amass user data to create and continuously improve AI algorithms. Users are not sufficiently aware of how the data they generate is deployed and do not share financially in the value they create (although strong arguments exist about the positive collateral benefits of platforms). This creates important asymmetries and market distortions in equitably leveraging the future development of AI. Insufficient transparency also feeds into the growing unease and lack of trust that consumers harbor about the new technology.

Blockchain could help buttress AI's trustworthiness by providing a system of decentralized ownership of data, thus breaking the oligopoly of large platforms while benefiting individual ownership and control of data. It can act as a platform to support individual rights while benefiting from the aggregation of vast amounts of data from the Internet of Things. Restoring trust in the system of data sharing can open access to vast numbers of data sources that can be used by AI developers that were previously inaccessible,[103] and can lower market barriers to new economic participants to reap the benefits of extensive predictive analysis.

Business models where both AI and blockchain converge can leverage huge computational power available through a blockchain network as a cloud-based service to analyze outcomes at a scale otherwise not possible, rendering the market more competitive and efficient. A decentralized data marketplace creates an economic mechanism for individuals and organizations to buy and sell data, reducing the incentive to hoard valuable unused data and remunerating the creators of data, not just the processors of it.

Cases that combine the power of both technologies are rapidly emerging—though they are still at early stages of development—in a wide variety of industries, from financial services, healthcare, and cybersecurity, to the creative industries, public services, and education. For example, Deep Brain, a Singapore-based foundation,

is using AI and blockchain technologies to develop a distributed AI computing platform that is low-cost and privacy-protecting to train AI. Chinese company Cortex provides a low-cost, off-chain solution for companies to do AI research.

In Hong Kong SAR, China, Datum is creating a blockchain-based marketplace where users can share or sell data on their own terms. It allows people to store duplicate copies of their data from social networks, wearables, smart homes, and other IoT devices securely, privately, and anonymously. California-based NetObjex is a smart city infrastructure platform that uses AI, blockchain, and IoT to power connected devices to cloud-based products. Cyware Labs, a U.S.-based startup, incorporates AI and blockchain-based tools into its cybersecurity and threat intelligence solutions. London-based Verisart combines AI and DLT to certify and verify works of art in real time by allowing artists to create tamper-proof certificates of work that prevent fraudulent copies from being sold as originals. U.S.-based Vytalyx and BotChain are using AI to give healthcare professionals blockchain-based access to medical intelligence and insights and to provide enhanced security of data.[104]

Global Supply Chains are Poised to Benefit

Global supply chains may have the most potential to leverage the advantages of artificial intelligence, blockchain, and IoT—and the convergence of the three. Supply chains have a high degree of organizational alignment and distinct business processes associated with supply chains, but they are encumbered by increasing complexity that puts a strain on technologies now in use.[105] Within supply chains, IoT interconnectivity has been difficult due to lack of common standards and interoperability. Each player promotes its own proprietary standards and protocols, with siloed systems the result.[106]

Trust is one of the most important features in supply chain management. IoT serves as the essential foundation for linking the physical world with the digital world through the collection and transmission of data. With the increased complexity and volume of information, decision-making requires real-time and

autonomous action, which AI can provide based on learned knowledge. Blockchain can provide the trusted registry needed to ensure AI learning is based on trustworthy and "clean" data.

Each transfer point in the supply chain tracks the status of the IoT devices and stores the data onto the blockchain. AI provides analytics and Smart Contracts with the flexibility to make decisions and trigger actions on the basis of this structured data.[107] Blockchain technology promises to accelerate the maturity of IoT and AI data exchanges by reducing the barriers to accessing data and providing a more efficient, secure, and transparent data storage and management option, creating a platform for value and asset exchange. Enterprise blockchains can develop across industry supply chains with a multitude of stakeholders breaking down silos and easing administrative procedures, both for the financial as well as the physical layer of the value chain, releasing significant amounts of untapped value.

Most of the blockchain-enabled supply chain platforms in operation today are permissioned. This fact raises concerns about potentially oligopolistic behavior—with the market dominated by a few big players—in the development of enterprise or consortia DLT solutions.[108] Additionally, on private blockchains there is a trade-off between: (i) the ability to decide access and therefore have "privacy by design" and better compliance with existing regulatory requirements; and, (ii) the reduced security robustness they afford, since by definition they are not fully distributed and have specific "gatekeepers" that can be targeted for attacks.

An important additional risk specific to AI is that a permissioned/private data management system requires the filtering of information by pre-certified parties that control access to the chain and make conscious decisions about which data goes on and off of it. The alleged implication is that these decisions may be more susceptible to explicit or implicit biases regarding information fed into the algorithms. For example, in establishing certification of persons for access to financial instruments (Anti-Money Laundering, Know-Your-Customer or others), a bias may be introduced around the characteristics of incumbent users, excluding new entrants, which could undermine

the primary goal of financial inclusion. Sufficient safeguards and vigilance should be exercised in the design of sourcing and processing information that goes into AI decision making to avoid bias.

The need for greater trust throughout global value chains has been extensively documented.[109] Blockchain, working in conjunction with IoT and AI systems, can provide a system of automated trust[110] to establish the identity of users and the origin of goods, thus ensuring the transparency of data and their use. Businesses, from food to automotive to logistics and trade finance, are developing initiatives that combine these technologies to test new business models or improve existing ones.

Stowk's and Hannah Systems are developing AI-powered blockchain-based platforms to streamline business processes in the automotive industry, improving logistics and management of autonomous vehicle fleets.

Microsoft and Adents, a supply tracking solutions provider, teamed up to develop a blockchain and AI-based product tracking platform for product distribution chains that addresses performance, security, and governance.[111] They claim an 80 percent reduction in the need for data entry related to transport documentation, streamlining required cargo checks and customs compliance.[112] Industry players are also forming consortia to test solutions and develop common standards in the food industry (FoodTrust), pharmaceuticals (MediLedger), logistics and freight management (TradeLens), and financial services (We. Trade, Marco Polo, Voltron), among others.

Looking Forward

Convergence among these new technologies is not a process that will happen immediately or in a linear progression. Adoption will take place at different paces depending on technical limitations, political and social conditions, as well as the existing business ecosystem and the pool of requisite digital skills. Blockchain, for example, is a fairly new technology, and one that is still struggling to gain acceptance.

As with any emerging technology, there are challenges and doubts about blockchain's reliability, speed,

security, and scalability. Such doubts are compounded by concerns about a lack of standardization and interoperability across blockchain systems, as well as associated regulatory uncertainty. On the other hand, proponents of artificial intelligence must also tackle mounting anxiety over the technology's rapid growth, which is sometimes perceived to be unchecked and/or unaccountable.

While AI and blockchain will not solve all problems, and there is little consensus about the contribution they will make to enhanced security and data protection, they have greater potential when they work in a complementary fashion to restore trust, both in the technology itself and with its stakeholders. Yet, important challenges remain for both AI and blockchain before they can attain real convergence—technical, regulatory, or even socio-political. In an IoT environment, enhanced connectivity will be required, including fast 5G cellular connectivity. Agreement over common industry standards will be necessary for interoperability and full network effects.

At present, blockchain struggles with scalability and is not capable of handling the enormity of data potentially generated by billions of IoT devices. Regulatory concerns will mount to address pivotal privacy issues, as well ethical considerations over the use of AI. A host of legal and regulatory challenges are associated with blockchain (see EM Compass Notes 57 and 59), including compatibility with data-privacy legislation, enforceability and jurisdiction, and legal recourse, among others. The risk to fair competition is especially pertinent for AI, given the oligopolistic concentration of the data holders, but it could also become a concern in blockchain development, given the rise of consortia in the search for standards.

In the EU, the European Commission has championed a multi-pronged approach to fostering the responsible development and deployment of AI, blockchain and 5G. A new €2.6 billion fund (Venture EU) has been established to spur investment in the fields, coupled with public investment in research and the promotion of public-private partnerships.

The EU has brought together experts from various disciplines in a European AI High Level Expert
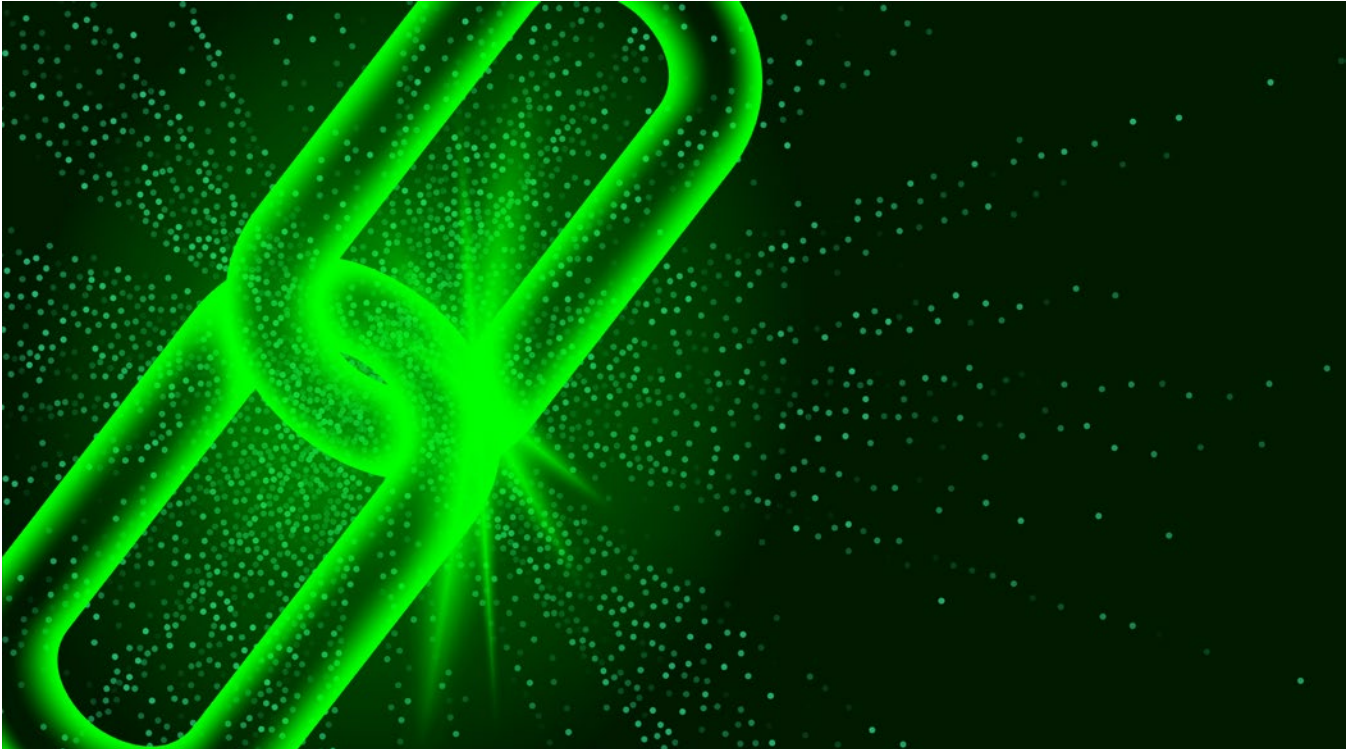
Group and the EU Blockchain Observatory to provide insights for the development of the guidelines[113] to promote the development of a human-centric approach. China has made artificial intelligence and blockchain pivotal vectors of the nation's thirteenth Five-Year Plan, and Chinese President Xi Jinping has stated China's intention of leading in blockchain innovation worldwide,[114] citing blockchain, AI, the Internet of Things and other technologies as the driving forces.[115] The United States adopted a U.S. plan (the American AI Initiative) for the strategic development of artificial intelligence,[116] promoting coordination across government agencies and providing financial means for research.

In emerging markets as well, many countries are mobilizing to articulate strategic plans concerning the development of AI (these include India, Mexico, Kenya, Malaysia, UAE, and South Korea, among others[117]). Significantly less strategic focus has been dedicated to blockchain development. In view of the increasingly dominant position of China and the United States around disruptive technologies and in particular AI, it is important to encourage a multi-disciplinary, multi-stakeholder approach that can build such a global system of trust in an inclusive manner and to the benefit of all. That system must include AI makers, AI users, and policymakers on an international basis, in order to ensure the principles of inclusive growth, sustainable development, and human-centric values for both developed and developing economies.

Such an interdisciplinary and collaborative approach would produce optimal solutions in efforts to foster a comprehensive environment for trustworthy AI. In June 2019 the G20 adopted human-centric principles, drawing from recommendations put forward by the OECD, which are well aligned with the recommendations of the High-Level Expert Group on AI appointed by the European Union. The framework for their implementation and monitoring remain to be tested in real-world scenarios. ■

Developing AI Sustainably: Toward a Practical Code of Conduct for Disruptive Technologies

By Gordon Myers and Kiril Nejkov

The adoption and diffusion of artificial intelligence and other disruptive technologies will play an important role in market creation and growth. Development finance institutions have a role to play in leveraging their investments to ensure that these technologies sustain both growth and development objectives. To this end, the authors propose adoption of a Technology Code of Conduct as a framework, supported by a set of practical tools for its operationalization, to assist IFC's clients engaged in technology intensive projects.

Artificial intelligence (AI) and other disruptive technologies, much like electricity and the Internet, are general purpose technologies (GPTs). GPTs matter for development because they contribute to innovation across the economy, resulting in exponentially higher growth outcomes.[118] Because of their broad impact, the extent to which GPTs are adopted by firms and diffused across a market depends on the quality of institutional settings and support.

A critical factor underpinning the institutional environment for disruptive technologies is trust. Consumers and stakeholders must trust that privacy will be respected, that data are used responsibly, that technologies are adopted in a way that is environmentally and socially sustainable, and that in particular, these technologies are adopted in a way that supports inclusion and equity.

Giving firms the practical risk management tools needed to develop trust is pivotal to achieving the real development promise that disruptive technologies like AI can offer (see EM Compass Notes 69 and 71). In the absence of these tools, the public conversation has focused on the very real concern that AI has a unique capacity to create harm and that AI-based innovation has accelerated beyond regulatory understanding and control. In some cases, absence of trust has already translated into market and political concern. Thus, ensuring trust has emerged as a precondition to realizing the social, commercial, and public benefits of implementing AI technologies.

There are ongoing global efforts to develop principles to guide the ethical development and use of AI and other new technologies. However, more practical guidance on managing AI risks and implementing agreed-upon principles is needed at the firm level. As a development finance institution (DFI) with clients across emerging markets, IFC is well placed to convene stakeholders to develop and deploy a Code of Conduct, together with a set of practical tools, to ensure such granular and practical guidance. IFC can play such role because of its reach to clients across emerging markets, its understanding of sustainability principles, its experience in translating these principles into practical operational guidance, and its strong history of collaborating with DFIs on frameworks designed to support sustainable, inclusive, and responsible investment. The purpose of this chapter is to explain the authors' work to date in developing a draft Code and tools, outline the next steps in refining these products, and invite interested parties' feedback.

What is AI?

AI is the science and engineering of making machines intelligent, especially intelligent computer programs.[119] AI is therefore a series of approaches, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve specific targets that can improve the provision of services.[120]

Toward a Technology Code of Conduct

Since 2018, a growing number of initiatives have supported the ethical use of AI. For example, the AI Ethics Guidelines Global Inventory, developed by Algorithm Watch,[121] lists over 80 frameworks, while the Principled Artificial Intelligence project at Harvard University developed a map of 32 ethical and rights-based approaches to AI ranging from civil society, government, international organizations, and multi-stakeholder initiatives to the private sector.[122]

Many of these frameworks reflect similar principles. Some of these principles go back to science fiction author Isaac Asimov's "three laws of robotics," articulated in the 1940s.[123] Others seem to reflect *prima facie* duties developed by a relatively small community of moral philosophers in the 1960s, including beneficence, non-maleficence (do no harm), and truth-telling.[124]

The two most important recent developments are the adoption of OECD Principles on Artificial Intelligence[125] and the European Commission (EC) Ethics Guidelines for Trustworthy Artificial Intelligence.[126] The OECD Principles are the first government-endorsed framework on AI policy. These Principles aim to provide high-level guidance on the development of the overall policy environment for AI at a national level, and to facilitate international knowledge sharing and cooperation. The EC Guidelines are more detailed and include some useful tools such as firm-level risk-assessment questionnaires designed to inform the European Union's overall approach to AI, including its strategy for investing in disruptive technologies.

The OECD Principles and EC Guidelines address five groups of issues:

- **The aspirational big-picture implications** of AI and how its design, development, and use should contribute to inclusive growth and societal and environmental well-being;

- **The implications of AI on humans** and how to embed human-centric values into the technology, most notably human autonomy and fairness;

- **Transparency and explainability** of both the AI systems and their individual outputs;

- **Technical robustness** of AI systems, ensuring their security and safety;

- **Accountability** for AI technology so that, consistent with ordinary public, legal and policy expectations, institutions and individuals involved in the AI systems lifecycle are held responsible for the operation and outcomes of such systems.

The OECD Principles and EC Guidelines have made a helpful contribution in narrowing the discussion from high-level ethical issues (like philosophical concern with the moral rightness of individuals) to more focused ones (the human-centeredness and trustworthiness of AI).

In the authors' view, these two frameworks provide an opportunity to consider the broader sustainability and inclusion aspects of AI. The immediate and ongoing benefits of sustainable AI investment can be bolstered through more granular guidance for firms in designing and adopting AI technologies.

The Proposed Technology Code of Conduct

IFC has played in important role in working with industry, investors and other stakeholders to develop standard-setting frameworks. For example, IFC's Performance Standards on Environmental and Social Sustainability,[127] the Corporate Governance Development Framework,[128] and the Operating Principles for Impact Investment[129] have been adopted as baseline standards across many DFIs and private sector investors.

In recent years, IFC clients have demanded more detailed guidance in managing the risks arising from the adoption of disruptive technologies, particularly in markets where clients move faster than regulators. That is why IFC has taken the initiative to canvass good practices and gaps in existing frameworks, and to take into consideration the needs of IFC's clients, to develop a draft Technology Code of Conduct ("the Code") and related tools to operationalize the principles of the Code.

The authors believe that the principles contained in the Code reflect the core values implicit in IFC's Environmental and Social Performance Standards

Core Values	1	**Benefit:** Technology should provide customers, individuals, and communities with access to products, services, and capabilities that benefit them.
	2	**Inclusiveness:** Technology should be designed and developed in a manner that ensures outcomes reflecting the requirements and values of individuals and communities expected to use or benefit from the technology.
	3	**Fairness:** Technology should be designed, developed and used in a fair and non-discriminatory manner. Technology providers should avoid anti-competitive or unfair commercial practices that unreasonably impede technology access and adoption.
Safeguards	4	**Transparency:** Affected individuals, communities, and stakeholders should be provided with access to information sufficient to understand the risks, opportunities, and impacts of the technology.
	5	**Informed Consent:** Affected individuals and communities should be provided with the right to give meaningful informed consent before using the technology.
	6	**Validation:** The claimed principles, norms, and outcomes of the technology should be validated by training and confirmation against scenarios and datasets appropriate to the envisioned purpose, risks, stakeholders, and implementation scale.
	7	**Security:** Technology should be designed, developed and used in line with technical and organizational safeguards sufficient to assure its secure use and protect against misuse, especially in relation to personal data.
	8	**Responsibility:** Technology providers and the technology developed shall comply with applicable law and should respect human rights. Technology providers should assist public authorities to understand the risks, impacts, and opportunities of the technology in order to develop effective policy and regulatory frameworks.
	9	**Accountability:** Technology providers should be accountable for the performance and foreseeable ethical implications of the technologies they develop and for managing evolving and emerging issues from continuous technology improvement. This includes ensuring that affected individuals and communities have recourse to judicial and administrative remedies, as well as appropriate mechanisms for consultation and redress.
Building Blocks	10	**Governance:** Technology providers should maintain governance and management systems appropriate to the purpose, scale, and potential impacts of the technology to assure reasonable control over such impacts. Technology providers should seek to avoid, minimize, and mitigate potential risks and impacts, including environmental, social, governance, and privacy risks and impacts.
	11	**Proportionality:** Application of these Principles should be scaled to risks and adverse impacts of the technology, and in the case of early stage technology providers, to their maturity, financial resources and capacity.
	12	**Continuity:** Any transfer of technology, including any licensing or joint venture arrangement, or any change in control transaction, should be made with due regard for the continued application of these Principles.

TABLE 5.1 IFC Technology Code of Conduct—Public Draft

Source: IFC.

that define IFC clients' responsibilities for managing their environmental and social risks (see Table 5.1) and provide a more useful roadmap to trust and operationalization of advanced technologies, including AI, across markets. In summary, the principles in the Code are organized into three tiers, from most conceptual to most operational:

The three Core Values—Benefit, Inclusiveness, and Fairness—provide the underlying, absolute priorities and provide a reference point for resolving potential conflicts and inconsistencies in the implementation of the safeguard and building block-level principles.

The six Safeguards—Transparency, Informed Consent, Validation, Security, Responsibility, and Accountability—build on the Core Values and provide a basis for developing concrete, practical tools, processes, and systems needed to achieve outcomes consistent with the Core Values.

Finally, the **three Building Blocks**—Governance, Proportionality, and Continuity—provide the overall framework and inform, integrate, and establish realistic expectations for the tools and approaches to be developed.

The authors have informally consulted with technology investors, other DFIs, and internal staff, including investment and ESG experts, for reaction. The reviewers noted that the Code strikes an appropriate balance between being both aspirational and operational and is neither overly intrusive nor unworkably abstract. They also felt that the Code would add value, support public trust, and provide a framework for sustainable investment in AI-based innovation.

The authors incorporated several revisions following this initial feedback. For example, the authors have clarified that compliance with applicable law is required in markets where the legal framework is well developed. At the same time, the Code should facilitate technological neutrality and identify areas for self-regulation. Revisions have also been made to ensure that the Code and the tools can be implemented—especially by investors—in a way that does not create disproportionate financial or operational burdens on investee companies, especially early-stage ones. Importantly, the tools must be flexible enough to be customized across use cases, for example, by industry, company maturity, and product type.

Operationalizing the Technology Code of Conduct

For the Technology Code of Conduct to be impactful, it must be underpinned by practical tools. To develop these tools, the authors analyzed 35 of the over 80 existing AI frameworks that are supported by practical tools and mapped these existing tools against the Code principles. Such mapping was used to identify good practices and gaps and develop a draft framework of key tools that client companies can use to implement the Code. Finally, a draft Progression Matrix was developed, identifying expected practices in relation to each principle of the Code for different stages of company maturity: from minimum acceptable practice for emerging companies, to expected practices for later stage companies, to leadership practices for mature companies.

Analysis of the good practices and gaps in existing tools

The authors believe that operationalization of the Code requires tools that address both the technical processes, such as privacy and compliance by design, and the business processes, such as risk governance and reporting. The authors have accordingly grouped the tools in these two categories. Obviously, some of the tools fit both categories, and the originators of the tools may not agree with the proposed classification, which is put forward only for easier analysis for the purposes of this chapter.

The 10 technical tools analyzed (Table 5.2) generally address practices related to the principles of Fairness, Transparency, and Validation.

As applied to AI, in relation to Fairness, the technical tools help their users determine whether data is complete and properly formatted and whether the datasets are representative of the AI live environment. For example, there are several notable cases where facial recognition algorithms have been trained on datasets containing a larger percentage of white, male faces, leading them to perform poorly on black women.

		Toolkit Format			Target Users			Relevance to Code of Conduct											
		Code	Workflow	Audit Software/Platform	Business	Developers	Others	Benefit	Inclusiveness	Fairness	Transparency	Informed Consent	Validation	Security	Responsibility	Accountability	Governance	Proportionality	Continuity
1	Aequitas Bias and Fairness Audit Toolkit			▲	✔	✔				•	•		•						
2	AI Explainability 360 Open Source Toolkit by IBM			▲	✔	✔	✔			•	•		•						
3	AI Fairness 360 Open Source Toolkit by IBM			▲	✔	✔	✔			•	•		•						
4	Deon	▲	▲			✔				•									
5	Fairness Flow by Facebook		▲	▲		✔				•			•						
6	Fairness Tool—Accenture		▲	▲		✔				•			•						
7	LF AI Foundation ML workflow		▲			✔				•	•		•	•					
8	Lime			▲		✔					•					•			
9	TransAlgo			▲		✔					•								
10	What-If Tool—Google			▲		✔	✔		•				•						

TABLE 5.2 Selected Technical Tools to IFC Technology Code of Conduct—Public Draft

Source: IFC.

Similarly, some hiring tools have not scored women fairly for technical positions, such as engineers, by comparing CVs to the existing, predominantly male, universe of engineers.

In relation to Transparency, the technical tools assist with the ability of AI systems to explain their decisions in a way that is comprehensible to humans. Examples include describing how lending algorithms take social-media connections into account and give better rates to people with "higher quality" networks.

Lastly, in relation to Validation, the technical tools assist with human interpretation of AI outputs by regularly testing for inaccuracies or discrimination in an AI system's conclusions and developing plans for responding to user complaints or potential harm caused by the AI system.

The authors' analysis also suggests that the technical tools analyzed do not yet sufficiently address the principles of Benefit, Responsibility, Accountability, and most notably, Governance. The draft Code and supporting tools focus on filling these gaps.

The 25 business process tools analyzed (Table 5.3) are much more diverse, both in terms of their format and their target users. Given that the business tools are much more comprehensive, the authors have focused on consolidating and leveraging the good practices embodied in these tools. For example, existing tools for policy makers are useful references for developing good practice guidance for operationalization of the Responsibility principle. Similarly, the existing business process tools that target technology professionals can provide guidance on how to comprehensively address end-to-end risks within the overall AI project development cycle—from design and development checklists to auditing tools.

Lastly, there is also room for better customization of some of the well-known business and investment-decision making tools (for example, BCG matrix, Porter's Five, SWOT, and PEST) to more systematically address the specific risks of AI applications.

#	Tool	Principles	Guideline/Directive	Worksheet	Questionnaire	Recommendation	Matrix	Heatmap	Checklist	Policymakers	Tech Providers	Business Decision Makers	Others	Benefit	Inclusiveness	Fairness	Transparency	Informed Consent	Validation	Security	Responsibility	Accountability	Governance	Proportionality	Continuity
1	AI4People's Ethical Framework	▲				▲				✔				•		•	•	•	•	•		•	•		
2	Singapore PDPC: AI Governance Framework		▲							✔	✔	✔				•	•		•				•		
3	Data Ethics Principles	▲			▲						✔	✔		•			•	•			•	•			
4	Data Ethics Decision Aid (DEDA) by Utrecht			▲							✔	✔				•	•	•			•	•			
5	Data responsibility guidelines by UN		▲										✔					•		•					
6	Digital Ethics by CIGREF								▲		✔				•	•		•	•			•			
7	Digital Impact Toolkit—Stanford	▲		▲									✔			•		•	•			•			
8	Dubai: AI Ethics and Principles and Toolkit	▲			▲					✔	✔	✔		•	•	•						•			
9	Ethical. Safe. Lawful A toolkit for AI projects	▲			▲							✔				•				•	•				
10	Ethically Aligned Design—2nd Edition IEEE	▲	▲							✔	✔	✔		•	•	•	•	•	•	•		•			
11	Ethics and Algorithms Toolkit (GovEx)	▲						▲		✔					•	•	•		•			•	•		
12	Use of Artificial Intelligence in judicial systems (EU)	▲				▲							✔		•	•	•		•						
13	IBM: Everyday Ethics for Artificial Intelligence	▲				▲					✔			•		•		•				•			
14	Guidance Data Ethics Framework (UK Gov)	▲		▲						✔	✔	✔					•		•		•	•			
15	Online Ethics Canvas			▲							✔				•										
16	AI -RFP Template	▲	▲								✔	✔				•	•	•	•	•		•			
17	People + AI Guidebook by Google	▲		▲							✔						•		•				•		
18	Responsible AI Practices (Google)	▲				▲					✔				•		•	•	•	•		•			
19	Risk Analysis Info Identification (RoundTable Tech)						▲				✔	✔								•					
20	The Advocacy Toolkit	▲							▲	✔	✔			•	•					•					•
21	Ethical Design Framework for Social Impact (Georgetown)	▲			▲								✔	•	•		•	•	•	•			•		
22	The Data Maturity Framework - University of Chicago	▲		▲		▲						✔											•		
23	The Good Technology Standard (GTS:2019-Draft-1)	▲									✔														•
24	IBM Trusted AI	▲									✔	✔					•	•		•		•			
25	Understanding artificial intelligence ethics and safety (Alan Turing Institute)	▲							▲		✔	✔					•	•		•		•			

TABLE 5.3 Selected Business Process Tools Mapped to IFC Technological Code of Conduct—Public Draft

Source: IFC.

Progression Matrix and Model Documents

Bearing in mind the above identified key gaps and good practices of the existing AI tools, the authors propose development of a Progression Matrix and selected model documents to operationalize the Technology Code of Conduct.

The Progression Matrix provides details on the technical and business processes that client companies should adopt, in relation to each of the principles of the Code and subject to client companies' financing stage and maturity. An extract of the Matrix is available at the end of this Note (Annex 1) and the full Matrix is available on page 44. The Progression Matrix details the practical implications of the Code's principles for different types of companies and anticipates development of good practice model guidance for adopting companies. Some of the model documents the authors plan to develop include:

- **Well-Being Impact Assessment**—a conceptual framework (for example, based on Maslow's hierarchy of needs) to identify beneficial and unbeneficial components of AI systems;[130]

- **Stakeholder Engagement Plan**—with defined principles of stakeholder engagement, stakeholder mapping, and practical steps;[131]

- **Bias Impact Assessment**—a set of questionnaires for assessment, review, and disclosure of AI systems' potential impact on fairness among affected communities;[132]

- **Privacy by Design**—a reference framework for privacy protection and information management that can be applied from specific technologies to whole information ecosystems and governance models.[133]

Conclusion and Next Steps

Adoption of the Technology Code of Conduct will help build trust with customers and ensure that AI technologies are human-centric. The Code will also support sustainability and impact, including investment by the impact investing community, by ensuring that AI systems contribute to the well-being of individuals, societies, and the environment.

The authors invite feedback on the proposed Code and Progression Matrix to ensure that the Code reaches its full potential as a practical tool for sustainable innovation. This is to incorporate and balance, from the outset, input from the investor, company, regulator, and civil society communities, before engaging in more formal and systematic consultation. The next step would be to test the draft principles and guidance, in a sandbox-type partnership with selected client companies, to confirm the practical usefulness and impact of our approach. The authors' hope is that donors, impact investors, and other DFIs will see value in cooperating in these efforts.

Finally, the authors hope to launch the Code iteratively, to assure rapid rollout and continuous improvement by supporting establishment of a community of stakeholders, similar to the Equator Principles.[134] Expressions of interest in participating in these efforts is welcome. Please send all feedback and expressions of interest to ifctechnologycode@ifc.org. ∎

IFC Technology Code of Conduct— Progression Matrix—Public Draft

Core Values

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
1. BENEFIT Technology should provide customers, individuals, and communities with access to products, services, and capabilities that benefit them.	BUSINESS PROCESS	Commercially viable product providing benefits to as many customers, individuals, and communities as possible	*Same*	*Same*
		No inherent harm that cannot be sufficiently minimized, mitigated, or responsibly accepted in the context of the industry and relevant social norms	Clearly articulated purpose of using the technology for the benefit of individuals, communities, and the environment; and not causing harm to individuals, communities, or the environment. All potential benefits and risks, with relevant mitigants, clearly documented	**Full Well-Being Impact Assessment** (for example, based on the Maslow Hierarchy of Needs) developed, with regular updates
	TECHNICAL ASPECTS	Product performs intended function consistently and correctly	*Same*, and guards against immediate negative side effects of technology incorporated into product design	Product design addresses potential indirect and negative longer-term impact of adoption
			Feedback about user experience incorporated into product design to increase benefit provided by product	Product continually updated to maximize benefit based on user experience and feedback

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
2. INCLUSIVENESS Technology should be designed and developed in a manner that ensures outcomes reflecting the requirements and values of individuals and communities expected to use or benefit from the technology.	BUSINESS PROCESS	Consultations with users and beneficiaries inform product design	Regular and formalized consultations to assure outcomes consistent with community and consumer expectations, and their systematic integration into product design	**Best-practice stakeholder engagement**, including with specifically affected communities
		Diversity of technical and business staff involved in product design, and of management and governance functions	**Same**, and specialized forms of consultation with vulnerable categories (children, individuals with disabilities, elders without IT literacy, etc.)	**Same**
	TECHNICAL ASPECTS	Product fulfills a need identified by user base	**Same**, and feedback about user experience (UX Design) incorporated to increase benefit provided by product	**Same**, and transparent use of appropriate, real-time feedback mechanism; appropriate AB testing to maximize usability
		Product can be used by all members of the intended user base	**Same**, and product enables access to individuals and groups with disabilities or similar access challenges	**Same**, and product is customized to maximize usability given a specific user profile, such as accommodating language spoken
		Datasets used are representative of most intended users and use cases	Underlying dataset is largely representative of the world the product will operate in	Underlying dataset is representative of the world the product will operate in; updated continually as new user profiles/edge cases are identified
3. FAIRNESS Technology should be designed, developed and used in a fair and non-discriminatory manner. Technology providers should avoid anti-competitive or unfair commercial practices that unreasonably impede technology access and adoption.	BUSINESS PROCESS	Potential discriminatory impact of the technology on various individuals, groups, and communities identified, mitigated, and disclosed	**Same**, and the identified impacts, mitigations, and disclosures clearly documented and regularly reviewed with all product iterations and in response to new information	**Full Bias Impact Statement** developed
			Governance body tasked with proactive risk assessment of emerging public and policy concerns and fairness considerations, including in relation to use of personal data and tax impact on markets	**Same**, and responsible tax practices consistent with relevant international best practice such as OECD, BEPS etc.
				Proactive **fairness and reputational risk assessment** integrated into robust compliance function
	TECHNICAL ASPECTS	Product does not derive insights or knowledge from protected classes, including indigenous or historically disadvantaged communities, without their knowledge or compensation	**Same**	**Same**
		Product uses heterogeneous data set (for example, collecting data from a variety of reliable sources)	**Same**, and **industry standard toolkits** used to identify and address potential bias (using agreed-upon definition of fairness to determine what constitutes objectionable results)	**Same**, and mechanism for continuous bias testing and related response of incorporated into design; repeated for any updates
		Algorithmic bias risks considered in development or acquisition of tools	**Same**, and outcomes of bias testing iterated into product improvement	**Same**

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
4. TRANSPARENCY Affected individuals, communities, and stakeholders should be provided with access to information sufficient to understand the risks, opportunities, and impacts of the technology.	**BUSINESS PROCESS**	High-level disclosures on the application of the **Technology Code of Conduct** to public—in any terms of use; and to investors—in any fundraising	**Same**, and integrated into privacy disclosure of the company	**Same**, and plain language explanation readily available to the public and as part of regular integrated reporting of the company
		Detailed periodic reporting on the application of the **Technology Code of Conduct** to governance body and investors	**Same**, and ability to explain individual decisions in a manner understandable by human expert	**Same**, and transparency by design, for example, with embedded reporting capacity and metrics
		Any material concerns relating to the **Technology Code of Conduct** are mitigated and/or escalated to management, as practical	**Same**	**Same**
	TECHNICAL ASPECTS	No algorithms used in the product are a "black box" and all underlying documentation is available for review	**Same**	**Same**
		Developers understand which factors are relevant for decision making and the general process by which those decisions are made	Developers and other experts can trace how any algorithm used makes individual decisions (for example, by using the **LIME package**)	**Same**
			External post-hoc explanation is available: observing output and reverse internal explanation; And counter-factual explanation: how specific factors influence algorithmic decisions	**Same**, and supplementary explanatory infrastructure, with immediate, easily understandable explanations of any decision making incorporated into regular use of the product, and shown to user automatically or upon request
5. INFORMED CONSENT Affected individuals and communities should be provided with the right to give meaningful informed consent before using the technology.	**BUSINESS PROCESS**	Notify individuals that their data are collected and for what purpose, in compliance with applicable law	**Same**, and easily understandable, plain-language consent language, with examples available to users	**Same**, and intuitive and customized for the different types of users; and design Terms of Service as negotiable to consumers (with company determining "deal-breakers" or non-negotiable conditions ahead of time)
			Users have the ability to request information update and to be able to provide consent again	**Same**, and conditional and dynamic consent, with downstream consequences (positive and negative) explicitly called out; and make easily available personal data management tools

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
INFORMED CONSENT *(continued)*	**BUSINESS PROCESS**		Data are not used to make sensitive inferences, infer traditional knowledge or practice, or make important eligibility determinations without the free prior informed consent of the individuals or communities concerned	*Same*
				Affirmative consent (on a rolling basis): initial consent based on currently available information, can be revoked at any time as information is being updated
	TECHNICAL ASPECTS	Product does not use any data obtained illegally or without consent	*Same*	*Same*, and identification technologies used to assure user control over data sharing and use preferences, including possible compensation
		Any algorithms used are not trained on datasets containing data obtained illegally or without consent	*Same*	*Same*
		If applicable, interface presents user with terms of service before use; user must agree before they are allowed to engage with product	*Same*, and terms of service are presented clearly, without any unnecessary barriers to comprehension (for example, requiring user to link to another page or zoom in on small text)	*Same*, and users are automatically re-prompted for consent when encountering a new use case or when organization plans to use their data in new ways; and any terms presented are clear, readable, and customized for maximum comprehension based on the available information on user
		If the technology involves "affective systems": opt-in policy with explicit consent	*Same*	*Same*
		Company business plan outlines roadmap for managing data, privacy, and consent issues	Project team assesses and mitigates data, privacy, and consent issues raised by proposed product offering	Company undertakes **Privacy Impact Assessment** on project, product, service, program level; and these cover various aspects of privacy, including personal information, personal behavior, personal communications, location.
				Appropriate AB testing employed to maximize engagement/understanding of terms
				Integration of tech solution such as value-based identity management system

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
6. VALIDATION The claimed principles, norms, and outcomes of the technology should be validated by training and confirmation against scenarios and datasets appropriate to the envisioned purpose, risks, stakeholders, and implementation scale.	BUSINESS PROCESS	Validate algorithms on separate dataset overseen by separate data team and report the findings to management and governance body	*Same*, and periodic validation, including in response to specific concerns and emerging risks	*Same*
		Limitations and assumptions of the system, as well as data sources are fully documented	*Same*, and the following is also documented: data used to train the system, algorithms and components used; results of behavior monitoring	*Same*, and such documentation is in line with methodology approved by the Board and reviewed by independent third party
	TECHNICAL ASPECTS	Any algorithms perform within acceptable window of accuracy (as determined for the use case) and consider appropriate information when making decisions	*Same*, and in known cases where algorithm fails, developers understand why (to trace root-causes in case of caused harm)	*Same*, and product failures are extremely rare and promptly addressed when identified
		Dataset contains no known pollution	*Same*, and data provenance record in place to trace the potential data update, missing and error cause by data transformation within the organization	*Same*, and validation methodologies and outcomes audited by an independent party
			Different data sets are required for training, testing, and validation	*Same*
			Behavior is constant under constant conditions	*Same*

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
7. SECURITY Technology should be designed, developed, and used in line with technical and organizational safeguards sufficient to assure its secure use and protect against misuse, especially in relation to personal data.	BUSINESS PROCESS	Key security vulnerabilities throughout operational lifetime of the technology (data pollution, physical infrastructure, cyber-attacks, etc.) understood and addressed	*Same*, and such understanding properly documented, including the corresponding controls	*Same*, and regularly checked/updated and integrated into comprehensive risk governance system reflecting "three lines of defense"
			Security maturity assessed in line with industry good practices (such as NIST or similar)	*Same*, and such documentation is in line with methodology approved by the Board and reviewed by independent third party
	TECHNICAL ASPECTS	Product contains no significant known security flaws	*Same*, and product designed with consideration of potential security risks	*Same*, and ISO or similar process certifications in place
			Targeted stress testing performed for high-likelihood/risk scenarios	*Same*, and comprehensive stress testing performed regularly, results implemented quickly and effectively

		Expected Practices for EMERGING COMPANIES	Expected Practices for LATER STAGE COMPANIES	Expected Practices for MATURE COMPANIES
8. RESPONSIBILITY Technology providers and the technology developed shall comply with applicable law and should respect human rights. Technology providers should assist public authorities to understand the risks, impacts, and opportunities of the technology in order to develop effective policy and regulatory frameworks.	**BUSINESS PROCESS**	Compliance with applicable law (NOTE: this is cross-cutting requirement relevant for all the other principles, most notably: Transparency, Informed Consent and Accountability)	*Same*	*Same*
			Positive response to asks for engagement with the community	*Same*, and proactively engaging with stakeholders including regulators and civil society to identify and manage risks, impacts, and opportunities
	TECHNICAL ASPECTS	Product developed with safeguards to not support illegal activities	*Same*, and use of industry best practice methodology for efficiently flagging and addressing suspicious activity	*Same*, and working with other members of the ecosystem to develop industry leading detection and removal technology for objectionable content
		Escalation mechanisms, including product development checkpoints, for modifying product if found to be supporting such illegal activities	*Same*	*Same*
		Data/other evidence could be extracted from system if requested by law enforcement	*Same*, and data can be easily extracted and explained to law enforcement or the general public when requested	*Same*, and effectiveness of processes periodically audited by independent third party
				Features proactively designed to minimize misuse and toxic behavior; updated continuously in response to data on engagement
9. ACCOUNTABILITY Technology providers should be accountable for the performance and foreseeable ethical implications of the technologies they develop and for managing evolving and emerging issues from continuous technology improvement. This includes ensuring that affected individuals and communities have recourse to judicial and administrative remedies, as well as to appropriate mechanisms for consultation and redress.	**BUSINESS PROCESS**	Company-level redress mechanism exists and does not impede access to judicial and administrative remedies	*Same*, and sophistication of redress mechanism scaled to the risks and adverse impacts and primarily focused on affected individuals and communities	*Same*, and reporting to the affected individuals and communities on the effectiveness of the redress mechanism
		Sufficiently independent function responsible for receiving and addressing concerns including escalation to management	*Same*	Fully independent function, reporting directly to Board, tasked exclusively with redress mechanism responsibilities
	TECHNICAL ASPECTS	Product team is equipped to modify product, if necessary, in response to results of redress process	*Same*, and method for submitting requests for redress is built into product	*Same*, and redress mechanism is highly intuitive, and presents clearly at the time a request would be likely
		Record of parties responsible for work on different products/features exists in case problems emerge	User can access data about their experience with product that could be relevant in a judicial or administrative remedy	*Same*, and relevant information for a redress case is clearly and easily available to user; suggestions are made for what information would be potentially relevant
			Modifications due to reported issues implemented quickly and effectively	Appropriate AB testing to maximize usability of these systems

		Expected Practices for **EMERGING COMPANIES**	Expected Practices for **LATER STAGE COMPANIES**	Expected Practices for **MATURE COMPANIES**
10. GOVERNANCE Technology providers should maintain governance and management systems appropriate to the purpose, scale, and potential impacts of the technology to assure reasonable control over such impacts. Technology providers should seek to avoid, minimize, and mitigate potential risks and impacts, including environmental, social, governance, and privacy risks and impacts.	BUSINESS PROCESS	Governance body and investors give innovation and technical teams clear direction on the values and norms to be promoted in the technology design, reflecting the **Technology Code of Conduct**	Technology provider has developed a full **Risk Governance Framework**, reflecting the **Technology Code of Conduct**, comprising: risk identification, high-level and detailed risk assessment, risk mitigation (through policies and procedures, training and communication), monitoring, reporting, and third-party audit	***Same***, and has established governance functions with appropriate level of independence, including a second line of defense role for programmatic implementation of the Risk Governance Framework, to support staff and supply them with methodology on how to consider the principles of the Technology Code of Conduct
		Sufficient knowledge and understanding of risk issues addressed in the **Technology Code of Conduct** on all levels of the organization, from individual teams to management, governance bodies, and investors	***Same***, and Board reviews effectiveness of Risk Governance Framework at least annually.	***Same***, and Board adopts **maturity roadmap on key risks**, mapped to business plan milestones, reflecting NIST-type frameworks and disclosed in fundraising documents

The EM Compass Note 80, *Developing Artificial Intelligence Sustainably: Toward a Practical Code of Conduct for Disruptive Technologies* to which this addendum refers can be found here: www.ifc.org/EMCompassNote80_TCoC.

ARTIFICIAL INTELLIGENCE IN SPECIFIC SECTORS

Chapter 6

Artificial Intelligence in the Power Sector

By Baloko Makala and Tonci Bakovic

The energy sector worldwide faces growing challenges related to rising demand, efficiency, changing supply and demand patterns, and a lack of analytics needed for optimal management. These challenges are more acute in emerging market nations. Efficiency issues are particularly problematic, as the prevalence of informal connections to the power grid means a large amount of power is neither measured nor billed, resulting in losses as well as greater CO_2 emissions, as consumers have little incentive to rationally use energy they don't pay for. The power sector in developed nations has already begun to use artificial intelligence, or AI, and related technologies that allow for communication between smart grids, smart meters, and Internet of Things devices. These technologies can help improve power management, efficiency, and transparency, and increase the use of renewable energy sources.

The use of AI in the power sector is now reaching emerging markets, where it may have a critical impact, as clean, cheap, and reliable energy is essential to development. Energy sector challenges can be addressed over time by transferring knowledge of the power sector to AI software companies. When designed carefully, AI systems can be particularly useful in the automation of routine and structured tasks, leaving humans to grapple with the power challenges of tomorrow.

Access to energy is at the very heart of development. Therefore, a lack of energy access—which is the reality for one billion people, mostly in Sub-Saharan Africa and South Asia—is a fundamental impediment to progress, one that has an impact on health, education, food security, gender equality, livelihoods, and poverty reduction.

Universal access to affordable, reliable, and sustainable modern energy is one of the Sustainable Development Goals (SDGs). Yet it will remain just that—a goal—unless innovative solutions and modern technologies can overcome the many energy-related obstacles that plague emerging markets, from a lack of sufficient power generation, to poor transmission and distribution infrastructure, to affordability and climate concerns. In addition, the diversification and decentralization of energy production, along with the advent of new technologies and changing demand patterns, create complex challenges for power generation, transmission, distribution, and consumption in all nations.

Artificial intelligence has the potential to cut energy waste, lower energy costs, and facilitate and accelerate the use of clean renewable energy sources in power grids worldwide. AI can also improve the planning, operation, and control of power systems. Thus, AI technologies are closely tied to the ability to provide the clean and cheap energy that is essential to development.

For the purposes of this note, we follow the definitions and descriptions of basic, advanced, and autonomous artificial intelligence that were put forward in EM Compass Note 69.[135] AI refers to the science and engineering of making machines intelligent, especially intelligent computer programs. AI in this note is a series of approaches, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve specific targets in energy.

Toward a Smart Power Sector

The power sector has a promising future with the advent of solutions such as AI-managed smart grids. These are electrical grids that allow two-way communication between utilities and consumers.[136] Smart grids are embedded with an information layer that allows communication between their various components so they can better respond to quick changes in energy demand or urgent situations. This information layer, created through widespread installation of smart meters and sensors, allows for data collection, storage, and analysis.[137]

Phasor measurement units (PMUs), or synchrophasors, are another essential element of the modern smart grid. They enable real-time measurement and alignment of data from multiple remote points across the grid. This creates a current, precise, and integrated view of the entire power system, facilitating better grid management.

Paired with powerful data analytics, these smart-grid elements have helped improve the reliability, security, and efficiency of electricity transmission and distribution networks.[138,139] Given the large volume and diverse structures of such data, AI techniques such as machine learning are best suited for their analysis and use.[140] This data analysis can be used for a variety of purposes, including fault detection, predictive maintenance, power quality monitoring, and renewable energy forecasting.[141]

Innovation in information and communications technologies (ICT), cloud computing, big-data analytics, and artificial intelligence have supported the proliferation of smart metering. The widespread use of smart meters and advanced sensor technology has created huge amounts of data that is generated rapidly. This data requires new methods for storage, transfer, and analysis. For illustration sake, with a sampling rate of four times per hour, one million smart meters installed in a smart grid would generate over 35 billion records.[142]

The use of smart grids in EM countries lags advanced economies, but several EM countries have taken steps to adopt them, with various level of development. These include Brazil, China, Gulf Cooperation Council (GCC) countries, Malaysia, South Africa, Thailand, and Vietnam, among others.

Deep learning techniques, a subset of machine learning, can help discern patterns and anomalies across very large datasets—both on the power demand and power supply sides—that otherwise would be nearly impossible to achieve. This has resulted in improved systems, faster problem solving, and better performance.

Advanced economies are leading the way in the application of AI in the power sector. For example, DeepMind, a subsidiary of Google, has been applying machine learning algorithms to 700 megawatts of wind power in the central United States to predict power output 36 hours ahead of actual generation, using neural networks trained on weather forecasts and historical wind turbine data.[143]

Deep learning algorithms are also able to learn on their own. When applied to energy data patterns, the algorithms learn by trial and error. For example, in Norway, Agder Energi partnered with the University of Agder to develop an algorithm to optimize water usage in hydropower plants.[144] Water may appear to be a seemingly endless source of energy, however only a limited amount of it is available to produce hydroelectricity, so it must be used optimally.

In Canada, Sentient Energy, a leading provider of advanced grid monitoring and analytics solutions to electric utilities, was selected in 2017 to support power and natural gas utility Manitoba Hydro. Its *Worst Feeder Program* initiative is anticipated to allow Manitoba Hydro to speed up system fault identification and restore power to customers faster at the most critical points on its distribution grid.[145]

AI can also help with prediction issues in hydroelectricity production. In general, most countries do have reliable hydrology data collected over a 40-year period, and in some cases, longer, that facilitates the prediction of hydrology using proven stochastic dual dynamic programing tools. However, in the past year climate change has disrupted such predictions. Currently, the mathematical models underlying the operation of power production are approximately 30 years old and are generally incompatible with the current realities of the hydro power sector.[146] The increasing uncertainty of parameters such as future precipitation levels or pricing are among the many challenges to optimizing production and profit.

AI Business Models in Emerging Markets

According to a November 2019 International Energy Agency (IEA) report, some 860 million people around the world lack access to electricity.[147] Around three billion people cook and heat their homes using open fires and simple stoves fueled by kerosene, biomass, or coal.[148] Over four million people die prematurely of illnesses associated with household air pollution. For these reasons, the provision of energy goes beyond mere

power supply: It is critical to human health and safety.[149] Renewables will play an important role in increasing access to electricity, which is one of the SDGs. According to World Bank data, the global electrification rate stood at 88.9 percent in 2017.[150] In terms of sustainability, while the share of energy from renewable sources (including hydroelectric sources) rose from 16.6 percent in 2010 to 17.5 percent in 2016,[151] these sources of power have yet to be widely adopted. This is partly because renewables present a particular challenge to the power grid due to their intermittency and difficulty to plan for in real-time.
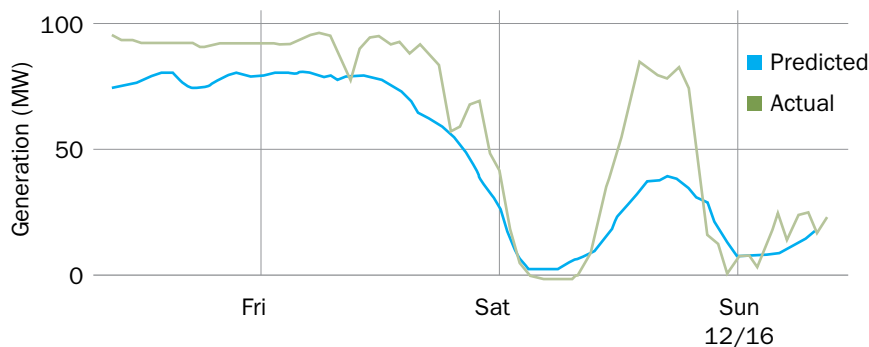
FIGURE 6.1 Example of DeepMind Predictions vs Actual in December 2018

The DeepMind System predicts energy output 36 hours ahead using neural networks, and recommends how to create optimal commitment on the grid. Source: Witherspoon, Sims and Will Fadrhonc. 2019. "Machine Learning Can Boost the Value of Wind Energy."

BOX 6.1 Anti-Theft Technology in Brazil

Ampla, an electric power distribution subsidiary of Brazil's Enel Group, an IFC client, operates in 66 municipalities of the State of Rio de Janeiro and serves nearly seven million inhabitants and 2.5 million customers. It is one of the largest power distributors in Brazil, responsible for 2.5 percent of the nation's energy turnover and 27.8 percent of the state's. It serves an area of 32,608 square kilometers, some 73.3 percent of the state territory. The Ampla market has a residential profile, with 80 percent of its clients in low-density, high-complexity areas.

Ampla has long been plagued by loss of power due to fraud and theft, with more than half of it concentrated in five municipalities, all of which are populous favelas with high rates of urban violence and drug trafficking. The high rate of non-technical losses (i.e., via theft) damages the quality of Ampla's services, the safety of the population, and also pushes national energy production above levels needed by the market and the formal economy, causing waste.

To address these theft and power-loss issues, Ampla deployed an Anti-Theft Machine Project for medium voltage customers. The system gathers all the elements of power use measurement through digital meters into a single device that connects to Ampla through a remote management system using cellular communication networks. The devices are intelligent modules with diverse functionalities, and once a day they transmit accurate consumption information to Ampla for efficient remote management of supplies, disruptions, and reactivations. Artificial intelligence is used in the control center to identify unusual patterns relative to customer profiles located in similar areas. This data is also used to anticipate consumer behavior and predict which customers are likely to have informal connections to the power grid. This information can then be used to curb such connections and cut waste. Brazilian business magazine *Exame* named Ampla's anti-theft system one of the top ten innovations of the last decade in Brazilian industry.

AI tools' speed, robustness, and relative insensitivity to noisy or missing data can address this by improving the planning, operation, and control of the power system. In doing so, AI can facilitate the integration of renewable energy into power systems to create hybrid low-carbon energy systems.[152] Thus the shift to renewables can occur at a much faster rate with the use of AI.[153]

India, in particular, has been recognized for its efforts to expand renewable energy production. Currently, India has an installed capacity of 75GW from various renewable energy sources (wind, solar, etc.), and it has a target of 175GW from renewable sources by 2022.[154] Despite regulatory efforts aimed at incentivizing clean energy investments, the diffusion and expansion of renewable energy remains a challenge. AI is being considered as a potential solution to boost renewable energy adoption.[155]

The increasing expansion of intermittent wind and solar generation, together with variable electrical loads such as electric cars and buses, energy storage (batteries), and decentralized renewable power such as rooftop solar PV systems, will need a more stable grid or smart grid.

A smart grid is able to learn and adapt based on the load and amount of variable renewable energy flowing into the grid.

AI-Supported Models in Fragile and Low-Income Countries

New business models built on AI are emerging that target underserved geographical areas where access to electricity remains a daily challenge. For example, Power-Blox is a distributed energy system fitted with battery cubes that can store 1.2 kilowatt-hours of solar or wind energy, and a single unit can serve several people. This solution can be scaled to multiple units to power an entire village.

FlexGrid is another example that builds an off-grid solution for rural villages. The company secured a grant from Electrifi, a European funding body, to establish a testing site in a remote community in Southern Mali where more than 10,000 villages lack

access to the electrical grid. Customers are charged a fixed rate in a tiered pricing structure, which is based on their ability to pay, and payments are made using a text-based system. Currently, Power-Blox is being integrated with Internet of Things (IoT) protocols to integrate remote control of the boxes.[156]

How Can AI Support Large Integration of Renewable Energy?

Excess solar or wind power is stored during low-demand times and used when energy demand is high. AI can improve reliability of solar and wind power by analyzing enormous amounts of meteorological data and using this information to make predictions and decisions about when to gather, store, and distribute wind or solar power. AI is also used in smart grids to help balance the grid. AI analyzes the grid before and after intermittent units are absorbed and learns from this to help reduce congestion and renewable energy curtailment.[157]

AI is also gaining ground in Latin America. Argentina has embarked on a modernization of its power grid infrastructure by investing in automation of power distribution, remote reading of energy meters across several cities, and the implementation of renewable energy generators.

In Baja California, IFC is helping CENACE (Centro Nacional de Control de Energía) model the effect of cloud coverage on solar generation to help balance the grid with batteries. The AI algorithms developed help the ISO react in seconds to provide primary regulation to stabilize the grid.

In much of Sub-Saharan Africa, access to home electricity remains a challenge. Africans spend as much as $17 billion a year on firewood and fuels such as kerosene to power primitive generators.[158] There are glimmers of hope, however. Azuri Technologies developed a pay-as-you-go smart-solar solution used in East Africa and Nigeria. Azuri's HomeSmart solution is built on AI. It learns home energy needs and adjusts power output accordingly—by automatically dimming lights, battery charging, and slowing fans, for example—to match the customer's typical daily requirements. The company recently secured $26

million in private equity investment to expand its solutions across Africa.[159]

AI Applications in the Power Sector

Fault prediction has been one of the major applications of artificial intelligence in the energy sector, along with real-time maintenance and identification of ideal maintenance schedules. In an industry where equipment failure is common, with potentially significant consequences, AI combined with appropriate sensors can be useful to monitor equipment and detect failures before they happen, thus saving resources, money, time, and lives.[160]

Geothermal energy, which yields steady energy output, is being discussed as a potential source of baseload power (the minimum amount of power needed to be supplied to the electrical grid at any given time) to support the expansion of less reliable renewables. Toshiba ESS has been conducting research on the use of IoT and AI to improve the efficiency and reliability of geothermal power plants.[161] For example, predictive diagnostics enabled by rich data are used to predict problems that could potentially shut down plants. Preventive measures such as chemical agent sprays to avoid turbine shutdowns are optimized (quantity, composition, and timing) using IoT and AI. Such innovations are important in a country like Japan, which has the third largest geothermal resources in the world, especially in the face of decreasing costs of competing renewable sources such as solar power.

Maintenance facilitated by image processing. The United Kingdom's National Grid has turned to drones to monitor wires and pylons that transmit electricity from power stations to homes and businesses. Equipped with high-resolution still and infrared cameras, these drones have been particularly useful in fault detection due to their ability to cover vast geographical areas and difficult terrain. They have been used to cover 7,200 miles of overhead lines across England and Wales. AI is then used to monitor the conditions of power assets and to determine when they need to be replaced or repaired.[162]

Energy Efficiency Decision Making. Smart devices such as Amazon Alexa, Google Home, and Google Nest enable customers to interact with their thermostats and other control systems to monitor their energy consumption. The digital transformation of home energy management and consumer appliances will allow automatic meters to use AI to optimize energy consumption and storage. For example, it can trigger appliances to be turned off when power is expensive or electricity to be stored via car and other batteries when power is cheap or solar rooftop energy is abundant. With population growth and urbanization in emerging markets and the resulting expanding of cities, artificial intelligence will play a pivotal role in this effort by using data—including grid data, smart meter data, weather data, and energy use information—to study and improve building performance, optimize resource consumption, and increase comfort and cost efficiency for residents.[163]

Furthermore, in deregulated markets such as the United States, where consumers can choose their energy providers, AI empowers consumers by allowing them to determine their provider based on their preferences of energy source, their household budget, or their consumption patterns. Researchers at Carnegie Mellon University have developed a machine learning system called Lumator that combines the customer's preferences and consumption data with information on the different tariff plans, limited-time promotional rates, and other product offers in order to provide recommendations for the most suitable electricity supply deal. As it becomes more familiar with the customer's habits, the system is programmed to automatically switch energy plans when better deals become available, all without interrupting supply.[164] Such solutions can also help increase the share of renewable energy by helping consumers convert their preference for renewables into realized demand for it, and can be used to signal to producers the level of consumer demand for renewable energy.

AI can help improve forecasts of electricity demand and generation, improving production decision making. This is particularly important in the transition to renewables, as they are often inconsistent due to their dependence on weather, wind, and water flows, and their reliance on fossil fuels for backup. AI-based forecasts combined with energy storage infrastructure

can reduce the need for such backup systems.[165]

Finally, the spread of distributed generation means that consumers will now contribute to power generation, effectively acting as producers (prosumers). As these prosumers become more important players in the system, AI will facilitate decision making about optimal times for distributed generation to contribute to the grid, rather than draw from it. AI can also assist traditional producers and system operators who will now have to balance increased intermittent renewables, distributed generation including prosumers, and new demand-side trends such as the increase in electric vehicles (EVs).

Disaster Recovery. When Hurricane Irma struck South Florida in 2017, it took 10 days to restore power and light, as opposed to the 18 days needed for the region to recover from a previous hurricane, Wilma. This time reduction was due to new technologies such as AI that can predict the availability of power and ensure it is delivered where it is most needed without negatively impacting the system. Furthermore, AI systems can improve assessments of damages and optimization of decision making thanks to faster access to imagery and information—within the first 12 to 24 hours—after the disaster has subsided.[166]

Prevention of Losses Due to Informal Connections. Losses due to informal connections to the power grid constitute another challenge for the power sector. AI could be used to spot discrepancies in usage patterns, payment history, and other consumer data in order to detect these informal connections. Furthermore, when combined with automated meters, it can improve monitoring for them. It can also help optimize costly and time-consuming physical inspections. For example, Brazil, which has been suffering from a high rate of nontechnical losses that include informal connections and billing errors, has benefited from such solutions. Furthermore, the University of Luxembourg has developed an algorithm that analyzes information from electricity meters to detect abnormal usage. The algorithm managed to reveal problem cases at a higher rate than most other tools when applied to information over five years from 3.6 million Brazilian households. The technology is slated to be deployed across Latin America.[167]

Looking to the Future

While AI holds considerable potential to improve power generation, transmission, distribution, and consumption, energy sectors in both emerging markets and advanced economies continue to face multiple challenges in terms of efficiency, transparency, affordability, and the integration of renewable energy sources in power systems.

First, AI companies have expertise in math and computer science, but they often lack the knowledge needed to understand the specifics of power systems.[168] And this problem is more acute in emerging markets. While the potential applications of AI in the power sector are multiple and varied, there is a need to educate the AI industry more deeply on the aspects of the power sector. For example, cloud-based applications are widespread and central to AI solutions, but there are regulatory restrictions on their use in the power industry. This is changing, however, as the benefits of AI cloud applications become more evident.

Second, the reliance on cellular technologies limits AI's potential in rural and other underserved areas in many emerging markets, particularly low-income countries. Smart meters rely on constant data communication, so a lack of reliable connectivity is a substantial impediment in areas where cellular network coverage is sparse or limited.

Third, the digital transformation of the power grid has made it a target for hackers. The world's first successful attack of this kind happened in Ukraine in 2015, leaving thousands without power.[169] Successful cyberattacks on critical infrastructure can be as damaging as a natural disaster. The growing threat from hacking has become common and a matter of significant concern, particularly due to the fact that smart metering and automated control have come to represent close to 10 percent of global grid investments, equivalent to $30 billion a year dedicated to digital infrastructure.[170]

Fourth, integrating different data sources and ensuring representativeness given the diversity within the data will be challenging. Other challenges may also arise as a result of a low volume of data for machine learning models to learn from. Contextualization and transfer
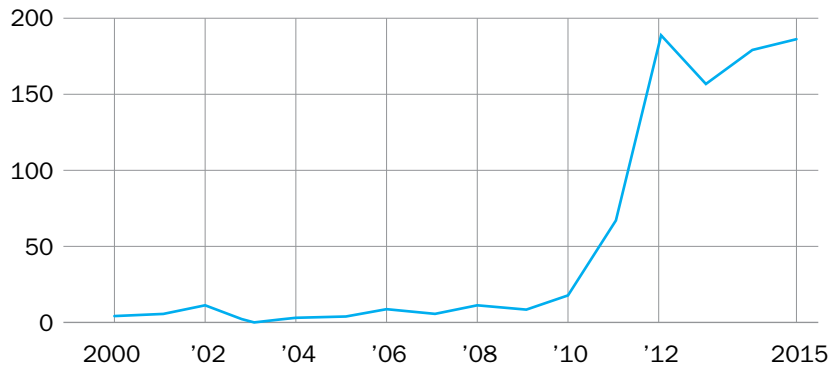
of learning of two similar tasks could prove to be difficult. Furthermore, these models could be susceptible to inaccurate data. These challenges are being partly addressed through reinforcement learning.[171]

Fifth, AI-based models are essentially black boxes to their users, the majority of whom do not understand their inner workings nor how they were developed, which constitutes a security risk. And given that existing models are far from perfect, it is necessary to have safeguards in place when incorporating them into energy systems. When combined with better analytics, sensors, robotics, and IoT devices, AI can be used for automation of simple tasks, allowing humans to focus on the unstructured challenges.[172]

Sixth, there has been an imbalance in priorities and therefore in investments in smart meters compared to smart grids. As Figure 6.3 illustrates, much of the attention has fallen on Smart meters. Smart meters are decision making tools for customer choice. Customers can decide when to turn their power on or off or change their consumption habits, during peak times for example.

FIGURE 6.2 Cyber Vulnerabilities

Identified cyber vulnerabilities in industrial-control systems have spiked in recent years. Source: Kaspersky Labs. Fickling, David. 2019. "Cyberattacks Make Smart Grids Look Pretty Dumb." Bloomberg.com. June 17, 2019. https://www.bloomberg.com/opinion/articles/2019-06-17/argentina-blaming-hackers-for-outage-makes-smart-grids-look-dumb.
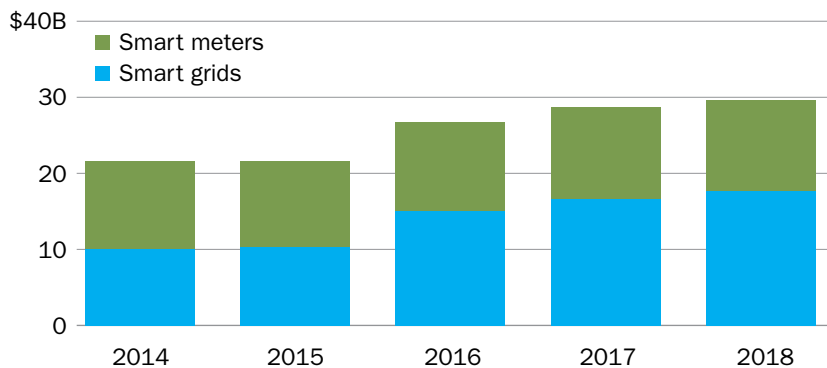
FIGURE 6.3 Smart Grid Expenditure 2014–2019 ($ billions)

Source: International Energy Agency. Mahendra, Ravi. 2019. "AI is the New Electricity." Smart Energy International. May 11, 2019. https://www.smart-energy.com/industry-sectors/new-technology/ai-is-the-new-electricity.

Smart grids, by contrast, are less about the consumer and more about making quick adjustments to ensure the electricity flows as efficiently as possible, for instance in case of disruption due to a faulty line, or imbalances brought along by variable renewable energy penetration.[173]

Finally, similar to other sectors that are increasingly applying AI technology, the power sector will need to address challenges such as governance, transparency, security, safety, privacy, employment, and economic

impacts. AI is certain to play an important role in reducing distribution losses in emerging markets and in helping with maintenance and reliability issues. AI will also help with integration of intermittent renewables into the grid and will give operational autonomy to distributed energy resources and micro grids. Given the fact that AI innovation is being driven primarily by the private sector, IFC could play an important role in bringing AI to the power sectors of emerging markets. ∎

How Artificial Intelligence is Making Transport Safer, Cleaner, and More Reliable and Efficient in Emerging Markets

By Maria Lopez Conde and Ian Twinn

Transport in emerging markets often faces acute challenges due to poor infrastructure, growing populations, urbanization, and in some regions rising prosperity, which increases vehicle traffic, cargo volumes, and pollution. Artificial intelligence offers new solutions to these challenges by making market entry easier and allowing countries to reach underserved populations, creating markets and private sector investment opportunities associated with them.

Artificial intelligence, or AI, is already having a profound impact on the way we interact with the world around us. As a powerful set of technologies that can help humans solve everyday problems, AI has significant applications in several fields.

One such field is transport, where AI applications are already disrupting the way we move people and goods. From scanning traffic patterns to reduce road accidents and optimizing sailing routes to minimize emissions, AI is creating opportunities to make transport safer, more reliable, more efficient, and cleaner. There are multiple applications of AI in both advanced economies and emerging markets that exemplify the contributions these evolving technologies can make to economies, though challenges the technology poses must be managed effectively.

What is AI?

AI has made substantial progress in the six decades since it was established as a discipline. Recently, AI advancements have accelerated, supported by an evolution in machine learning, as well as improvements in computing power, data storage, and communications networks.[174]

For the purpose of this note, we follow the definition and description of basic, advanced, and autonomous artificial intelligence that were put forward in EM Compass Note 69.[175] This also means that AI is not one type of machine or robot, but a series of approaches, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve specific targets that can improve various modes of transport.[176]

AI in transport

Market size

AI has already begun to dramatically change the world economy and will likely continue to do so. AI advances could add some $13 trillion to global economic output by 2030, according to analysts.[177] This includes the transport sector, where AI is expected to drive additional disruption. In 2017, the global market for transportation-related AI technologies reached $1.2 to $1.4 billion, according to estimates from global research firms. It could grow to $3.1 to $3.5 billion by 2023 (see Figure 6.1), registering a compound annual growth rate (CAGR) of between 12 and 14.5 percent during 2017–2023, according to studies from P&S Market Research and Market Research Future.[178] The rapid growth of this market is driven by the many benefits AI can deliver to transport, including increased efficiency, pedestrian and driver safety, and lower costs. In 2017, North America is estimated to account for the largest share in the global AI transportation market, at 44 percent.[179]
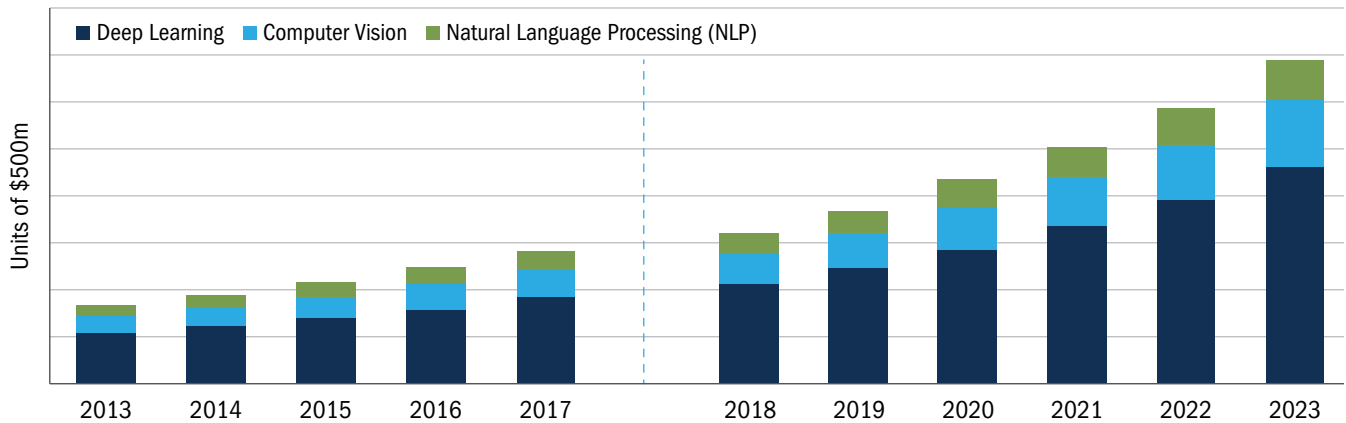
FIGURE 7.1 Global Artificial Intelligence in the Transportation Market by Technology, 2013-2023 (US$ Millions)

Source: Prescient & Strategic Intelligence. 2018. "AI in Transportation Market Overview."

Opportunities for AI interventions

Though autonomous vehicles, or AVs, get much media attention, AI applications in transport go far beyond driverless vehicles and are already having impact. On a much broader scale, AI can help solve a variety of problems in transport related to safety, reliability, and predictability, as well as efficiency and sustainability.

Safety: Road safety for both drivers and pedestrians is a major public health issue. Road traffic-related deaths reached 1.35 million in 2016, up from 1.25 million in 2013.[180] Most of those deaths occurred in low-income countries.[181] While inadequate infrastructure—in particular, poor roads and vehicles without modern safety equipment—plays a role in the high death toll, human error is an important contributor. In the EU, human error (speeding, distraction, and drunk driving) plays a part in more than 90 percent of accidents on roads. More than 25,000 people lost their lives in these types of accidents in the EU in 2017.[182] Researchers believe that AVs could reduce traffic fatalities by up to 90 percent by 2050 in some developed countries.[183] Tesla's first attempt at an AV reduced accident rates by 40 percent when self-driving technologies were activated.[184] While AVs may not be ready for mass deployment in emerging markets in the short term, some ambitious estimates project there will be 10 million AVs on the road by 2020, with 1 of 4 cars being driverless in 2030.[185]

Reliability and predictability: As an enabler of the movement of people and goods, transport is dependent on consistent performance and the ability to forecast arrival and departure times. In public transport, providing timely and accurate transit travel time information can attract ridership and increase satisfaction of transit users.[186] The World Bank's Logistics Performance Index (LPI) includes timeliness as one of its six dimensions of trade to develop an indicator for a country's supply chain management. Uncertain and unreliable infrastructure, as well as congestion, have an impact on reliability and predictability. Urban mobility solution providers, such as Uber and Lyft, use AI in multiple ways to provide reliable pickup and drop-off times for their routes, and such technologies can be harnessed to improve the quality of public transport solutions globally. One example is Via, which is licensing its technology to the New York City Department of Education to design smart bus routes and provide transparency on pickups and drop-offs.[187]

Efficiency: Developing countries often rank low on the LPI because logistics expenditures as a percentage of GDP are usually higher, partly due to a lack of efficiency caused by inadequate infrastructure and poor customs procedures. Whereas developed countries usually spend between 6 and 8 percent of GDP on logistics, these costs can range from 15 to 25 percent in some developing countries.[188] AI can help optimize movements

in order to maximize efficiency. In particular, the field of e-logistics—in which Internet-related technologies are applied to the supply and demand chain—also incorporates AI in several ways, such as matching shippers with delivery service providers.

Environmental: The transport sector worldwide is responsible for 23 percent of total energy-related CO_2 emissions.[189] Without sustained mitigation policies, emissions from the sector could double by 2050.[190] AI technology that reduces the number of inefficient trips at sea and on the road by optimizing routes can improve fuel efficiency and reduce greenhouse gas emissions. One eco-friendly AI application is truck platooning, a technique that connects several trucks wirelessly to a lead truck, allowing them to operate much closer to each other safely, realizing fuel efficiencies.[191]

How does the provision of AI-supported business models differ in emerging and advanced economies?

The adoption of AI technologies differs across industries and geographies. AI offers the promise of rapidly increasing productivity, but progress has not been even across the board. Some industries are at the vanguard of AI adoption partly because AI applications are more obvious for them. These sectors include healthcare, financial services, and transportation. Nevertheless, there is much variation in adoption across regions due to the state of infrastructure, scientific research, and the talent needed to implement AI solutions. Many EMs lag in the building blocks that enable AI, such as semiconductors, advanced telecommunication networks, and open-data repositories. On the other hand, mature economies with established technology firms and research institutes have created ecosystems that are conducive to AI development; such ecosystems are not be present in many EMs.

While the United States is the global leader in AI development, China is leading the way in AI investment and adoption in EMs, with efforts on both the private sector and public sector fronts. On the public sector side, the Chinese government launched an AI strategy reaching to 2030, while private players such as search

company Baidu and ridesharing app Didi are heavily investing in AI research.[192] Though other EMs may not lead in producing these technologies, as users of the technologies they can harness the power that AI can unlock, adapting them to their own contexts.

In addition, AI solutions can help EMs leapfrog development. AI-powered technology can allow small players with few assets and little capital to tap into existing resources, such as a city's truck drivers or motorcycle couriers, in order to provide efficient solutions for their clients. This can disrupt traditional business models and bring more cost-efficient solutions to sectors ripe for technological advances. This is already happening in the e-logistics space and can be beneficial in EMs, where barriers to starting a business, such as access to capital, are high.

Emerging market start-ups and mature business in the transportation space are already starting to digitalize their businesses or build new tech-enabled business models altogether (such as e-logistics and e-mobility). With these data building blocks, on which AI applications can be further developed, comes the opportunity for further development and application of AI to optimize reliability, predictability, and efficiency.

Mature Economies—Sample Use Cases

In advanced economies, there are several transport subsectors in which AI is already making a significant impact.

Urban mobility: Small-scale autonomous bus trials have been implemented around the world, in places as diverse as Finland, Singapore, and China. Autonomous shuttles are already operational in Norway, Sweden, and France.[193] One example is Olli, a self-driving electric shuttle by Local Motors, an American company powered by IBM Watson. Olli is the first AV to use IBM's Watson and its Internet of Things database to analyze the surrounding traffic and make decisions based on that data.[194] Besides driving itself, Olli also provides its passengers with restaurant and weather information. Olli has been trialed in several U.S. cities. Ride-hailing and sharing platform Uber uses AI for driver and ride matching, route optimization, and driver onboarding.[195]

BOX 7.1 Examples of AI Models Finding their Way into the Transport Sector

1. Artificial neural networks (ANNs):
Description: They are inspired by the neural networks found in a human brain. They use previous experience and data points with varying weights to make decisions. ANNs can handle complex problems as they operate with large amounts of data, detecting nonlinear relationships. *(Gharehbaghi, Koorosh. 2016. "Artificial Neural Network for Transportation Infrastructure Systems." MATEC Web of Conferences, 81 (05001), 2016.)*

Uses: Some more sophisticated Global Position Systems (GPS) use ANN to determine the mode of transportation being used by gathering data from a GPS, an accelerometer, and a magnetometer. This is analogous to humans "feeling" distance by considering several data points. Furthermore, ANN models can be used in public transport to help predict arrival times for buses at stop areas. *(Gurmu, Zegeye Kebede, and Wei Fan. 2014. "Artificial Neural Network Travel Time Prediction Model for Buses Using Only GPS Data." Journal of Public Transportation, 17(2), 2014.)*

2. Artificial Immune System (AIS)
Description: This algorithm takes its inspiration from human biology, specifically, how human bodies react to disease-causing agents known as antigens. AIS models the feature extraction, pattern recognition, learning, and memory of human immune systems.

Uses: AIS are useful for pattern recognition, anomaly detection, clustering, optimization, planning, and scheduling. Engineers have used AIS to create a real-time regulation support system to help public transport networks find solutions when the network experiences a disturbance. *(Masmoudi, Arij, Sabeur Elkosantini, Sabeur Darmoul, and Habib Chabchoub. 2012. "An Artificial Immune System for Public Transport Regulation." HAL, August 2012.)*

3. Fuzzy Logic Model
Description: Modeled after human decision-making, fuzzy logic assigns data with numeric values between 0 and 1 to denote uncertainty. TutorialsPoint. "What is Fuzzy Logic?" Artificial Intelligence Tutorial. This system has been used for over 30 years and is best for situations with ambiguous conditions where the consequence

for each action is unknown. *(Chattaraj, Ujjal, and Mahabir Panda. 1999. "Some Applications of Fuzzy Logic in Transportation Engineering." Lecture, Department of Civil Engineering, National Institute of Technology, Rourkela. Scientific American, 1999. "What is 'Fuzzy Logic'? Are There Computers That Are Inherently Fuzzy and Do Not Apply the Usual Binary Logic?" October, 1999.)*

Uses: Fuzzy logic has potential for modelling traffic and transportation planning problems, as they are ambiguous and vague. It also has traffic control applications, as it can signal time at a four-approach intersection and determine for how much time cars should be stopped. *(Chattaraj, Ujjal, and Mahabir Panda. 1999.)*

4. Ant Colony Optimizer (ACO)
Description: This algorithm simulates ant colony behavior: the way ants choose their paths based on their own wish to take a short route and pheromones that relay the experience of other ants with each path. *(Kazharov, Asker, and V Kureichik. 2010. "Ant Colony Optimization Algorithms for Solving Transportation Problems." Journal of computer and Systems Sciences International, 49(1) pp. 30–43.)* This mechanism helps ants find the quickest course between two points. In computer science, this problem is also called the Traveling Salesman Problem, in which a salesman must visit X towns and return to the starting point using the path with the minimum cost.

Uses: ACOs can be used for better routing of public transport buses, as well as ride-sharing platforms that pick up various users, such as Via or Uber Pool.

5. Bee Colony Optimization (BCO)
Description: Similar to ACO, this algorithm takes the collective foraging movements of honeybees as an example of organized team work, coordination, and tight communication. The bees' movements inside the hive help scientists optimize movements for machines. *(Kaur, Arvinder, and Shivangi Goyal. 2011. "A Survey on the Applications of Bee Colony Optimization Techniques." International Journal on Computer Science and Engineering, 3(8) 2011.)*

Uses: BCO can be used to optimize travel routes, diminishing travel times, number of waits, delays, and air and noise pollution.

Traffic management operations: Many AI algorithms are well-suited to solving complex problems such as those posed by traffic operation, and they are being used around the world. One example is SurTrac from Rapid Flow Technologies, a Carnegie Mellon University spinoff, which provides solutions for intelligent traffic signal controls. It has coordinated traffic flows at a network of nine traffic signals in three major roads in Pittsburgh.[196] Rapid Flow helped reduce travel times by over 25 percent on average and wait times declined by an average of 40 percent during trial.[197] It also reduced stops by 30 percent and emissions by 20 percent.[198]

Logistics: Trucking is a key target for AI interventions, with cargo delivery as a potential early space for adoption of AV technology across the world. In 2015, Uber bought driverless technology firm Otto and a year later it completed the first autonomous truck delivery carrying 50,000 cans of Budweiser beer over a distance of 120 miles from Fort Collins to Colorado Springs.[199] Established players like Volvo, as well as trucking firms like Starsky, are also testing their own prototypes.[200]

Railways: GE transportation has developed intelligent technologies to improve the efficiency of its locomotives. The smart-freight locomotives are equipped with sensors that collect data and feed it into a machine-learning application. The app analyzes the data and facilitates real-time decision making.[201] In Europe, 250 locomotives from freight carrier Deutsche Bahn Cargo have been retrofitted with GE's performance management software to monitor brake performance, motor temperature, and other conditions to predict maintenance. The system is more accurate because it feeds on real-time data on the locomotives' conditions rather than set metrics, like distance traveled. The smart locomotives were reported to have reduced locomotive failure rates by 25 percent in Deutsche Bahn's pilot project.[202]

Marine: Autonomous ships are one obvious application of AI in the shipping sector. Shipping companies like Nippon Yusen and Rolls-Royce's marine operation (now Kongsberg) are testing their prototypes, the latter of which successfully tested an autonomous ship in Finland in 2018. But AI also provides the opportunity to optimize networks and routes, which could reduce fuel costs and emissions. In 2018, Hong Kong SAR, China-based shipping line OOCL partnered with Microsoft's AI research center to optimize their network operations, a 15-week effort that generated savings of $10 million per year for OOCL.[203]

That same year, American company Sea Machines Robotics worked with the world's largest shipping company, Maersk, to install AI situational awareness technology on Maersk's ice-class container vessels.[204] This marked the first time that computer vision, Light Detection and Ranging (LiDAR), and perception technologies were used on a working ship. Sea Machines claims its enhancements can diminish operational costs by 40 percent.[205]

Aviation: Many companies have been looking into using drones for cargo delivery. For example, Nautilus, a California-based start-up is developing a cargo drone with a 90-ton capacity.[206] Beyond unmanned aerial vehicles in aviation, aircraft makers are already using AI to solve problems pilots face in the cockpit and predictive maintenance. English start-up Aerogility has been working with low-cost carrier EasyJet since 2017 to automate daily maintenance planning for its fleet, including forecasting heavy maintenance, engine shop visits, and landing gear overhauls.[207] The manufacturer Airbus uses a similar tool, Skywise, to offer predictive maintenance and data analytics. Other potential areas of focus include AI assistants for customer service and facial recognition for passengers.

Emerging Markets—Sample Use Cases

Traffic management operations: Just like in Pittsburgh, many cities around the world are beginning to use AI to help solve traffic flow problems. In Bengaluru, India, where traffic jams are common, Siemens Mobility built a monitoring system that uses AI through traffic cameras that detect vehicles and calculate density of traffic on the road, and then alters traffic lights based on real-time road congestion.[208] Alibaba, China's e-commerce giant, launched "City Brain" to minimize road congestion, utilizing data from traffic lights, CCTV cameras, and video recognition to make suggestions for traffic flow management.

Trucking: China Post and Deppon Express, two Chinese logistics companies, are now using intelligent driving technology from Fabu to deploy autonomous trucks on Chinese roads. The trucks were successfully tested at Level 4 of autonomy, which means they can operate under select conditions without human input.[209] (Automation in vehicles is measured on a standard six-level classification system where Level 0 entails no automation and Level 5 is full automation).

Aviation: There are opportunities for AI technologies in drones, with many applications for deliveries of all sizes and types. In places without established infrastructure such as parts of Sub-Saharan Africa, drones are being used in healthcare. In Rwanda, American start-up Zipline partnered with the Rwandan government to launch the world's first commercial drone delivery service, flying medical supplies—namely blood—by air faster than transport on wheels.[210] A Beijing-based start-up, Sichuan Tengden Technology, is developing a drone capable of carrying 20 tons of cargo and flying up to 7,500 kilometers.[211] Smart airport applications are also available, such as the initiative in Chinese airports to use intelligent navigation systems equipped with facial recognition and big data analysis for a paperless and more efficient experience.[212]

Logistics: Established logistics players can also harness the benefits of AI in their operations. Logiety, a Mexican company, is using machine learning to streamline the international customs and taxing process by classifying and sorting products for import and export by material, size, and weight, as well as matching them with their corresponding tariffs.[213]

Investment Opportunities

E-logistics is the most promising area for immediate investment opportunities that involve AI applications in EMs. Poor roads, suboptimal truck utilization, unreliable tracking and routing, as well as a lack of transparency in cargo movement, all hinder the efficiency of traditional logistics. A host of new start-ups have been utilizing technology, including AI, to help solve the efficiency and reliability problems that the traditional logistics industry faces, introducing data analytics and optimization to lower costs.

Known as e-logistics companies, the services these start-ups specialize in tend to fall into three categories: (1) transportation data enablers, which provide platform-as-a-service offerings to improve transportation/location services; (2) long-haul/inter-city transportation, which usually aggregate truckers and shippers to facilitate the movement of goods across cities through a digital platform; and (3) last-mile/intercity transportation, which aggregate local delivery drivers and SMEs/e-commerce companies for last-mile delivery solutions within cities. Over $4.2 billion has been invested in the global e-logistics sector as of December 2017.[214]

AI is helping fuel the success of e-logistics providers in emerging markets. Since 2015, IFC has invested in nine e-logistics companies across China, India, Brazil, Sri Lanka, and Africa. Launched in 2015, Shadowfax, an IFC investee, is an Indian last-mile express logistics start-up that integrates with e-commerce companies' online deliveries through its partners, the drivers. A leading player in the space, Shadowfax is operational in 80 cities and services large corporate clients across the food, grocery, fashion, and consumer durables industries, mostly utilizing motorbikes. To power its delivery platform, Shadowfax uses an AI-driven solution named Frodo to optimize delivery routes. "Frodo determines, for instance, which partner would be able to go and the most optimal route for the rider," the company's vice-president said last year.[215] Machine learning is also incorporated into the algorithm, so that Frodo tracks data points, timeliness, and driver performance to continue optimizing routes.[216] In 2019, IFC invested $4 million in Shadowfax as part of a Series C round to help the company expand to new cities and customers.

Players like these utilize powerful AI technology and asset-light business models to provide e-logistics service to large clients in the disorganized and fragmented logistics sector in India—a sector that is expected to grow at a compound annual growth rate of 10.5 percent in the next two years. This is essential, as India, which has made much progress toward reducing logistics costs in recent years, still spends between 13 and 14 percent of GDP on logistics.[217]

Loggi, another IFC investee company and one of Brazil's newest unicorns, is a logistics start-up that

connects couriers to customers that need express last-mile delivery services. The company already uses an app to connect motorcycle delivery drivers and its clients in various sectors. In order to fund its expansion over the next five years, the company is looking to leverage AI and big data to optimize delivery routes and timeliness. To that end, the company is looking into attracting a team of programmers.[218] IFC has invested over $9 million in Loggi since 2017.

Though not strictly AI, investments in big data and digitalization more broadly form the building blocks of AI technology. Start-ups and mature companies that digitalize faster and have more tech-enabled business models will have the data necessary to deploy AI to optimize their reliability, predictability, and efficiency. China's Uber-for-trucks start-up Full Truck Alliance, an IFC investee, collects data from its truck drivers on delivery and reliability and utilizes that information to provide ancillary services, such as credit lines to its customers alongside partners. Full Truck Alliance also boosts efficiency by matching trucks, loads, and drivers, and helping them find gas stations. The company generates revenue from membership fees from companies that use the system for long-haul services, as well as truckers' shipping fees, highway toll-card refills, and fuel purchases. In 2018, Full Truck Alliance also invested in plus.ai, a driverless truck start-up based

in California that can assess how to deploy driverless technology on long-haul routes in China. In 2016, IFC invested equity to support the company's growth in the world's largest logistics market. This allowed IFC to participate in an innovative company that is enhancing efficiency in a fragmented industry.

The applications for AI in urban mobility are extensive. The opportunity is due to a combination of factors: urbanization, a focus on environmental sustainability, and growing motorization in developing countries, which leads to congestion. The rising predominance of the sharing economy is another contributor. Ride-hailing or ride-sharing services enable drivers to access riders through a digital platform that also facilitates mobile money payments. Some examples in developing countries include Swvl, an Egyptian start-up that enables riders heading the same direction to share fixed-route bus trips, and Didi, the Chinese ride-hailing service. These can be helpful in optimizing utilization of assets where they are limited in EMs, and increase the quality of available transportation services.

While AVs might already be deployed in mature economies, EM countries may have to wait before they can capitalize on this technology fully. KPMG's Autonomous Vehicle Readiness Index, which measures 25 countries' levels of preparedness for autonomous vehicle adoption, only includes five developing

economies: China, Russia, Mexico, India, and Brazil. They occupy the last four spots on the list, except for China, which ranks above Hungary, at number 21 out of 25.[219] This is partly because some of these countries, including Brazil and Mexico, do not have many homegrown companies working on AVs at the moment. Some studies show Level 4 or 5 AVs may be commercially available in the 2020s, but their deployment will be limited by cost and performance. In the 2040s, approximately 40 percent of vehicle travel could be autonomous in mature economies.[220] Some EMs, including India and China, might see faster adoption than others.

Risk and Challenges

AI can improve productivity and efficiency, but it may also have significant socioeconomic effects that must be managed. Some of the most significant effects are outlined below.

Loss of jobs: More than four million jobs will likely be lost in a quick transition to AVs in the United States, according to a report by the Center for Global Policy Solutions.[221] These jobs would include delivery and heavy truck drivers, bus drivers, taxi drivers, and chauffeurs.[222] AI is likely to accelerate the transition to a service economy, upending established economic development models by accelerating job losses for low-skilled workers in many fields, including transport.[223]

Cost: A major constraint on the growth and development of AI in the transport market is the potentially high cost of some AI systems, including hardware and software. In addition, restrictions on foreign exchange and complex import procedures for computing equipment can pose additional barriers.[224]

Poor and underdeveloped infrastructure: Low-income and fragile countries face an enormous challenge in utilizing AI-based transport applications, as their infrastructure is not ready for implementation and is incapable of providing maintenance and repairs. A lack of reliable power sources and weak telecommunications networks is part of this obstacle. Countries that make few investments in technology research and hard infrastructure as a percentage of GDP may have a harder time harnessing the power of AI.

Lack of skills and education: Demand for AI experts has grown over the last few years in developed countries and EMs where AI investment is increasing. A lack of skilled AI talent has been widely cited as the largest barrier to AI adoption in developed countries.[225] The critical shortage is even greater in EMs (with the exception of China).[226] It takes time for a country to effectively incorporate new technologies, particularly complex ones with economy-wide impacts such as AI. This means it takes time to build a large enough capital stock to have an aggregate effect and for the complementary investments needed to take full advantage of AI investments, including access to skilled people and business practices.[227]

Regulatory requirements: The regulatory requirements for AI are difficult to predict, especially when it comes to assigning responsibility when machines, like humans, make mistakes. Although research shows that AVs could reduce traffic deaths, it is unclear who would ultimately be held liable if an AV were to cause an accident, injury, or fatality.

Privacy concerns: Asking users to opt in and provide more personal data for machine learning requires robust privacy laws. These laws must be balanced against the benefit of having more data in a telecommunications network.

Conclusion

AI holds the promise of dramatically increasing productivity and efficiency in several sectors, including transport, and these changes are not in some distant future; they are happening now. AI is already helping to make transport safer, more reliable and efficient, and cleaner. Some applications include drones for quick life-saving medical deliveries in Sub-Saharan Africa, smart traffic systems that reduce congestion and emissions in India, and driverless vehicles that shuttle cargo between those who make it and those who buy it in China. With great potential to increase efficiency and sustainability, among other benefits, comes a host of socioeconomic, institutional, and political challenges that must be addressed in order to ensure that countries and their citizens can all harness the power of AI for economic growth and shared prosperity. ■

Artificial Intelligence and the Future for Smart Homes

By Ommid Saberi and Rebecca Menes

The floor area of the buildings we occupy is expected to double by 2060, with most of this growth occurring in residential construction. And population growth and urbanization in emerging markets will mean expanding cities and rising demand for new housing in urban areas around the world.[228] These trends represent an enormous opportunity to design, build, and operate the homes of tomorrow in intelligent ways that minimize energy consumption and carbon emissions, lower building and homeowner costs, and raise home values. Artificial intelligence will play a pivotal role in this effort by using data—including grid data, smart meter data, weather data, and energy use information—to study and improve building performance, optimize resource consumption, and increase comfort and cost efficiency for residents. AI will also analyze data collected from multiple buildings to improve building design and construction and inform future policy making related to construction and urban planning.

Homes waste energy and water when they aren't designed well. This is a particular challenge in emerging markets, where resources are less plentiful and utility costs are high relative to incomes. Even in homes that are designed with efficiency in mind, energy and water use can increase beyond original estimates, depending on behavior. Rising bills can negatively influence a homeowner's ability to meet monthly mortgage payments.

Yet there is a potential solution at the intersection of artificial intelligence (AI) and human behavior. Part of this solution is already in place in the form of smart meters, which can be preinstalled in residences to help occupants make better daily energy choices. Smart meters could capture utility usage and track indoor temperatures and then deploy that information for action, which is where AI steps in.

While the concept is still in its infancy, an AI-based framework could collect data from smart meters in an anonymous way and then interpret and share it for better decision-making by multiple stakeholders, from residents and builders to utilities and governments. Using smart meters and AI, homes would become the ultimate example of biomimicry (the design and production of materials, structures, and systems that are modeled on biological entities and processes), acting like redwood trees that grow and protect each other through interconnected roots.[229]

While AI was established as a discipline more than half a century ago, advances in the technology have accelerated in recent years due to an evolution in machine learning and improvements in computing power, data storage, and communications networks. This chapter adopts a definition of AI as the science and engineering of making machines intelligent, especially intelligent computer programs (see EM Compass Note 69).[230] AI can therefore be characterized as a series of systems, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve pre-specified outcomes.[231]

The Birth of Smart Homes

While the concept of smart homes has had several false dawns in recent decades, new technologies are starting to vie for the attention of homeowners, with the potential to better control energy and water use. Smart speaker technologies such as Amazon's Echo, Google Home, and Apple's Siri have all made inroads through their voice interaction capabilities, with Google Nest providing a breakthrough with its smart thermostat.[232] On the water side, a smart phone-enabled technology promises to "virtually" control the temperature in

your hot water tank,[233] with a clamp-on meter that can detect leaks and monitor peaks in water use.[234] Still, these technologies fall short of tying together the plethora of systems that support a consumer's energy, water, security, and ambient needs.

Eventually these technologies will become so interconnected and intelligent that human intervention is barely needed. When they are AI-enabled, the systems and design solutions of a building will interrelate intelligently to respond to the comfort of the occupants, including window openings, shades, lighting, insulation, cooling, heating, and hot water systems. For thermal comfort in hot climates with the least amount of energy use, for example, AI technologies could cool a home by opening a window when outside temperatures are preferable and air quality is suitable, or start a ceiling fan, shade windows to reduce glare, and cycle the air conditioning. The appropriate temperature would be reached depending on who is home and in which room they are located, with a persona-based approach relating to behavior and historical preferences.[235]

Smart Meters on the Rise

In the quest to achieve this new frontier in intelligent building, a starting point is needed, and it is most likely smart meters. By directly linking to energy loads in the house, smart meters enable consumers to take advantage of time-of-day tariffs where advanced metering infrastructure is in existence.[236] When installed in a visible location, they serve as reminders and motivators for residents to monitor their energy use, resulting in a minimum 5 percent reduction in consumption peaks.[237] International Housing Solutions in South Africa, a company that both rents and sells quality affordable homes, educates its customers on how to use preinstalled smart meters, demonstrating how conscientious behavior produces savings typically equivalent to one month's rent each year.[238] The more sophisticated smart meters become, the more they can be programmed to maximize efficiency both for the benefit of consumers and to take pressure off the grid.

Smart-meter implementation is starting to take off in emerging markets. Vinte, a large-scale developer

of affordable green homes in Mexico, has installed smart meters in each of its solar-powered residences so occupants can see utility usage in real time.[239] These smart meters, which cost Vinte $40 each, help to avoid surprises when bills are due. DCM, a high-end developer in Mexico, offers proprietary smart meters in its new development called ELEMENTS, a state-of-the-art complex just outside Mexico City that is powered completely by co-generation.[240] DCM's smart-meter app has an automation system compatible with Google Assistant and Alexa to control lighting, air conditioning, blinds, and even stereo levels. Other companies using smart meters include Vega Tobar with their Edificio Edwards[241] project in Quito, and iJenga in Nairobi in their Aashiana home.[242]

As of early 2019, 54.7 million smart meters were installed across 50 emerging countries in Latin America, the Middle East, Africa, Central and Eastern Europe, South Asia, and Southeast Asia.[243] Between 2019 and 2023, 269 million smart meters or Advanced Metering Infrastructure (AMI) devices will be deployed in emerging markets.[244] In terms of investment, the global smart meter market is valued at $5.8 billion (2018) and is projected to reach $7.06 billion by 2023.[245]

Connecting Smart Meters to Artificial Intelligence

In and of themselves, smart meters don't constitute artificial intelligence. They don't make judgments as humans do, nor do they solve problems. But with smart meters preinstalled in resource-efficient homes, data from multiple homes could be gathered and analyzed for better conclusions on construction, energy policy, and efficient use of resources. Increased resource efficiency will result in lower utility bills for homeowners, with the opportunity to repurpose savings toward healthcare, education, and other needs.

At a city or global level, the data analysis from smart meters could be divulged—in an open-source way that protects privacy through anonymous aggregation—to also benefit architects and engineers. A large number of external variables could be searched and then pondered when simulating a building model. The idea would be to combine performance history with evolving climate

informatics that impact design decisions, including fluctuating temperatures, changing rainfall patterns and cloud coverage, and the angle of the sun.[246]

The science of entwining resource-efficient design with human behavior is expected to become more agile, granular, and advanced in the near future. AI-enabled machines and algorithms will analyze the massive data collected and then develop logic and make informed decisions for humans. By coding these machines to recognize patterns and constantly improve predictions and decisions, the evolution of their learning capabilities is unlimited.

Figure 7.1 below illustrates various ways that smart homes and smart devices can help homeowners reduce their carbon emissions and their use of heating, lighting, and other power needs. These can also save homeowners money by decreasing their energy consumption and utility bills or by helping them qualify for lower electricity rates by, for example, attaching their electric vehicles to the power grid. Smart meters are central to such a smart home, and AI may improve these smart energy strategies.

AI-Based Models in Commercial Buildings

Progress has already been made in the application of AI-based models in the commercial building space, where companies use data-collecting sensors and the Internet of Things (IoT) to study and improve building performance and resource consumption. Small sensors are installed on systems or mounted on ceilings, creating a "nervous system" with interrelating data points. The data collected is then sent to the cloud for interpretation by platforms such as Siemens' MindSphere or Schneider Electric's EcoStruxure, which allow engineers to control utility usage and costs.

Tech companies that create construction management software, such as PlanGrid and Procore, have also made progress toward machine learning, with an eye to prioritizing tasks, preventing injuries at the construction site, and maintaining equipment.[247] But the construction of a building is only a snapshot in time, providing little value to the architect who designs it beforehand, the banks that invest in the project, the

building manager that needs to control operational costs, or the occupants who eventually make it their residence or workplace.

IFC's EDGE as a Potential Platform

IHS, Vinte, and several other builders certify their homes with IFC's EDGE, a green-building certification system for nearly 160 countries.

A core component of EDGE is its software, which provides a foundation of bio-climatic data while eliminating silos among its categories of energy, water, and embodied energy in materials, serving up cross-pollinations that rely on a user's inputs and selections.

EDGE is able to analyze the relationships between the local climate, humans, and systems in order to estimate how the building will perform. The software also calculates the length of time before the building earns a positive return on investment through savings on utility costs. The idea is to balance inhabitant comfort with costs while improving environmental performance.

For now, building designers use EDGE and similar products to determine the most cost-effective systems and relevant design concepts for optimal performance. By adding feedback loops and increasing computing capabilities, such products could eventually serve up optimal scenarios at the click of a button. This process, referred to as generative design, would continually evaluate tradeoffs among comfort, cost, and resource intensity.[248]

Intel for Banks and Governments

Whether EDGE evolves rapidly enough to become the ideal platform or a better solution emerges, exciting opportunities exist to develop artificial intelligence in the real estate industry.[249]

Other applications for such machines include overlaying data for certified green buildings with evidence of investment performance. Providing proof of whether a certified building rents or sells faster or at a higher value could be a condition of incentivized financing and/or preferred insurance rates. How about insisting on carbon emission read-

FIGURE 8.1 Twelve Ways to Save With Your Smart Home

Source: IFC, EDGE.

outs? Local and national governments could gain a better understanding as to whether they're on track with climate commitments if they could obtain this information from the building sector.

Artificial intelligence would then play a role in helping banks decide whether they should even offer conventional financing. Algorithms could be built to identify which developers have lower risk profiles and what their preferential rates should be. Governments could use such information to design incentives to minimize carbon emissions.

As the building and construction industries adopt these technologies, the hope is that manufacturers will also eventually compete to produce the most ideal systems and materials. Consumers, too, might jockey to obtain the least expensive green mortgage or cut their energy use dramatically, which will result in more comfortable homes that cost significantly less to heat, light, and power.

Once demand for energy has fallen and pro-environment building practices become widespread, resource-guzzling homes will be a thing of the past, with AI likely playing a pivotal role. When that happens, we'll reflect back and remember that it all started with a smart meter perched on the wall, glowing with its potential to change the world. ∎

Chapter 9

Artificial Intelligence in Agribusiness is Growing in Emerging Markets

By Peter Cook and Felicity O'Neill

Business models utilizing artificial intelligence (AI) can help meet rising global demand for food and support a more inclusive and sustainable food system by: (1) enhancing the resilience of farming methods; (2) reducing the cost of quality inputs and services to underserved farmers; and (3) improving market access to facilitate smallholder farmer integration into regional and global supply chains. Although nascent in emerging economies, applications for artificial intelligence in agribusiness will proliferate as farmers' access to the Internet and adoption of smart devices increases across low-income countries.

Meeting the food and agriculture related Sustainable Development Goals (SDGs) in a sustainable and inclusive manner is daunting. Progress toward these SDGs over the past decade has been hampered by an increase in global hunger, with 820 million people hungry today.[250] The challenge is to make food systems more efficient to meet the needs of the one-in-ten people who suffer from chronic hunger,[251] to meet the projected doubling of global food demand by 2050 (from 2009),[252] and to sustainably adjust to increased demand for animal-based products.[253] Yet current production practices in many food systems result in up to a third of food being wasted. Private sector investment is critical to addressing these pain points, with UNCTAD estimating that the food and agriculture SDG investment gap is almost $200 billion per year, through 2030.[254]

Investing in new technologies will be critical to meeting these challenges to agriculture. The term "agtech" describes the application of technology—especially software and connected hardware—to the agriculture value chain. Agtech innovations have significant development potential, as they can help farmers use scarce resources such as water, and external inputs like agrichemicals, more efficiently, effectively, and

sparingly. Agtech can also help farmers access the more advanced inputs they need to increase output, such as machinery and finance, and allow them to trace the origin and quality of their produce.

In recent years, AI technologies—including machine learning, natural language processing, robotics, and computer vision—have been incorporated into agtech business models. Applications of AI—for use in alternative credit scoring or 'smart' farm equipment, for example—have the potential to reduce the cost of serving smallholder farmers across the agriculture ecosystem, improve the efficient and sustainable use of resources, and overcome market asymmetries that prevent farmers from accessing regional and global value chains. The use of AI technologies has become commercially feasible for agtech in recent years through advances in big-data analytics, increased computing power, and cloud-based storage, as well as cost reductions in satellite imagery, remote sensors, and other hardware (including smart phones), and the increased affordability and availability of mobile connectivity.

Despite these advantages, there are barriers to replicating and scaling AI technology, particularly in emerging markets. First, smallholder farmers often lack the skills and capital needed to utilize new technologies. Second, there are gaps in the agronomic data needed to teach AI systems, particularly given the diversity of farmland and crop varietals. Third, there are limits to the adoption of AI technology in markets where IT infrastructure is inadequate or the infrastructure needed to connect farmers to supply chains—including roads, cold storage, and freight capacity—suffers from underinvestment. Yet the potential of AI to help meet the critical challenges of hunger and climate change creates a clear incentive for development finance institutions (DFIs) such as IFC

to invest in demonstrating the feasibility of these technologies in emerging markets.

What is AI?

AI is the science and engineering of making machines intelligent, especially intelligent computer programs (see EM Compass Note 69).[255] AI is, therefore, a series of approaches, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—to achieve specific objectives.[256] AI techniques have seen rapid progress over the past decade, supported by an evolution in machine learning, improvements in computing power and data storage,[257] and upgraded energy and communications infrastructure.

The use of AI in agriculture is nascent but expanding

As the distribution of venture capital into AI technologies closely tracks total venture capital flows, the latter can be used as a proxy for interest in AI (see EM Compass Note 71). Venture capital flows to agtech firms have increased rapidly in the past five years, with the majority received by firms headquartered in the United States (Figure 9.1). Agtech firms using AI make up a growing share of these flows, receiving $6.7 billion in venture capital flows over the past five years, including $1.9 billion in 2018 alone.[258] These flows illustrate that the feasibility of using AI in agtech has been demonstrated.

Although nascent, investors are showing interest in directing funds to emerging market businesses that use AI. China has seen around 200 agtech venture capital deals, and the number of deals in India and Brazil is growing.[259] In Asia and Africa, where smallholder farmers dominate the agricultural sector, agtech startups are focused on connecting farmers to larger buyers or cooperatives. Alternatively, markets like Brazil, where there are a number of significant
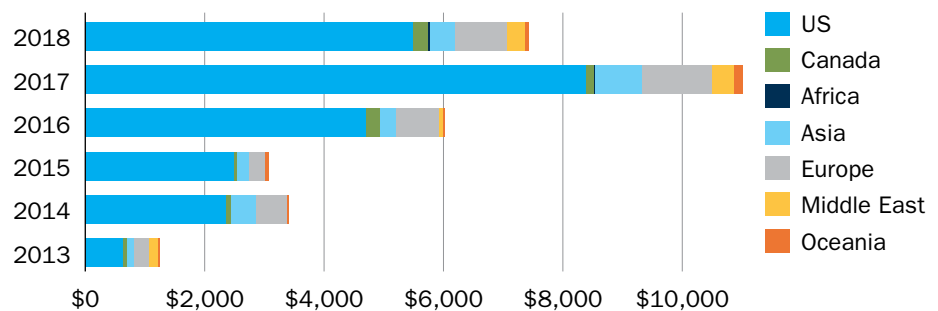
FIGURE 9.1 Global Agtech VC Deals (US$ millions) by Investor HQ

Source: Finistere Ventures, 2018, using Pitchbook data as of 31 October 2018.

larger holdings, are seeing more startups focused on precision farming.

AI technologies can improve food system performance

Improvements in the productivity and sustainability of the global agricultural system, as well as higher returns on investment for farmers, are critical to meeting the SDGs. In emerging markets, losses of food take place throughout the production, post-harvest handling, storage, and processing stages. The U.N.'s Food and Agriculture Organization estimates that annual food losses that occur from farm to fork are as much as one-third of annual global food production, or about 1.3 billion tons.[260] In addition, emerging market agriculture sectors suffer from low total factor productivity growth, as the main contributors to productivity in low-income countries since the 1960s have been increased agricultural inputs and land use (Figure 9.2). Currently, the yield gap—the difference between a crop's potential yield and actual yield—exceeds 50 percent in most low-income countries, and 76 percent in Sub-Saharan Africa.[261]

Another critical development challenge is that agriculture both contributes to and will be fundamentally affected by climate change. Land use, including agricultural practices, deforestation for arable land, and the forestry industry, account for 28 percent of net greenhouse gas emissions, while climate change affects the availability of, access to, and stability of the global food system.[262] The challenge in meeting

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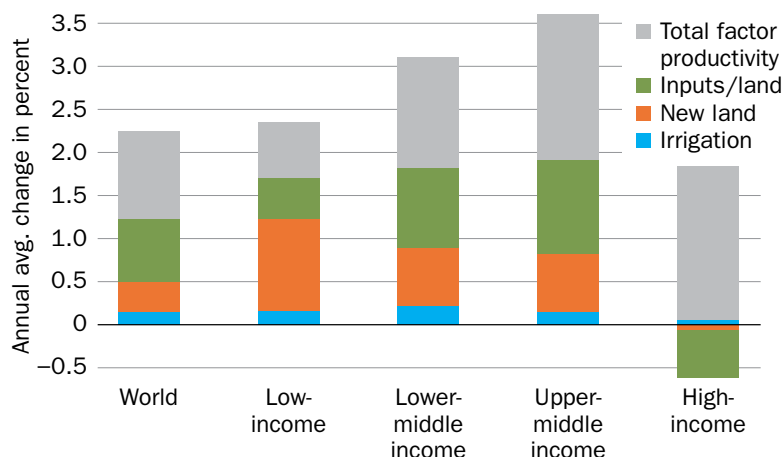
FIGURE 9.2 Sources of Productivity Growth in Agriculture, 1961–2010

Source: Fuglie and Wang. 2012.

and pesticide use, enhancing the accuracy of pest and disease detection, and facilitating the automated grading of crops. And combining data on soil characteristics, weather, and other climactic factors and interpreting them through machine learning software helps planting, the management of farm operations, and harvesting. Additionally, AI technology can help enhance the transparency of global food supply chains, minimize food loss, and facilitate the monitoring of food quality standards.

food demand and transporting food across markets sustainably cannot be solved through business-as-usual farming practices.

The adoption and diffusion of AI technology and precision agriculture into agtech business models holds promise for addressing these challenges (Table 9.1). For instance, AI applications in financial services, knowledge, and capital can help improve the cost efficiency of agribusinesses by using inputs "intelligently" and increasing the quality of outputs. AI applications also hold promise for improving the sustainability of farming practices by reducing fertilizer

AI technologies are transforming agtech business models

Extending products and services to underserved farmers. Farmers need access to credit and insurance to expand their businesses and manage risk, and to enhance the resilience of their operations. Many emerging market farmers lack access to affordable financial products because of the significant time and cost required to price their risk and collateral, as well as the difficulty of serving farmers in rural and remote areas. Technological advancements in satellite weather data collection and the wider adoption of

Decision support	On-farm analytical support and software for farm operations
Marketplaces	Online markets for purchasing farming inputs & for selling crops
Logistics & infrastructure	Digital management and optimization of farm produce to markets
Financial services	Credit scoring facilitating lending and insurance for farmers
Livestock solutions	Traceability, increased yield, management of nutrition, disease, and breeding
Irrigation & water tech	Low-cost 'smart' irrigation through integrated sensor data
Robotics & equipment	Using satellite and weather data and computer vision to optimize deployment of agrichemicals

TABLE 9.1 Applications of AI Technologies in Emerging Markets

Source: IFC.

mobile technology has dramatically reduced these costs, facilitating the extension of financial products to farmers in emerging economies.[263] Machine learning platforms are increasingly being employed by lenders to generate credit scores or price new products to help farmers access the microloans and insurance needed to upgrade their inputs to production, and this includes farmers without traditional collateral or bank accounts. In general, these platforms allow farmers to upload photos of crops and pests or disease, which are processed alongside satellite, geospatial, and other data sources, to estimate a farmer's collateral and/or to make estimates of the farmer's individual financial health and creditworthiness.

For example, financial services providers can leverage a greater number of new and existing data points to price new insurance contracts and potentially trigger a payout for a predefined event such as below-average rainfall.[264] Precision agriculture, alongside machine learning, has the potential to reduce agricultural insurance premiums by defining risks and improving risk assessment tools, and allows farms to move more quickly to prevent crop losses. WorldCover is an early example of an intermediary helping to connect farmers with insurance products. WorldCover uses AI to assess satellite, weather station, and agronomic data to determine the risk of weather events, and is working on smart contracts that use blockchain to trigger automatic payouts.[265] The automatic disbursement of payouts via nonbank payments providers like M-Pesa allows farmers without bank accounts to obtain insurance. Such automatic payouts through nonbank providers reduces the frictions involved with farmers adopting financial products like crop insurance, which they need to enhance their resilience to climate shocks.

Farmers in emerging markets often also lack timely, reliable, and sufficiently granular weather, pest, and market data to choose an appropriate crop to sow, and to realize the yields needed to service existing loans. Platforms using machine learning algorithms assess farm-level data against publicly available data sources to generate real-time business analytics that help farmers manage production risk, increase the effective use of inputs to generate cost savings, and optimize planting and harvest times to increase yields and farm-

gate prices. The algorithm is refined as data is added through each crop cycle to improve the accuracy of farm-management recommendations.

In India, for example, B2B platform CropIn allows agri-businesses to upload unstructured data into a smartphone app (farmer information on planting, varietals used, photos of crops). Machine learning algorithms can combine unstructured data with a range of other data sources to generate real-time advice on risk management, sales, warehousing, and sustainable farm practices. The app can be used offline with analytics applied once the device is connected again. Data from the app can also be used to generate credit risk assessments for access to finance, and for farm-to-fork traceability and quality control for access to global value chains.[266] CropIn's weather algorithms currently provide course correction advisory services for 5,000 farmers' plots.

Increasing market access through the reduction of trade frictions and facilitated adoption of new technologies will help smallholder famers integrate into regional and global supply chains. In emerging markets, agricultural supply chains are often inefficient or incomplete, with many smallholder farmers excluded from regional markets due to complex regulatory arrangements, outsized market power of commission agents, a lack of access to quality inputs, and a lack of knowledge of available markets, prices, and standards.

AI can help address these market failures by improving traceability to prove the origin and quality of produce, which is needed to secure supply contracts and access markets. For example, Stellapps has developed a digital platform that collects data on cows and food safety and cooling equipment owned by small farmers in India; it uses the data to generate recommendations for the farmer on actions that will improve nutrition, growth, and milk production. The company also digitalizes the milk procurement process, including volume and quality measures, which can be done reliably on site with Stellapps equipment. Stellapps monitors dairies' chillers to provide assurance that quality is maintained throughout the supply chain. Ultimately, dairies can provide traceability in their supply chain and access premium milk markets. The company enhances the value of these data monitoring applications through

its machine learning algorithm to assign each farmer a credit score, or 'mooScore,' based on their personal data and cow data (health, nutrition, fraud proofing), which allows lenders to expand their financing of farmers. Stellapps' business model has been designed to scale, with the SmartMoo suite of apps currently touching over two billion liters of milk annually.[267]

AI-enabled platforms also give smallholder farmers the information they need to connect directly to buyers of their produce, reducing food waste and increasing farm income. IFC and TLcom Capital Partners invested $10 million in Kenyan company Twiga Foods in 2018. In 2019 the company raised an additional $30 million in a round led by Goldman Sachs. Twiga's platform aggregates market participants, facilitating a more efficient matching of buyers and sellers in Africa's large but fragmented fruit and vegetable market.[268] For farmers, the platform enables access to a fairly priced, transparent, mobile marketplace. For vendors, the benefit is increased reliability in sourcing high-quality produce. Twiga's system has reduced post-harvest losses to 5 percent, compared to 30 percent in informal markets where farmers typically sell produce. Twiga is now increasing the value of its platform for users by integrating AI to expand its service offering, recently partnering with IBM to design a machine learning algorithm to provide small-scale vendors with a credit score to disburse loans. Through an eight-week pilot, more than 220 loans were processed with an average size of around $30, which allowed vendors to increase the size of the orders they handled by 30 percent and increased profits for each retailer by 6 percent, on average.[269]

Another example of how AI can help make the food and agricultural supply chain more transparent and efficient, as well as reduce food waste, is Indian company Intello Labs, which is digitalizing the process of grading and tracking the quality of agricultural produce. Intello Labs' technology system uses deep AI algorithms (convolutional neural networks) to identify produce defects and track the movement of produce across the supply chain. The company's data-driven system has been designed to improve customer-level quality of produce, reduce food loss along the supply chain, and achieve better prices for producers by

removing human subjectivity from the grading process and moving that process further upstream and closer to the farmer. The company has also designed the system for implementation across delivery modes—mobile applications, fixed cameras on the processing line, and cloud or edge computing—so that it is cost effective and can be scaled. Intello Labs is currently trialing their system with a few companies in India and the United States.

Enhancing the sustainability of agricultural farming methods. There are also a number of ways that businesses are using AI to improve agricultural sustainability, both in terms of environmental impact and return on investment at the farm gate.

First, AI can improve on-farm management of pests and diseases. Cameroon-based start-up Agrix Tech has developed an application that helps farmers with low levels of literacy manage these issues. Farmers can upload photos of infected crops on their phones. Machine learning and translation technology is then applied to the images to provide pest and disease management advice in the local dialect. Importantly, the app can be used offline, as the AI-technology does not require Internet connectivity, which is limited in parts of rural Cameroon.[270]

Second, applications using AI allow farmers to access more advanced or 'smart' machinery, which helps optimize the use of capital inputs. Hello Tractor operates in Nigeria, Kenya, Mozambique, Bangladesh, and Pakistan, offering tractor services between farmers so that owners of compact tractors can maximize their investment. The platform takes on the risk of payment, delivery, and asset security, creating an additional income stream for farmers.[271] The business recently partnered with IBM to use machine learning to help farmers predict crop yields and, when combined with advanced analytics and blockchain technology, can be mined to develop a credit score for loans. Forecasted weather data from The Weather Company, an IBM business, remote sensing data (e.g., satellite), and IoT data from tractors will also be incorporated into the app to help smallholder farmers know when to cultivate, the quality of their farm cultivation, what to plant, and the appropriate fertilizer using remote sensing and IoT data.[272] If successful on a large scale,

How the Platform Works

Value Chain	AG input companies	Food & beverage, trading & cooperatives	Credit & insurance

Insights	Irrigation	Pest & diseases	Weather & crop	Seed placement	Farmers' local knowledge	Yield forecast • Fertility recommendation Machinery monitoring Planting, harvesting & application efficiency

Data Science	Meteorological & agronomic models	Data science

Data Collection	Weather	Soil	Crop sensors	Imagery	Grower data

FIGURE 9.3 Agrosmart's Data-Driven Insights

Source: Agrosmart.

applications like Hello Tractor could help farmers simultaneously access the equipment and knowledge needed to improve the efficiency of their farming practices, and may facilitate the expansion of their area under cultivation.

Third, digital technologies including AI are being leveraged for so-called precision farming, in which intelligence from both farmers and public data sources is assessed by algorithms in order to use inputs to production—water, land, pesticides, fertilizer, and nutrition—more effectively and increase the farmer's return on investment. Intelinair is an American agtech business that gathers high-resolution aerial images, temperature readings, humidity measurements, rainfall, soil samples, terrain type, equipment utilized, planting rates, applications, and other datapoints, and applies hyperspectral analysis, computer vision, and deep learning to identify patterns and build a complete and precise situational representation of every monitored field for the entire growing season. As the machine learning system trains on new data, it becomes stronger, smarter, and more effective. The system can, for instance, identify abnormal crop conditions before the human eye can detect them. The intelligence generated by the system is delivered to farmers via smart alerts that allow them to make proactive, real-time decisions in their fields.[273] Minimizing the cost of

inputs should improve the sustainability and resilience of farm-gate returns.

Although precision agriculture is dominant in higher-income economies like the United States, there are new applications by agtech businesses in emerging markets with large-scale production systems. For example, Agrosmart is a Brazilian company offering its technology platform to farmers in Latin America, the United States, and Israel. Agrosmart consolidates millions of data-points from field sensors and satellites, and applies machine learning and other AI technologies to improve farming performance, reduce environmental impact, and deliver intelligence across the agriculture value chain (Figure 9.3). The company offers several packages of services to producers of various sizes for an annual subscription fee. Each package delivers different information to the client, such as weather forecast, irrigation advice, and soil conditions. The system also eliminates the need for Internet or cellular coverage in the field to send the data to the Internet.[274] With the insights provided, producers can become more efficient, reducing labor time and water and energy consumption, while increasing yield. Users also benefit from a connected and monitorable supply chain.

Precision farming is now being extended, from applications that provide insights and information to farmers, to on-farm robotics equipment that acts

autonomously. For example, India-based robotics company TartanSense is building a semiautonomous rover to traverse cotton farms with a downward facing camera capturing images of plants and weeds. When AI algorithms running on the system detect weeds, the rover automatically sprays them with agrichemicals through precision nozzles.[275] This can increase farm income by reducing labor required to pull weeds. It can also minimize chemical residue levels from broadcast spraying in the soil and reduce health risks to operators—traditionally women— from residue from traditional spraying methods. AI-enabled applications like TartanSense's spraying system are increasingly being trialed and rolled out in conjunction with pest and disease detection, pruning, harvesting, and crop grading.

Challenges in scaling AI across emerging markets

The focus of AI technology today is on larger farming operations with the aim of reducing input costs. Yet there are technical difficulties in building reliable AI systems that can be applied across different terrains. On-farm conditions are continuously changing, even across the same plot. For example, different crops vary in their physical characteristics due to differences in rainfall or soil quality (among other factors), which makes it difficult for machine learning systems to identify and provide actionable advice, even for the same crops.[276] Additionally, the seasonality of the agricultural sector increases the time needed for machine learning algorithms to learn and prove their value, creating a time lag to replication. Adoption will therefore be slow until the return on investment for applications using AI is proven in each market context.

At the smallholder level, agtech companies need to understand the needs, capacity, and constraints of emerging market smallholders in order to design and distribute appropriate solutions. This requires stakeholders like government, agtech companies, and other capacity building institutions to undertake hands-on training in the use of digital technology with farmers across emerging markets so that they are equipped to use AI applications as they become more cost-effective.

Barriers to adoption exist beyond the technology itself, with challenges in data supply, data use, and a lack of enabling infrastructure. Like companies in other industries that compile large data sets, agtech companies are increasingly ensuring that their data security practices and systems are ISO 27001 and EU Global Data Protection Regulation (GDPR) compliant, with supporting policies and data recovery plans in place. Empowerment of farmers who provide the data that the technology depends on is also critical and begins with obtaining the informed consent of farmers to collect their data, including any third-party use arrangements. Additionally, farmers cannot realize the benefits of digital technologies without improvements in complementary infrastructure, including the telecommunications, transport, and irrigation required to support AI innovations.

DFI's have a role to play in supporting agtech businesses

AI applications have yet to penetrate the poorest frontier countries. Agtech is now at an inflection point, however, with venture capital flows increasing to emerging markets in recent years. The cost of enabling technologies continues to fall, which allows scalable product and service companies to be built. This cycle leads to product adoption and further capital flows. DFIs like IFC have a role in demonstrating the feasibility of AI use in agtech to catalyze these flows, as well as in addressing enabling barriers such as farmer training.

IFC invests in and provides advisory support across the agribusiness supply chain—from farm to retail— to help boost production, increase liquidity, improve logistics and distribution, and expand access to credit for small farmers. Since 2014, IFC has invested over $60 million in agtech-related companies and has made more than 10 indirect agtech investments through accelerators, seed funds, and venture capital funds. Agtech is increasingly becoming a centerpiece of IFC's Manufacturing, Agribusiness & Services (MAS) advisory work with IFC clients. That includes supporting clients to deploy and effectively use farmer information service tools like CropIn and Farm Force that leverage local weather monitoring stations and

unaccompanied aerial vehicles (UAVs) to capture appropriate spatial and temporal data. Application of these tools at various nodes in a client's production and distribution chains enables improved decision making, increased access to inputs, finance and markets, and improved visibility of production across the chain.

IFC is also working to reduce barriers companies face in adopting agricultural technologies.[277] In 2018, IFC held its inaugural Global Agribusiness Conference in Amsterdam, which focused on the challenges faced by smallholder farmers, as well as solutions to promote sustainable development, reflecting the need to ensure all stakeholders benefit as value chains become increasingly complex and global. The conference brought together companies whose supply chains rely on smallholder farmers, organizations offering products and services, investors, donors, and government officials from around the globe.

In addition, IFC and the World Bank held the first Digital Disruption in Agriculture Forum in Addis Ababa in May 2019. The purpose of the Forum was to help identify digital tools and service providers that can benefit the mainly smallholder farmers in Ethiopia, helping professionalize agribusiness and improve livelihoods. The use of digital technologies in agriculture remains limited in many low-income countries, and conferences like these provide an opportunity for learning, networking, and knowledge sharing that can help identify promising digital products and services to improve smallholder agriculture practices and yields. Building on interest in the first digital forum, IFC and the World Bank arranged a second forum in Ethiopia, scheduled for April 2020. This conference has been postponed due to the outbreak of coronavirus and will be held later this year.

Conclusion

Agribusinesses are leveraging AI to create new cost-effective business models and to provide the information they need to reach small farmers in emerging markets. Agtech firms using AI—for now mostly with large-scale farmers—have just begun to demonstrate their viability and are looking to scale their innovations. With growing deal activity and size, there will be plenty of opportunities for private sector investors to mobilize their capital toward meeting the agriculture-related SDGs. However, governments, investors, and industry will need to collaborate in addressing data, infrastructure, and human capital gaps before commercial AI integration is feasible at a larger scale. ■

Artificial Intelligence Innovation in Financial Services

By Margarete Biallas and Felicity O'Neill

Artificial intelligence technologies are permeating financial services sectors around the world. The application of these technologies in emerging markets allows financial service providers to further automate their business processes and to leverage new and big data sources to overcome obstacles—including the high cost of serving rural and low-income customers and establishing customer identity and creditworthiness—that prevent the delivery of financial services to many consumers. Realizing financial inclusion benefits through the adoption of artificial intelligence relies on its responsible adoption by firms, on competitive market settings, and on continued investment in the necessary infrastructure.

Artificial intelligence (AI) was established as a discipline some 70 years ago, but its applications have accelerated in recent years, supported by an evolution in machine learning and improvements in computing power, data storage, and communications networks. This note defines AI as the science and engineering of making machines intelligent, especially intelligent computer programs (see EM Compass Note 69).[278] AI can therefore be characterized as a series of systems, methods, and technologies that display intelligent behavior by analyzing their environments and taking actions—with some degree of autonomy—toward achieving prespecified outcomes.[279]

Reductions in the cost of Internet connectivity, increased mobile device penetration, and increased computing power over the past decade have helped digital consumers and businesses generate a wealth of new and real-time data through mobile phones and other digital devices. Concurrent advances in data storage, computing power, energy reliability, and analytic techniques have made it cost-effective for businesses to analyze this wealth of real-time and alternative data. As a result, it is now increasingly

commercially viable for emerging market financial service providers (FSPs) to begin integrating AI technologies into their service offerings. A recent survey of 151 firms, which was conducted jointly by the World Economic Forum and the Cambridge Centre for Alternative Finance and included both financial technology (Fintech) firms and incumbent banks, suggests that this is indeed happening, with 85 percent of respondents saying they are "currently using some form of AI."[280]

In emerging markets in particular, the need for AI stems from the fact that individuals and businesses are often underserved because they lack the traditional identification, collateral, or credit history—or all three—needed to access financial services. AI can address this problem by providing analytically sound alternatives to determining the identity and creditworthiness of individuals and businesses, based on alternative data collected from mobile phones, satellites, and other sources.

An additional obstacle to emerging market customers accessing financial services is cost—the cost to reach and serve these customers is often too high relative to the size of their financial transactions and the revenue they represent. AI can help address this problem, too, by automating various processes—customer service and customer engagement are a few obvious ones—to reduce costs. In this way, AI can enable higher volumes of low-value transactions and, by doing so, begin to turn these formerly underserved individuals into potentially profitable customers and include them in the contestable market for FSPs.

Thus, to the extent that the use of AI by emerging market FSPs results in the extension of services to previously underserved individuals or underfunded businesses, these technologies have the potential to

enhance financial inclusion. Yet the pace and extent of adoption, and hence the degree to which inclusion benefits are realized, relies on efforts by government, businesses, and investors to generate institutional and market settings that facilitate the responsible and sustainable integration of AI into financial services. This includes FSPs generating trust by lending responsibly, addressing algorithmic bias and error, managing cyber risk, and striving for informed consent in the use of consumer data. These settings also rely on supervisors enhancing their capacity to regulate algorithms, and authorities continuing to foster a competitive environment for financial services.

This chapter explores the early applications of AI in the financial services sector in emerging markets, and canvasses challenges to the responsible and sustainable use of AI by emerging market FSPs. It also outlines what actions investors and development finance

FIGURE 10.1 Credit Scoring by FarmDrive

Source: FarmDrive.

BOX 10.1 FarmDrive

Kenya-based FarmDrive is an agricultural data analytics company delivering financial services to unbanked and underserved smallholder farmers, while helping financial institutions cost-effectively increase their agricultural loan portfolios. Using simple mobile phone technology, alternative credit scoring, and machine learning, FarmDrive closes the data gap that keeps smallholder farmers from the financial services that would allow them to grow their agribusinesses and increase their incomes. FarmDrive collects a farmer's data using questions and answers via text messaging. The questions are designed to identify the farmer's location, crops cultivated, farm size, assets such as tractors, and farming activities. This data is combined with existing agricultural data to develop a credit profile. FarmDrive also uses testing to determine the likelihood that a farmer will repay a loan. The aggregate profile is then shared with lending institutions for credit assessment and funding.

FarmDrive's algorithm is currently in its second stage. During the first phase (the pilot), which ran between December 2015 and December 2016, the company collected environmental data (weather and climate patterns and soil data), economic data (income and market data), and social data such as social network information including apps usage and individual data, from participating farmers. The aggregated data is fed into FarmDrive's algorithm, which generates credit scores that can be used by financial institutions.

In its next phase of development, FarmDrive will seek to expand the environmental arm of the algorithm by incorporating more alternative datasets, including satellite imagery and remote sensing data. In addition, FarmDrive plans to use these environmental datasets in combination with crop cycle data to predict seasonal yields and influence agricultural insurance products. When smallholder farmers have access to credit, they can sustainably contribute to economic development while improving their livelihoods.

institutions like IFC can take to ensure that AI is deployed to maximize financial inclusion.

AI applications: Analyzing New and Complex Data Sets

The first broad application of AI by emerging market FSPs is to analyze alternative data points and real-time behavior to more effectively: (1) improve credit decisions; (2) identify threats to financial institutions and help meet compliance obligations; and (3) address financing gaps faced by businesses in emerging markets.

Improving credit decisions. Lenders and credit ratings agencies routinely analyze data to establish the creditworthiness of potential borrowers. Traditional data used to generate credit scores include formal identification, bank transactions, credit history, income statements, and asset value. In emerging markets, underbanked individuals—and particularly women—do not always have access to the traditional forms of collateral or identification that creditors need to extend financial services. By using alternative data sources—public data, satellite images, company registries, and social media data such as SMS and messenger services interaction data—AI can help lenders and credit-rating institutions assess a consumer's behavior and verify their ability to repay a loan. For example, Box 10.1 illustrates how FarmDrive aggregates alternative datasets to build credit scores for smallholder farmers in Africa.

Start-ups like Kenya's mSurvey, a mobile survey platform that drives decision-making for businesses across Africa and the Caribbean, are using mobile phone applications to generate the requisite data needed to feed scorecards and build real-time profiles of local consumers.[281] As the results of consumer scorecards are fed back into a machine-learning system, the algorithms improve, refining which data points are the most predictive in assessing creditworthiness. Once the AI system is in place, predictive scorecards are inexpensive to generate for consumers who have access to mobile phones, which means the addressable market for financial services is greater and the cost and speed of underwriting loans is lower, enabling FSPs to extend services to underserved consumers (Box 10.2).

BOX 10.2 Branch

Branch is a mobile app digital lender operating in Kenya, Nigeria, Tanzania, Mexico, and India. Since its establishment in 2015, Branch has provided more than 15 million loans to over three million customers, disbursing a total of $350 million.

Branch applies machine learning to create an algorithmic approach to assess the creditworthiness of potential borrowers based on thousands of data points on the individual and the accumulated experience across borrowers. A potential borrower downloads the Branch app, verifies his or her identity, and provides consent for Branch to access the customer's smartphone data. Branch applies its algorithms to data like text messages, call logs, contacts, and GPS, combined with a borrower's loan repayment history, to make a lending decision. The system creates personalized loan options in a matter of seconds, allowing Branch to approve a loan within minutes. Loan durations range from a few weeks to more than a year, with a typical loan of around $50. Underwriting loans of this size would not be viable at scale using traditional credit assessment methods.

Early evidence suggests that predictive scorecards may also help reduce rates of non-performance across loan portfolios. For example, African FinTech MyBucks provides microloans and insurance directly to customers in 12 countries, including Zambia, Malawi, and Uganda, by applying its AI technology Jessie to scrape data from a potential borrower's phone to generate a lending profile.[282] The use of predictive scoring reduced the default rate on MyBucks' loan portfolio in South Africa by 18 percent over the 2017–18 financial year.[283] However, it is too early to tell whether AI will facilitate a net improvement in non-performing loan (NPL) rates, with responsible lending practices by FSPs still critical to market sustainability regardless of whether AI is used to assess creditworthiness.

Identifying threats. Financial institutions are vulnerable to a wide range of risks, including cyber fraud, money laundering, and the financing of terrorism. In order to combat these threats, financial institutions undertake know-your customer (KYC) and anti-money laundering and countering financing of terrorism (AML/CTF) compliance activities, among others, to verify the identity of their customers, to understand the purpose and intended nature of transactions between individuals and businesses, to conduct ongoing due diligence to ensure that transactions match customer profiles, and to meet regulatory requirements. Detection of fraud and anomalies is among the most commonly cited reasons for adoption of AI by financial service providers.[284] And risk management is currently one of the most common uses of AI technology in financial services sectors. According to IFC research, more than 250 regulatory technology companies (RegTechs) provide their services worldwide. A strong focus of these technologies is on suspicious transaction monitoring, where AI is used to identify anomalies in user behavior.[285] In emerging markets, KYC compliance is difficult because many individuals lack primary identification documents, registries are often patchy, and there is a lack of confidence in some sources of government data needed for verification. Yet it is critical that emerging market FSP's meet KYC requirements, because they underpin correspondent banking relationships that allow individuals and businesses to send and receive payments across borders. This matters for financial inclusion because remittance flows between markets are now the largest source of foreign exchange earnings in low- and middle-income countries, excluding China.[286]

AI-enabled compliance technology can reduce the cost for FSPs to meet KYC requirements and decrease false positives generated in banks' monitoring efforts by sifting through millions of transactions quickly to spot signs of crime, establish links, detect anomalies, and cross-check against external databases to establish identity using a diverse range of parameters. McKinsey estimates that AI-algorithms can help reduce the number of false reports by 20 to 30 percent, though they also observe that many financial institutions have been slow to adopt these techniques because the algorithmic "black box" is often too difficult

to validate for the purpose of meeting supervisory requirements.[287] In addition, to date, the cost of the enabling software is beyond what many emerging market FSPs can afford. However, research conducted by IFC indicates that for emerging market FSPs, the cost can be reduced through shared services arrangements (see IFC EM Compass Note 59, "How a Know-Your-Customer Utility Could Increase Access to Financial Services in Emerging Markets").

The volume of digital financial transactions— remittances, savings deposits, and online purchases—is growing at double-digit rates annually. The growth in the value and volume of these transactions exposes financial services firms to fraud and cyber-attacks, with downside risk to firms' reputations. A 2017 CGAP survey of digital financial services companies in Kenya, Tanzania, Zambia, Uganda, and Ghana found that unplanned system outages due to events like cyberattacks decrease customer trust.[288] Like KYC compliance, leveraging the predictive and learning capabilities of AI through security software to identify and manage cyber threats will help FSPs maintain confidence in the security and integrity of transactions for customers and correspondent banks. However, software-as-a-solution packages to monitor and address cyber and fraud risk are currently prohibitively expensive for many emerging market FSPs, preventing the potential benefits from being fully realized.

Addressing financing gaps: the case of supply chain finance. Globalization has increased the scope and complexity of supply chains. FSPs take on credit risk for supply chain transactions by intermediating the financial instruments such as loans and cash management that enable trade between buyers and sellers. The Asian Development Bank estimates that there is a global trade finance gap of $1.5 trillion, which is driven by the relatively high cost of assessing firm creditworthiness and meeting KYC and AML/ CTF requirements, particularly for emerging market small and medium enterprises.[289] The application of AI by originators of supply chain finance (SCF) has the potential to help bridge this trade finance gap.

Originators of supply chain finance now have access to a greater wealth of data about the behavior and financial health of supply chain participants. Machine learning

algorithms can be applied to these alternative data-points—records of production, sales, making payments on time, performance, shipments, cancelled orders, and chargebacks—to create tailored financing solutions, assess credit risk, and help predict fraud and detect supply chain threats in real time and cost-effectively.

For example, Tradeteq is a platform that provides investors and SCF originators with the technology to negotiate, analyze, and manage trade finance investments, using alternative data to provide credit analysis and facilitating originators to pool assets, with the objective of reducing the structural costs that drive the trade finance gap.[290] Although costly, the accessibility of services like Tradeteq for FSPs have been improved through software pricing models based on optional use-of-service, rather than upfront capital expenditure models. At the same time, AI solutions in trade finance are limited by the extent to which SMEs along the supply chain have digitalized their operations.[291] Nevertheless, continued innovation to reduce the structural costs that sustain financing gaps in emerging markets, such as trade finance, is a nascent benefit of AI in the financial services sector.

AI Applications: Automating Business Models to Differentiate Services and Capture Market Share

The second broad application is the use of AI by emerging market FSPs to automate business models and processes to lower the cost of transacting with a wider range of consumers. This includes lower-income consumers and businesses who are benefitting from access to financial products that are tailored to their specific needs through the use of AI.

Increasing access through process automation. AI software helps automate aspects of digital financial services such as customer engagement and customer service, reducing the cost to FSPs of extending tailored support to a wider range of consumers. Juniper Research estimates that banks globally will save $7.3 billion in operating costs by 2023 through the use of chatbot applications.[292] An example is Bank BCP in Peru, which has partnered with IBM Watson to develop a personalized chatbot, Arturito, that facilitates

customers in converting currencies, meeting credit card repayments, and accessing 24-hour customer support via Facebook. Similarly, Brazil's Banco Bradesco has worked with IBM Watson to develop a chatbot that answers 283,000 questions a month in relation to 62 products, with 95 percent accuracy.[293]

This tailoring and automation has financial inclusion potential if it facilitates the extension of financial services to individuals and businesses that might have been deterred from accessing financial products due to an inability to transact in their own language or to physically access a branch or banking agent. For example, IFC client MTN in Cote d'Ivoire is working with tech company Juntos to incorporate AI-support into its digital wallet MoMo, so that customers can better understand their financial products and obligations. To date, 95 percent of MTN's digital dialogue conversations have been successfully automated. This use of chatbots and language processing to help address trust and financial literacy barriers for consumers in accessing financial services remains an underexplored application of AI in emerging markets.

Personalized Banking. To date, the high cost of developing personalized relationships with clients has restricted "relationship banking" by financial institutions to large companies and high-net-worth individuals. FSPs are increasingly looking to differentiate their services to attract greater market share by using AI and big data (sets of structured and unstructured data) to automate an assessment

FIGURE 10.2 Example of a Chatbot in Peru

"Chatea con Arturito" or "Chatting with Little Arthur" is an automatic response channel working as a chatbot that is offered by Banco de Crédito (BCP), the largest bank in Peru. Its conversations can be followed at https://www.facebook.com/pg/ArturitoBCP/posts/.

Source: Banco de Crédito (BCP), Peru.

of consumer behavior to provide simple savings and investment advice, often for free. Such "robo-advice" has financial inclusion potential if it can automate various processes and by doing so lower the costs of serving customers with low-balance accounts.

To date, the deployment of robo-advisors in emerging markets is largely limited to Brazil, China, and India, where there are significant savings pools. India-based ArthaYantra, for example, aims to circumvent the culture of accepting financial advice from family and friends as well as the commission-based model of existing financial service brokers, both of which result in suboptimal savings outcomes. Instead, the company's AI robo-assistant Arthos analyzes customer data to recommend mutual funds matched to each consumer's risk profile and track financial decisions to generate monthly rebalancing options.[294] Careful analysis of early attempts to automate wealth management advice will help determine if robo-advice provides better savings and investment outcomes for consumers, on average, than human advisors. Unlike chatbots, which are interactive systems conducting a conversation via text or audio designed to simulate how a human would behave, Robo advisors are highly specialized bots mostly employed as automated financial advisor and investment platforms. The system uses a software algorithm to build and manage portfolios.

More Complex AI Applications Are Under Development

These early examples have illustrated how FSPs are integrating narrow AI—such as machine learning algorithms—into their services to reduce business costs and overcome operational hurdles in order to serve more customers. Still under development are more complex AI applications with greater potential to address financial inclusion barriers. For example, weather risk transfer contracts are financial tools that protect farmers from climate risk by triggering a payout for predefined weather events.[295] WorldCover is using AI to assess satellite, weather station, and agronomic data to determine the risk of weather "events," and is working on smart contracts that leverage AI and blockchain to trigger automatic payouts.[296] The automatic disbursement of payouts via nonbank

payments providers like M-Pesa will allow farmers without bank accounts to access insurance cover. Identifying and addressing barriers to the scalability of insurance solutions such as weather risk transfer contracts will be critical to meaningfully addressing the insurance protection gap in emerging markets, which currently accounts for $160 billion, or 96 percent, of the total global insurance protection gap.[297]

Managing the Risks that AI Poses

Integrating AI into financial services presents sector-specific privacy and algorithmic bias challenges. The International Committee on Credit Reporting (ICCR) has identified a number of risks associated with credit scoring models, including: data inaccuracies; the use of data without informed consumer consent; the potential for bias and discrimination in the design and decisions of algorithms; and heightened exposure to cyber risks.[298] These risks are enhanced in AI models where data is fed back into systems to refine decision making.

Additionally, early adopters of AI in financial services may be able to leverage their head start to generate ever larger data sets on which algorithms can be further trained and refined. An early mover may get so far ahead, and be able to tailor finely priced offerings so much better than competitors, that it captures an outsized market-share, resulting in a winner-takes-all scenario. This would reduce competition for services, with the risk that consumers lose choice and price competition in the longer term. An alternative scenario is that AI adoption creates new business models that enhance cost-competitiveness among technological suppliers. Avoiding a winner-take-all scenario, through efforts by government and regulators to monitor anti-competitive effects, will be important to maintaining consumer benefits of AI in financial services.

As FSPs adopt AI, they need to attract staff with the right skills to understand how AI technologies, like credit-scoring algorithms, work, so that lending is issued responsibly. Otherwise, there is a risk that AI innovations do more harm than good by increasing indebtedness for vulnerable consumers and eroding consumer trust in the industry, which in aggregate may increase systemic risk. Adopting responsible

lending and risk management practices like the ICCR will be important in avoiding overindebtedness for EM consumers.

These risks raised through AI adoption require FSPs to carefully assess and actively govern their operations in terms of data ownership, privacy, security, and biases. This task will require coordination between FSPs and others—international organizations, governments, and industry—to develop robust privacy, data management, cyber security, and supervisory regulations/processes to facilitate AI adoption across the sector.

In contexts where the digitalization of financial services—a prerequisite for AI adoption—still lags, additional efforts are needed by governments and investors to develop the prerequisite settings. For example, CGAP has identified interconnected and open digital platforms, shared market infrastructure and data, and support for public goods like foundational IDs as structural requirements for digital financial services innovation.[299] In addition, government and private sector investors must continue to invest in telecommunications and energy infrastructure to improve the enabling environment for the digital economy. Without this enabling support, there is a risk that digital financial services, whether using AI or not, will continue to be commercially and practically infeasible, leading to a deepening of the digital divide.

As with any process automation, the integration of AI into financial services is likely to displace jobs in EM countries. For example, natural language processing could replace outsourced customer care services, which is an industry that employs thousands of workers in countries like Vietnam, South Africa, and Morocco. Alternatively, some jobs will be created in technology companies and large financial institutions to meet the aforementioned governance, regulatory, and maintenance obligations associated with successfully managing a system using AI. However, there is a question about where those jobs are created, with some EM countries potentially losing out on human capital and knowledge transfers if the jobs are created in company headquarters rather than EM subsidiaries. There are also some jobs required for financial service delivery in lower-income contexts, such as banking agents, that are still largely outside the digital realm

and are therefore much further from displacement via technological advancement.

Facilitating Responsible and Sustainable deployment of AI

IFC's digital financial services and fintech practice has invested in and provided advice to over 150 financial services providers since 2007. Through its investment and advisory services, IFC has considerable experience in assessing how new technologies, including AI, can be deployed in the financial services sector to help achieve the World Bank Group's twin goals of ending extreme poverty and boosting shared prosperity. For example, IFC client Yoma Bank in Myanmar has developed a scoring algorithm to provide loans to suppliers and distributors, leveraging their payment and order data to build a loan book that funds micro, small, and medium enterprises (MSMEs). Yoma Bank's nonperforming loan ratio is well below one percent.

As early as 2015, through a partnership between IFC, Ant Financial, and Goldman Sachs, IFC provided $245 million in financing to Ant to launch a data-driven lending product for women-owned small businesses in China. Although MSMEs account for 90 percent of all Chinese firms and 60 percent of employment, only 30 percent of formal banking system loans are disbursed to them. With 560 million people in China
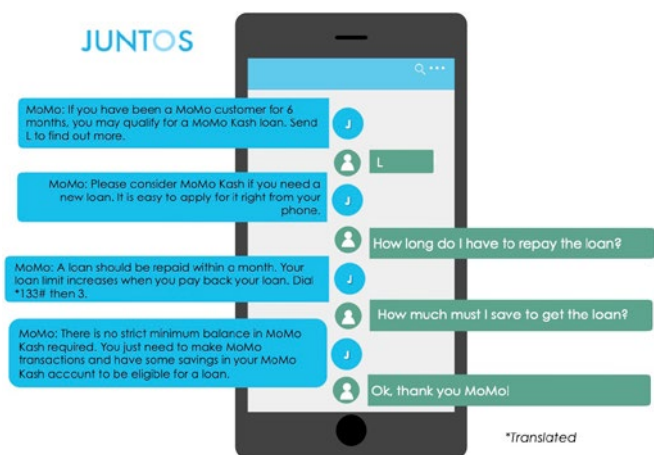
FIGURE 10.3 Example of an AI-Supported Digital Dialogue

Source: Juntos.

BOX 10.3 Two Examples of Applying Artificial Intelligence to Housing Finance in India

Aadhar Housing Finance Ltd. was established in 2011 as a joint venture between IFC and Dewan Housing Finance Ltd with IFC investing Rs. 200 million ($4.5 million). In June 2019, Blackstone acquired a majority of the company (98.28 percent), including IFC's share. The company has 133,000 customers and 154,000 active accounts. It operates 311 branches across twenty states and one union territory. About 87 percent of its loan book is comprised of affordable housing lending to salaried individuals and self-employed individuals.

Aadhar has employed an AI-based 25-factor credit scoring model in its core business process of credit scoring for risk profiling and pricing. In addition, the digital verification of know-your-customer and credit bureau records strengthened the underwriting performance at Aadhar's central processing unit. It improved the rate of loan approvals from two per day per officer to between four and five per day. The capabilities are built in to soon improve the rate of loan approval to seven and eight per day. Further, an AI pilot study is underway on 20,000 open borrower accounts to test default predictability.

Aavas Financiers Ltd. was incorporated in 2011 as a subsidiary of Au Financiers (India) Limited. IFC invested Rs. 1.3 billion (about $20 million) in 2017 and another $50 million in debt funding in 2019. Subsequently, to comply with Small Finance Bank

guidelines, Au Financiers (India) Limited divested its stake in AFL to private equity investors Kedaara Capital and Partners Group in June 2016. The company has over 100,000 active accounts and operates through 250 branches across nine states. About 75 percent of its loan book is comprised of affordable housing lending, predominantly to self-employed individuals.

Aavas has implemented a technology platform called "Aavas Mitra" for sourcing low- and lower middle-income clients. Further, Aavas integrated digital analytics, data science, AI, and machine learning applications into its business strategy to derive insights from data. Digital verification of the customer with the credit bureau records, in conjunction with AI solutions that determine credit scores and predict check-bouncing based on clients' patterns of making payments, resulted in improved underwriting and collection performance. Together, these processes have reduced loan-processing turnaround time from 23 days to 12 days.

—Friedemann Roy, Advisor to the Vice President, Economics and Private Sector Development, IFC;

Prajakta Diwan, Consultant, Quantitative Analysis, Research and Analytics, Treasury, IFC; Research Assistant, Thought Leadership, Economics and Private Sector Development, IFC.

Sources: Aadhar Housing Finance Ltd. Annual Report FY 2018–19. https://aadharhousing.com/pdf/AnnualReport18-19.pdf; Aavas Financiers Ltd. Annual Report 2018–19. https://www.aavas.in/sliders/website/pdf/Aavas%20Financiers%202019.pdf; Tripathi, D.S., Beniwal, R., Jambukar, S.Y., Jain, A. and Verma, S. 2019. Interview with Deo Shankar Tripathi, MD and CEO, Ravinder Beniwal, COO, Sharad Yashwant Jambukar, Head of IT, Anil Jain, Head of Credit and Satyam Verma, Head of Operations at Aadhar Housing Finance Ltd.; Agarwal S.K. and Rawat G. (2019, October 31). Interview with Sushil Kumar Agarwal, MD and CEO and Ghanshyam Rawat, CFO of Aavas Financiers Ltd.

connected to the Internet and small firms increasingly operating online, Ant Financial (a subsidiary of Alibaba Group) saw an opportunity to apply machine learning that leverages online transaction data to assess the creditworthiness of loan applicants, even those without collateral.[300] While collateral provides comfort to lenders, relying on it for lending decisions excludes

millions of small businesses with high potential. Instead, Ant Financial was able to apply AI to big data to make lending assessments based on actual payment history, enhancing its competitiveness by bringing high-performing small businesses into its customer base at a more rapid pace and at lower cost, which would be hard for traditional banks to replicate. As a result, Ant

increased its loan portfolio from $0.5 billion to $4.0 billion over a four-year period.

IFC also helps educate market participants about how to deploy technological innovations responsibly.

- IFC partnered with the Mastercard Foundation in 2017 to publish a handbook on how to apply data analytics to digital financial services, including how practitioners can use data to develop algorithm-based credit scoring models for financial inclusion.[301]

- The World Bank Group, through the ICCR, has developed guidelines on Credit Scoring Approaches that include guidance on the use of AI in credit scoring. These guidelines will soon be published.[302]

- IFC, together with private sector investors, has developed Guidelines for Responsible Investing in Digital Finance, which has been endorsed by over 100 investors and financial services providers, including Branch.[303] The adoption of these practices will be important to financial institutions to maintain consumer trust in digital financial services and to minimize the risk of harmful lending practices.

Looking Forward

Early applications of AI in the financial services sector are helping to overcome obstacles that impede the extension of financial services to underserved individuals and businesses in emerging markets. These obstacles include the difficultly some individuals and businesses encounter in accessing traditional forms of identification, collateral, or credit history needed to secure a loan, as well as the high cost to FSPs of meeting their compliance and regulatory obligations

and in managing cyber and fraud risk using existing processes. Instead, AI technologies can analyze new and real-time data sources and further automate business processes to overcome these operational and cost hurdles, with the result that it is now commercially feasible to extend financial services to more people. However, the early use of AI by FSPs is still narrow in scope, with many unexplored opportunities to use the technology to enhance development impact, such as improving consumers' financial literacy. In addition, many of the lowest-income consumers will still remain out of reach of FSPs where there is low smart-device penetration and unreliable Internet connectivity and energy supply.

Investors and development finance institutions like IFC can mitigate risks associated with the deployment of AI by adhering to the Guidelines for Responsible Investing in DFS,[304] an industry standard developed under the leadership of IFC. It requires investees to be certified by the SMART campaign, which is a set of principles for responsible financial inclusion, or endorse relevant guidelines such as the ICCR guidelines. DFIs should also monitor and evaluate projects to generate empirical evidence of how AI is contributing to financial inclusion in different contexts. This includes understanding if the application of AI is reducing nonperforming loan ratios and service costs, improving customer service, and resolving KYC and AML risks. Finally, DFIs must continue to invest in the enabling infrastructure for digital financial services—including telecommunications and energy infrastructure, and human capital skills—to ensure that the three billion people without access to or effective use of digital technologies are not left further behind as the benefits of AI spread elsewhere.[305] ∎

AI Investments Allow Emerging Markets to Develop and Expand Sophisticated Manufacturing Capabilities

By Sumit Manchanda, Hassan Kaleem, and Sabine Schlorke

As advances in machine learning, computer vision, and robotics help manufacturers around the world improve their processes and produce new and more complex products, artificial intelligence (AI) is becoming an integral tool of modern manufacturing, and one that is increasingly important to the industry's future. By combining large volumes of data with the computing power to simulate human thinking, AI is increasing the efficiency, capacity, and complexity of factory floors, and is introducing robotics, the Internet of Things, and other cutting-edge innovations to manufacturing value chains across the globe. Artificial intelligence is a critical enabler of manufacturing complexity that is essential for companies to produce an expansive range of sophisticated products and dynamically engage with regional and global value chains. Firms and economies can increase both their manufacturing complexity and their market competitiveness by developing the foundational capabilities and know-how needed to adopt AI and other advanced technologies.

Companies in both advanced and developing economies increase their levels of manufacturing complexity and contribute to economic growth and societal advances by identifying and capitalizing on disruptive technologies. Investments in artificial intelligence in particular will be critical to development, as they will allow emerging markets to create and expand sophisticated manufacturing sectors, participate in increasingly interconnected value chains, and compete in markets where speed and data are essential.

Historically, there has been a strong relationship between economic complexity, technical know-how, and economic growth. All countries that have been

able to harness new technologies have consequently been able to expand their economies. It was true during the First Industrial Revolution, when machines and mechanized factories began to replace hand production, and it remains true today as automation, cognitive computing, and high-speed data exchanges recast the methods of production and accelerate the development of new and more sophisticated products.

AI accelerates economic complexity and economic growth in three specific aspects of manufacturing: products, processes, and value chains. For the purposes of this chapter, we follow the definition and description of basic, advanced, and autonomous artificial intelligence that were put forward in EM Compass Note 69.[306] That is, that artificial intelligence is the science and engineering of making machines intelligent. In this chapter, the term AI refers to all computer systems that can continuously scan their environment, learn from it, and take action in response to what they sense, as well as to human-defined objectives.

What Is a Complex Manufacturing Economy?

Countries with a high degree of economic complexity are able to manufacture an expansive range of sophisticated products using advanced processes. They also have dynamic relationships with multiple regional and global value chains. These economies possess specialized know-how, and are generally where market leading firms and conglomerates have cultivated sophisticated relationships with a network of companies in the supply chain. Examples of high-complexity countries include Germany, Japan, the United States, and the Republic of Korea.

Drivers of production	Structure of production
Technology and innovation	Scale
Human capital	**Complexity**
Global trade and investment	
Institutional framework	
Sustainable resources	
Demand enforcement	

Product Complexity — Number of components in a product

Production Complexity

Process Complexity — Number of tasks in a process through which a product is made

Value Chain Complexity — Number of activities it takes to deliver a product to market in a specific industry
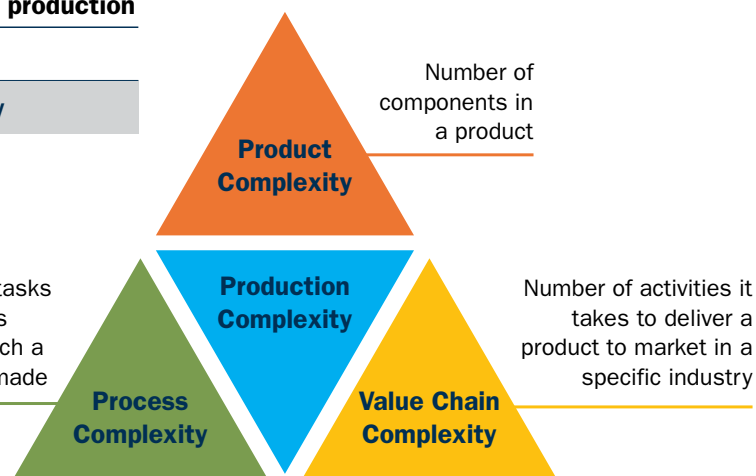
- Technological changes impact the structure of production in all dimensions (complexity and scale)
- Positive changes in product, process, and value chain complexity are important for industrialization

FIGURE 11.1 Manufacturing Contributes to Economic Complexity

Source: IFC Analysis.

On the distribution side, advanced economies possess recognizable global brands; strong research and development, design and innovation capabilities; client-oriented quality controls; and a flexible network of outsourcing partners. On the buying and selling side, competition is based on brand and quality, with many companies operating at the forefront of the technology frontier.

The Three Dimensions of Manufacturing Complexity

AI accelerates manufacturing complexity in three ways:

1. **Product complexity:** AI enables companies to more efficiently manufacture sophisticated products such as automobiles, which contain a large number of complex parts and components, all of which are separately produced and ultimately assembled into a single unit.

2. **Process complexity:** Today, by combining large volumes of data with computing power,

manufacturers are using AI to simulate human cognitive abilities such as reasoning, language, perception, vision, and spatial processing. AI is being used for predictive maintenance, assembly line inspections, and other tasks that range from the mundane to the cutting edge.

3. **Value chain complexity:** The real-world benefits of AI were emphasized recently in a World Economic Forum survey of corporate executives that was conducted during the Covid-19 crisis.[307] The executives said that "their past investments in new technologies are paying off now." They emphasized, for example, how big data platforms and the Internet of Things (IoT) enabled them to quickly gather large quantities of information that helped to predict supply chain disruptions that would impact production. AI helped provide instant visibility into the value chain and enabled quicker mitigation, which may have allowed some manufacturers to survive.
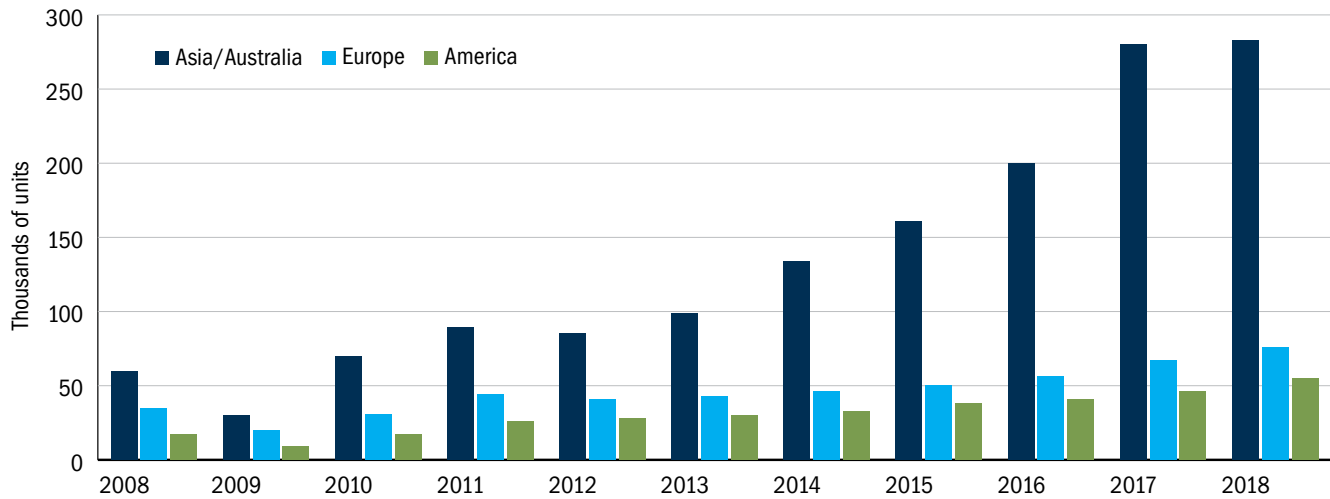
FIGURE 11.2 Estimated World Shipments of Industrial Robots by Region

Source: International Federation of Robotics.

Mounting Momentum for Smart Machines

According to market intelligence firm TrendForce, the demand for global technology-based manufacturing applications will increase to more than $320 billion in 2020, from about $200 billion in 2019, and will grow at a compound annual rate of 12.5 percent.[308] In a 2017 report published by Infosys,[309] 75 percent of a sample of medium and large U.S. companies said they had yet to reach their automation potential because of complexity and legacy issues. Seventy-six percent viewed AI as a key factor in transformation where artificial intelligence agents could replace human cognitive tasks. The Covid-19 pandemic has disrupted adoption of AI in all regions as companies work to rebuild and countries rethink their industrial strategies in the wake of the crisis. But it is reasonable to assume that the global appetite for smart technologies that can accelerate growth and complexity will continue, and companies will weigh their future AI investment decisions, in part, on how well AI performed during the crisis. Major manufacturers plan to monitor, record, and analyze data across all stages of manufacturing.[310]

In September 2019, the International Federation of Robotics predicted that industrial robot shipments would increase 12 percent annually from 2020 to 2022,

on average.[311] Today, robots are used almost exclusively for automation. But robotics is advancing rapidly, integrating cutting-edge technologies that enhance automation and functionality. While most demand for commercial robots has been in advanced economies and higher-income emerging markets, manufacturers in low-income countries are beginning to invest as costs decline (Figure 11.2).

As Industry 4.0 matures, technology companies will continue backward integration into existing manufacturing functions, retrofitting machines and processes to make them smarter, analytical, and increasingly data-oriented. At the same time, established industrial companies will continue to innovate and incorporate more complex technologies into their production processes. Enterprises will continue to adopt technologies that are relevant to the stage of development of the economies in which they operate, and AI—as it becomes less expensive and more commonplace throughout the value chain— will inevitably spread to countries at every stage of complexity and will play an increasingly important role in the industrialization process. As Figure 11.3 illustrates, over the past two centuries, every industrial revolution has been distinguished by a new technology that has driven manufacturers to a more complex economic stage.
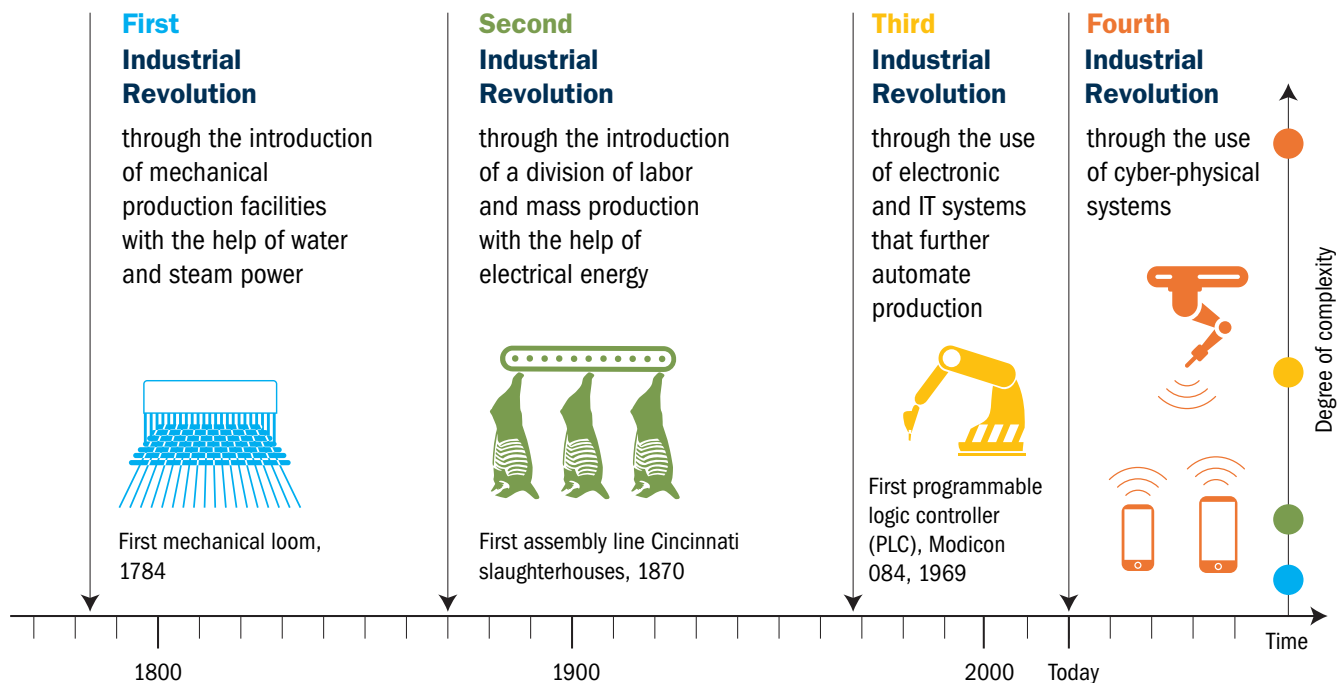
FIGURE 11.3 Four Stages of Industrial Revolutions Leading to Industry 4.0

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).

An AI Solution for Every Level of Complexity

Manufacturing economies can be categorized into three broad pillars of complexity depending on the level of maturity and sophistication in their manufacturing subsectors. As would be expected, AI can be more economically justified in wealthier, complex manufacturing economies where it is applied in large-scale industrial applications. But equally important, there are many instances around the globe where AI could have a profound impact on the manufacturing processes and growth of less complex economies. Already, AI is being used in some of those countries for capital-intensive and labor-intensive processes such as monitoring and scheduling pipeline maintenance and performing heat inspections in cement kilns—critical and often dangerous tasks normally relegated to specially trained employees.

Pillar 1 Economies: Low-income countries and those in fragile and conflict-affected situations.

Goal: Lay a foundation for industrial production in countries with a low-complexity manufacturing sector.

Country classification: These countries generally have a small industrial base, lack economic diversity, have limited skills and technology intensity, and have low or no manufacturing exports. They are narrowly engaged with global value chains, usually in agriculture, textiles, ready-made garments, light engineering, electronics assembly, footwear, and leather goods. They are also typically characterized by low labor costs (this includes most countries in Sub-Saharan Africa). Low-income economies are generally less technologically advanced in manufacturing and remain dependent on manual labor and processes. They often lack the requisite capacity to develop diversified manufacturing bases to broaden the complexity of their economies, or to provide people with opportunities to gain the skills that can drive human development. Advanced technologies, however, can improve these countries' manufacturing processes, help them produce

more sophisticated products, and enable them to engage with increasingly complex regional and global markets and value chains. Advanced data analytics and artificial intelligence have enormous potential to propel manufacturing forward in these economies.

AI adoption and use: AI in Pillar 1 countries is mostly limited to digitalization of production data with IoT, including in account payments and inventory management systems. At the consumer level, mobile technology and financial services companies such as Ant Financial in East Asia, M-Shwari in East Africa, M-Kajy in Madagascar, and MoMo Kash in Cote d'Ivoire are harnessing AI applications to better predict customer default probabilities, increasing their confidence in credit scores and enabling them to expand financial services to unserved, underserved, and unbanked populations, while facilitating industrywide financial efficiencies such as digital wage payments.

Pillar 2 Economies: Emerging markets.

Goal: Expand and diversify the manufacturing base in countries with a mid-complexity manufacturing sector.

Country classification: These countries have an evolving industrial base that is becoming more diversified and competitive, the technology skills of their workforces are improving, and they have developed some global value chain relationships (e.g., Brazil, Turkey, India, Serbia, Thailand, and Greece).

AI adoption and use: Pillar 2 countries adopt and use artificial intelligence algorithms more broadly, including for asset performance management, smart image recognition, process and quality control, and product engineering, as well as optimization of resources and supply chain management. These countries are involved in all industrial sectors and interact with companies that span the range of complexity. In some cases, Pillar 2 overlaps with Pillar 3 and, consequently, these economies often adopt advanced AI applications.

Pillar 3 Economies: More advanced markets.

Goal: Support more complex manufacturing in countries with a higher-complexity manufacturing sector.

Country classification: These countries have broad and sophisticated industrial bases where technology, education, and skills traverse sectors to drive growth via collective know-how and resilient industry networks. Pillar 3 economies are characterized by their global competitiveness in multiple value chains and their high levels of technological sophistication (e.g., Germany, Japan, United States, and China).

AI adoption and use: AI is adopted faster and has more impact opportunities in Pillar 3 countries where applications are used for planning, designing, mocking up, prototyping, testing, fine-tuning, producing, and post-design product and process improvements. What distinguishes Pillar 3 countries is the volume and capability of companies that can invent, access, and utilize cutting-edge technologies to manufacture a range of sophisticated products such as autonomous cars, smart robotic applications, and passenger jets. Many Pillar 3 manufacturers are capable of optimizing their supply chains, production processes, inventory-management systems, and transportation logistics.

How AI Can Accelerate Complexity

Investment in artificial intelligence tooling can be costly and therefore constitutes an impediment to adoption. But AI is being readily adopted for a slew of industrial applications ranging from robotic assembly to high-speed communications to air filtration systems for sterile manufacturing. And AI can accelerate complexity by empowering companies to manufacture more sophisticated products that are sought in more affluent markets. Another benefit is that the development of AI may be encouraging greater skills building and education achievement by labor forces eager for more sophisticated and higher-paying jobs.

Industrial robots in emerging markets. Some industrial robots can be seen as potential opportunities for AI applications. This is the case with some robots equipped for image recognition-oriented tasks. Figure 11.2 shows that the vast majority of industrial robots were shipped to more advanced manufacturing subsectors in emerging economies in Asia between 2015 and 2017. Robots are mostly used in the automotive, electrical, and electronics industries,

Our vision is to unlock the value of manufacturing for development to strengthen economic complexity. To achieve this, we will develop a portfolio approach that incorporates…

1 Laying the foundation for industrial production

- Building commercially viable resource-based industries for local consumption and higher value added exports
- Strengthening basic supply chains mainly targeting local and regional demand [anchor companies]
- Supporting production and assembly of simple products in GVCs

2 Supporting more advanced manufacturing

- Continuing the build-up of foundational manufacturing capabilities
- Developing products and solutions focusing on local and regional markets
- Helping countries become more competitive by entering multiple GVCs

3 Helping countries enhance and deepen manufacturing complexity

- Strengthening inter-industry linkages to sustain global competitiveness
- Supporting leading domestic/regional firms to build a global footprint
- Enhancing "Servicification," R&D leadership and branding

Technology: IFC's approach is to work with clients to take advantage of disruptive technologies to accelerate manufacturing complexity across all pillars

FIGURE 11.4 A Framework for the Manufacturing Sector, from Low-Income Countries to Advanced Economies: The Three Pillars of Manufacturing Complexity

Source: IFC.

although applications are deployed in other sectors, mainly in handling.[312] There has been very limited adoption of industrial robots in lower-income and fragile and conflict-affected countries, where resource-intensive manufacturing is the main focus.

Asset performance management. Data-driven maintenance decisions are a cost-effective way to predict and prevent breakdowns in machinery and production. Effective maintenance practices are critical to an efficient manufacturing value chain. Oniqua Enterprise Analytics estimates that 40 percent of scheduled machinery and plant maintenance costs are spent on assets with negligible failure impact.[313] Up to 30 percent of maintenance activities are carried out too frequently, and up to 45 percent of all maintenance efforts are ineffective, according to T. A. Cook.[314] Data-driven AI solutions leverage historical data and correlate manufacturing breakdowns with critical process parameters to create rules that allow manufacturers to operate more reliably and with less downtime.

Smart image recognition in advanced countries. Smart image recognition, or the use of AI in machine vision, has many potential manufacturing applications, such as

detecting product defects by conducting pixel-to-pixel comparisons. The global machine vision market is not highly concentrated, and the key players are American, Japanese, and Chinese companies. But with the advent of AI, other companies are emerging in this space, including Facebook and Alibaba, which have made acquisitions in machine vision firms.[315] The California-based company Similarity specializes in Automated Image Anomaly Detection, which uses vast amounts of satellite imagery data to generate rapid awareness of critical anomalies on the ground.[316]

Machine makers have also developed such algorithms for manufacturing applications, where, for example, image recognition is part of a quality-control process. In the food processing industry, Domino's Pizza has integrated an image-recognition video control system driven by artificial intelligence that checks whether pizzas meet the company's quality standards before they are delivered to customers.[317]

Process and quality improvement in more advanced countries. The Advanced Manufacturing Research Centre's Factory 2025 demonstrated that computing devices fitted in computer numerical-control machines could collect power consumption data, run it through

an AI algorithm, and analyze production variations against the production cycle to achieve efficiency gains and cost savings. The ramifications for production processes are myriad, ranging from improved product quality, increased savings on repairs and warranties, and a reduction in production downtime, all of which are efficiencies that can bolster a company's market share and profits. Taking these factors into account and weighing the costs and benefits is an important exercise for companies contemplating an investment in AI applications.

Resource and supply chain optimization in more advanced countries. The increasing importance of global value chains has driven demand for data-hungry applications that can sense, control, monitor, analyze, and independently maintain not only machinery but also the processes—from raw material extraction to successful product delivery—that companies rely on. The focus on value chain optimization with AI is largely due to: (1) the increasingly important revenue-generating role that services play for manufacturers; and (2) the increasing dependence on efficient global value chains.[318] Historically, the gap between revenues from services and revenues from direct sales of products has been blurry. An example of a company that has successfully bridged that gap is IBM, which has evolved from a "box" manufacturer into a high value-added and complex services company. Communication and data exchange have been an essential part of this transformation. In most industrial environments, communication within and between industrial sites has been based almost exclusively on wired networks due to a need for reliability.

Remote maintenance, network, and enterprise communication in emerging markets. Time-critical process optimization inside factories of different tiers of suppliers can reduce inefficiencies, support zero-defect manufacturing, increase worker satisfaction, and improve safety. In the most sophisticated cases, this could include: remote maintenance and control that may use connected cameras and possibly 3D virtual reality applications; connected goods that can create new value-added services, including real-time monitoring of fluid levels in engines; seamless intra/inter-enterprise communication, for example,

the widespread use of tracking devices such as RFID stickers or connected sensors that can monitor assets distributed over large areas; and the efficient coordination of cross-value chain activities and optimization of logistical flow.

New cellular network technologies. With the advent of 5G, seamless real-time data communication between a manufacturer and its value chain partners allows for more comprehensive and precise tracking of deliveries and usage of products, not to mention quicker identification and response to problems and failures. 5G will impact manufactured products that need to exchange massive amounts of data in real-time with the rest of the world.

Over the years, the progressive introduction of 2.5G and 3G mobile communication systems on plant floors has helped open more options in mobile Internet for digitalized communications. But it is the more recent preponderance of remote video surveillance, which requires a massive amount of data transmission broadband,[319] that augers for more robust networks. Machine communication aims for lower complexity, less power usage, deeper coverage, and higher device density. As the volume of data grows with data-heavy applications, so will the need for higher data transmission rates for such applications. In oil, gas, and water plants, 4G LTE, which is low-cost, reliable, and flexible, has aided physical security and cybersecurity protection.[320]

AI-based virtual reality is being applied in creative ways to improve productivity and complexity in manufacturing. At Ericsson's factory in Tallinn, Estonia, the company uses AI-based augmented reality to help predict and troubleshoot breakdowns that could interrupt production, idle workers, and increase costs. Using AI, the company, which has an established data and quality culture, can reduce the cost of a breakdown by as much as half. Generally speaking, AI technology provides incrementally increasing benefits for companies that grow their data-based learning methods. Therefore, it is critical for manufacturing companies in Pillars 1 and 2 to establish data and quality cultures based on conventional approaches before embarking on AI-based techniques.

An Approach for Each Pillar

Pillar 1 Economies: In fragile and conflict-affected situations and low-income countries, it is necessary to build commercially viable, resource-based industries that manufacture products for local consumption and for higher value-added exports. Strengthening local supply chains and building capacity to produce and assemble low-complexity products as part of global value chains is key. AI adoption is limited, but it is important for new investments in resource-based industries to involve the best available process technologies, including AI. It is also important for these countries to build technical foundations in data usage, capture, and statistical analysis.

The Dangote Group, for example, uses cement-loading robots. Sophisticated cement companies have kiln control systems with rules-based programs that optimize yield, reduce thermal and electricity consumption, and improve process quality and reliability.[321] This conserves fossil fuels, minimizes CO_2 emissions, and encourages a sustainable industrialization approach. Chemical companies typically incorporate similar technologies in their offerings. Thus, a few process-heavy Pillar 1 industries already use some AI applications. But because of the low cost of labor in most Pillar 1 countries, the economic calculus for making an expensive investment in AI is very different than in an expensive labor market. On the other hand, engineers and technicians may cost much less in low-income countries, significantly reducing the cost of developing and implementing advanced applications.

Pillar 2 & 3 Economies: In recent years, more advanced developing countries have embraced sophisticated manufacturing applications, including some powered by AI and machine learning. Mexico, for example, added 6,334 industrial robots in 2017, largely to service its automobile industry. AI adoption by Pillar 2 countries, particularly in established applications such as asset performance management, smart image recognition, process and quality control, and product engineering, as well as supply chain management, is encouraging.

For example, IFC is exploring a partnership with a textile manufacturer that uses computer vision and AI to detect defects on its production line. The technology will allow the company to reduce waste and shrink its environmental footprint.

In areas such as resource efficiency, DataProphet,[322] a business consulting firm in Cape Town, specializes in AI for manufacturing by improving process efficiencies through optimization of process variables.[323] It has helped a major engine-block manufacturer attain zero-percent external scrap, and helped an international car manufacturer reduce stud-welding defects by 75 percent.[324] These examples are indicative of various AI efforts in emerging markets. However, the reality is that most manufacturers in emerging markets are still using traditional data analysis methods.

Developed countries: The most advanced industrial countries, which are also part of the Pillar 3 group of economies described above, are the primary users of AI across many manufacturing sectors. For example, the automotive industry has triggered tremendous interest with self-driving vehicles, a very sophisticated example of AI-based robotization and driving automation. A large automotive parts manufacturer that is an IFC client is developing an AI-based virtual-simulation program in collaboration with a German start-up to accelerate development of the company's advanced driver assistance systems and automated driving functions. The simulation program creates a realistic traffic environment that enables new driver assistance products to be tested virtually. Up to 8,000 kilometers per hour of testing can be performed with virtual simulation, while only about 10,000 test kilometers per month can be driven by a real vehicle.

Another IFC client in the automotive sector is adapting AI-integrated sensors in air filtration systems in its paint shops to predict and analyze dust particles in the air and create cleaner and more sterile manufacturing environments for production of sensitive products. That technology promises to have multiple applications for manufacturers in a range of industries that require such production environments. At a major original equipment manufacturer, an innovative "dust particle analysis technology" has been deployed as a pilot project in the automaker's paint shop. The application can forecast and identify instances when there will be an increase in dust particles in the air

that can mar a car's painted finish. It can then fine-tune filter replacement based on a series of factors such as historical levels of airborne dust by season, or by monitoring trends in prolonged dry periods. The algorithm monitors 160 factors related to the application of paint and can make highly accurate predictions about the quality of the paint process.

This AI solution can also be applied in production facilities of Pillar 2 and 3 countries to series production as the database expands, capturing more and more sensitive information and enabling manufacturers to produce more complex products. Robots and smart factory floor automation are other indicators of industrial complexity. According to the International Federation of Robotics, in 2017, robot sales increased by 30 percent to a new peak for the fifth year in a row. Five major markets—all of them among the world's most diverse and complex economies—represented 73 percent of the total sales volume in 2017: China, Japan, Korea, the United States, and Germany.[325]

Conclusion

Similar to previous industrial revolutions, when innovative machines and technologies replaced conventional methods of production and spurred the invention of sophisticated new products, artificial intelligence has the potential to transform today's manufacturing. The most complex economies are predictably the earliest and biggest adopters of AI technologies, as they already had the foundations and well-established tech centers in place, where

some of the earliest AI applications were created. These economies possess a wealth of capital and an abundance of data for machines to analyze and adapt into the algorithmic patterns that are economically scalable for AI.

Yet AI is not confined to the world's biggest and most complex economies. As cloud computing capacity expands, global data volumes balloon, and processing power becomes more affordable, cutting-edge applications have been winding their way through global value chains and planting seeds in every pillar of complexity.

In less complex economies, companies can gradually acquire and adapt AI to address unique market needs. This will require additional investment to cultivate and strengthen sustainable and socially sound manufacturing cultures. In Pillar 1 economies, manufacturers need to build more sustainable and efficient industrial sectors and minimize the negative impacts of pollution, CO_2 emissions, and weak labor standards by adopting advanced technologies that bolster complexity.

For years—and particularly in emerging economies—the biggest obstacle to adopting AI was the extravagant cost. Measured against inexpensive workers in low-wage economies, the investment made little sense. Now, however, as the price of implementing AI falls and data analytics increasingly become the language of global value chains, companies and governments are reevaluating their options and rethinking their policies. ■

Chapter 12

Leveraging Big Data to Advance Gender Equality

By Ahmed Nauraiz Rana

Gender equality and the empowerment of women and girls, one of the Sustainable Development Goals, is a highly complex and challenging undertaking. We must address multiple issues—discrimination, violence, education, employment, economic resources, and technology—and work across economic sectors, from agriculture to financial services. Achieving gender equality will require significant amounts of accurate data about the situations and struggles of women and girls. Globally, however, there is a major gap in data that is disaggregated by sex, and this gap often renders women's societal, cultural, and economic contributions and obstacles practically invisible. It can also exacerbate existing gender divides, feeding and reinforcing biases in social programs, access to financial and other services, economic opportunities, and even development programs designed to address gender inequality. Part of the solution may be in the form of big data, which, if used effectively, can provide the volume of data needed to portray women and their situations accurately, which in turn can inform the creation of evidence-based solutions.

The social and economic integration of women into society is increasingly becoming part of all development discourse. Various mechanisms are being employed around the world to shed light on the issues and inherent biases that women are subject to, and numerous interventions focused on greater gender equality are being implemented. But the success of all these efforts is dependent on data that is verifiable, reliable, and ensures integrity. Just 21 percent of the data required to monitor 54 gender-specific indicators within the Sustainable Development Goals (SDGs) is current.[326]

Additionally, the overrepresentation of men in the tech field filters into content creation, with recommendation algorithms often trained on male-majority data. As a result, disaggregating data based on gender is critical to understanding how developing countries can help women living on the border between poverty and prosperity. Gender equality is a fundamental prerequisite for multiple development goals, so it is imperative to emphasize the fact that progress will falter without a data-driven focus.

Discrimination against women is a multifaceted phenomenon that spans economic sectors and is ingrained in societal practices. Issues such as land rights, access to education, financial inclusion, healthcare, gender-based violence, family planning, and many others can only be correctly addressed if evidence-based policies are formulated and progress is monitored in a quantifiable manner.

This is contingent on the use of big data—extremely large data sets that can be analyzed for patterns and trends. However, up-to-date data exists for only a small fraction of indicators that were developed to evaluate SDG #5, Gender Equality. As a result, most countries have never been able to measure more than three of the 14 indicators that were created to assess progress toward this goal.[327] Clearly, innovative approaches are needed to ensure effective data collection that is disaggregated by sex, which is defined by the United Nations as "data collected and tabulated separately for women and men."[328]

For private sector businesses, sex-disaggregated data is a necessity where the aim is to build consumer-centric business strategies and enhance the company's value proposition to specific market segments, including the women's market. It allows for the recognition of customer segmentation and the market opportunity.[329]

Inclusive approaches to gender data collection and usage have been shown to yield greater revenues, as well as numerous other nonfinancial positive outcomes such as employee retention, and operational

replicability and scalability. Furthermore, a number of existing studies have identified various avenues through which sex-disaggregated data can assist women entrepreneurs in overcoming barriers to market access, financial inclusivity, and identification of prospective opportunities, and address value-chain bottlenecks using gender-specific information.

McKinsey Global Institute estimated that an increase in the level of gender equality alone will add $28 trillion to global GDP by 2025.[330] The revenue share was estimated to be higher for tech companies, start-ups, and industries where innovation is the key to growth, highlighting the fact that greater gender equality is not just desirable but is an integral part of successful revenue-generating businesses.

The data revolution currently underway can—and in certain places already is—being leveraged to achieve sustainable development goals pertaining to gender rights and equality. In 2017, for example, the Bill & Melinda Gates Foundation launched a tech initiative in partnership with UN Women to help countries improve the quality of gender-specific data collected globally.[331] Similarly, the United Nations Foundation spearheaded Data2X, a technical platform initiative to help close the daunting gender data gap in five development domains—health, education, economic opportunity, political participation, and human security—by collaborating with government agencies and the private sector.[332]

How Can Big Data Support Gender Equality?

Traditional data collection methods include surveys, interviews, and focus groups, among others. However, these methods have shown limitations in their ability to collect quality data about female subjects and target groups. They have also been found to incorporate

Human sourced data
» social media
» blogs
» vlogs
» internet forums
» wikis
» internet searches
» email or SMS content

Process mediated data
» health records
» mobile phone data
» credit card data
» public transport usage data
» job application records
» chips identifcation data
» e-government data

Machine generated data
» road sensor data
» smart meter electricity data
» scanners data
» satellites imagery/aerial imagery data
» traffic loops webcams data
» vessel identification
» internet of things (IoT)

Crowdsourcing data
» citizen-generated data
» images collection
» volunteered geographical information (VGI)

Media sourced data
» TV and radio broadcast data
» podcast data
» digital newspapers

(DIGITAL) CRUMBS · COMMUNITIES · CAPACITIES

VOLUME · VELOCITY · VARIETY

FIGURE 12.1 Current Data Sources for Big Data

Source: United Nations Entity for Gender Equality and the Empowerment of Women, also known as UN Women.

stereotypes and other socio-cultural factors that induce gender biases. Such barriers raise valid concerns about construct and external validity, and lead to incomplete or inaccurate information that obstructs both the formulation of evidence-based policies and the determination of the root causes of gender discrimination.

Big data allows researchers and policy makers to transcend ineffective means of data collection. It offers policymakers and investors alike an additional

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BOX 12.1 Coping With COVID-19 Through a Gender Lens

The COVID-19 pandemic poses a serious threat to women's employment and livelihoods due to its potential to exacerbate preexisting inequalities and reinforce gender gaps in social, political, and economic systems. From a lack of access to health services, social protections, and digital technologies, to a significant rise in domestic violence and unpaid care work, the impacts of COVID-19 are being felt acutely by women around the world. Recognizing the range of gender-based differences in the implications of the crisis is critical to ensuring that men and women have equal opportunity to benefit from response efforts and can participate in the eventual economic recovery.

As economies around the world gradually recover, it is advisable for private sector firms to fill information gaps by leveraging sex-disaggregated data as they begin the work of rebuilding a resilient economy. Assessing the gender-differential business impact of COVID-19 is absolutely essential to creating effective strategies and designing crisis solutions that meet the needs of both female and male entrepreneurs. Similarly, in order to develop a diverse and inclusive workforce that is resilient to another such crisis, it is imperative to collect, analyze, and utilize sex-disaggregated data to better understand gaps and how they might lead to lower productivity or profitability at the firm level.

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evidence base and complements traditional forms of data collection. In recent years big data has evolved as a parallel source for understanding gender perceptions and forms of discrimination and marginalization due to its ability to detect large-scale data patterns and generate predictive models. A study commissioned by UN Women to understand the role of big data in evaluating women's political participation and leadership found that the analysis and interpretation of conversations within a cultural context can be significantly enhanced by focus groups with social media users.[333]

Areas of Intervention—Current Trends

Geospatial data accessed via satellite imagery can be leveraged to predict women's wellbeing. A number of research studies have found social and health indicators such as child stunting, infertility, literacy, and access to contraception to be correlated with geospatial factors such as climate, elevation, aridity, and geographical location.[334] And it is relatively easy to map such geospatial factors across countries and complement that data with information gathered via demographic and health surveys (DHS). This allows for the modelling of possible wellbeing indicators where data from DHS is not readily available, transforming inaccessible and neglected areas into a continuous landscape of information for gender wellbeing.

Similarly, mobile phone data can be leveraged to make better-informed decisions regarding women's social protection. A study commissioned by the Massachusetts Institute of Technology in collaboration with UN Global Pulse used data from credit cards and mobile phones to identify patterns of women's spending and physical mobility.[335] Using these to project women's economic status, researchers were able to identify seven economic lifestyle clusters among women in the dataset. The categorization of clusters allowed development professionals to understand individuals' economic status and needs. The technique helped identify women who were more vulnerable to economic downturn and shock, and improved targeting methods and interventions for extending socioeconomic protections.

Big data extracted from patterns of Internet use also aids in monitoring women's mental health. Most publicly available mental health data does not include sex-disaggregated information, yet there is a significant need for gender specific mechanisms for data collection and analysis. Internet use data can be leveraged to analyze the expression of thoughts on social media platforms and provide insights into women's mental health and welfare. To this end, researchers at UN Global Pulse successfully employed artificial intelligence machine-learning techniques to determine if expressions of distress or anxiety on social media accurately identified mental health disclosures. They analyzed publicly available tweets from women and girls in India, South Africa, the United Kingdom, and the United States to locate signals of depression and make appropriate and targeted recommendations.[336]

Of the many challenges that women face, one of the most staggering is access to financial services. For example, in Senegal some 87 percent of women lack access to any formal financial products or services.[337] This financial exclusion can be attributed both to gender discrimination and to a lack of data that may prevent financial institutions from making sound decisions. This lack of financial inclusion thus directly impacts women's ability to improve their earning capacity and engage in entrepreneurial activities, making them more vulnerable to economic shocks and downturns. An analysis of the Senegal River Valley rice value chain by Feed the Future revealed that financial institutions were hesitant to lend to female rice farmers due to perceived high risk, a lack of available collateral, and most important, a lack of information that prevents financial institutions from being able to evaluate risk and tailor lending terms to female customers.[338]

Such a lack of information is not unique to agricultural lending; it occurs across economic sectors. Readily available data on key transaction factors can help address many of the concerns of financial services suppliers.

Data Innovation Projects Advancing Gender Equality

Various other projects using big data to address gender inequality issues have been undertaken. The following are a few of them.

Discovery of Complex Anomalous Patterns of Sexual Violence in El Salvador. A Carnegie Mellon University project applied data mining techniques to uncover complex anomalous spatio-temporal patterns of sexual violence. The researchers identified patterns after analyzing data on rape incidents in El Salvador over a period of nine years. These patterns helped formulate real-time early detection that would allow law enforcement agencies to initiate early rapid response.[339]

The Everyday Sexism Project is an initiative by the Oxford Internet Institute to create a semantic map of sexism via the application of a natural language processing approach that analyzes a large-scale, crowd-sourced dataset on sexism collected from the project website. The goal is to develop an advanced sociological understanding of women's life experiences of sexism and compute a methodological, evidence-based approach for modelling relevant interventions.[340]

Two-way Radio: Engagement with Somali Women. Africa's Voices, a University of Cambridge tech startup, designed five interactive radio shows on gender and child protection issues to address the gaps in data and evidence pertaining to (i) female genital mutilation/cutting, (ii) child marriages, (iii) girls' access to education, and (iv) juvenile justice. The show was broadcast across 27 stations and was leveraged to collect data via SMS messages in local dialects from radio audiences. The data that was collected was instrumental in generating insights regarding cultural beliefs and practices and was further used to develop gender equity programs and map health vulnerability areas.[341]

Identifying Trends in Workplace Discrimination. This combined initiative by UN Global Pulse, the International Labour Organization, and the Government of Indonesia was designed to address discriminatory behavior against women in the workplace in Indonesia. Researchers collected and analyzed data from publicly available tweets over three years to identify real-time signals of discrimination.

The data helped understand women's unwillingness to report experiences related to discrimination and violence in the workplace.[342]

Mapping Indicators of Women's Welfare: Literacy, Stunting, Poverty, and Maternal Health. An initiative of World Pop/Flowminder and Data2X is developing modelling techniques that use high-resolution geospatial data to infer similar high-resolution patterns of social and health phenomena across entire countries. Based on deduced correlation, the method is used to predict social and health outcomes where surveys have not been performed, generating a series of highly detailed maps that illustrate landscapes of gender inequality, including stunting, literacy, and the use of modern contraceptives.[343]

Big Data and the Cloud: Piloting eHealth. The Government of Ghana, in partnership with the World Bank Group, implemented a performance-based financing project in four regions with particularly poor maternal child health nutrition outcomes to incentivize community health teams to improve female health outcomes. The quantity and quality of performance-based indicators was assessed by means of data collected directly from beneficiary communities, using an Android-based survey tool.[344]

Girl Effect's Springster Mobile Platform. Researchers from Girl Effect have been using a wide range of techniques to comprehend how user engagement affects girls' lives after they engage in conversations with other users, and/or read content on Springster, a global mobile-first platform developed for confidence and skill development of vulnerable girls aged 14 to 16. Researchers have been using Google Analytics, comment analysis, online surveys, and social media analytics to combine big data with traditional approaches to find innovative and improved ways of influencing positive change and strengthening female image building in an online space.[345]

Measuring Economic Resilience with Financial Transaction Data. The project, undertaken by BBVA Analytics, explored ways that financial transaction data could be analyzed to determine the level of economic resilience of people affected by natural disasters. It did not focus solely on women but did

incorporate a gender lens that revealed differences in how women and men are impacted, including their differences in coping and recovery mechanisms. The project used the Mexican state of Baja California Sur as a case study to assess the impact of Hurricane Odile on livelihoods and economic activities over a period of six months. The project team measured daily point-of-sale transaction and ATM withdrawals at high geo-spatial resolution to gain insights into the way people prepare for and recover from disasters. Findings revealed that women increased their spending twice as much as men in preparation for the disaster, and that they took much longer than men to fully recover from it. These findings are instrumental as a starting point to design programs to assist and rehabilitate women after natural disasters.[346]

Conclusion

Big Data can play a fundamental role in achieving gender equality and empowering women and girls across the globe by identifying multi-sectoral gaps in the provision of equal opportunities and the protection of female rights, and by aiding in the implementation of evidence-based policies and interventions. Data from sources such as radio transmissions, social and digital media, call records and mobile network operations, and satellite imagery, both alone and in combination with traditional data sources, can help highlight the needs and concerns of women and girls. However, it is important to be cautious of the limitations and concerns that big data poses, including careless interpretations that can lead to disproportionate representation and biased recommendations.

Data collection and processing requires an adequate framework, extensive digital infrastructure, stringent regulations for privacy protection, and tools to mitigate risks of harm to data subjects. Access to big data is also challenging due to the high associated costs and technical expertise required to retrieve scattered information. However, given these considerations, big data analytics has enormous potential for policy makers and investors as a fast-evolving source of information that can be leveraged to gain valuable insights regarding women and girls. ■

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List of Previously Published EM Compass Notes Included as Chapters in this Report:

Chapter 1, *The Role of Artificial Intelligence in Supporting Development in Emerging Markets,* was published previously under the same title and was expanded for this report (Davide Strusani and Georges Vivien Houngbonon, EM Compass Note 69, IFC, July 2019).

Chapter 2, *Artificial Intelligence: Investment Trends and Selected Industry Uses,* was published previously under the same title (Xiaomin Mou, EM Compass Note 71, IFC, August 2019).

Chapter 3, *Artificial Intelligence and 5G Mobile Technology Can Drive Investment Opportunities in Emerging Markets*, was published previously under the same title (Peter Mockel and Baloko Makala, EM Compass Note 76, IFC, December 2019).

Chapter 4, *Bridging the Trust Gap: Blockchain's Potential to Restore Trust in Artificial Intelligence in Support of New Business Models*, was published previously under the same title (Marina Niforos, EM Compass Note 74, IFC, October 2019).

Chapter 5, *Developing AI Sustainably: Toward a Practical Code of Conduct for Disruptive Technologies,* was published previously under the same title (Gordon Myers and Kiril Nejkov, EM Compass Note 80, IFC, March 2020).

Chapter 6, *Artificial Intelligence in the Power Sector,* was published previously under the same title (Baloko Makala and Tonci Bakovic, EM Compass Note 81, IFC, April 2020).

Chapter 7, *How Artificial Intelligence is Making Transport Safer, Cleaner, More Reliable and Efficient in Emerging Markets,* was published previously under the same title (Maria Lopez Conde and Ian Twinn, EM Compass Note 75, IFC, November 2019).

Chapter 8, *Artificial Intelligence and the Future for Smart Homes,* was published previously under the same title (Ommid Saberi and Rebecca Menes, EM Compass Note 78, IFC, February 2020).

Chapter 9, *Artificial Intelligence in Agribusiness is Growing in Emerging Markets,* was published previously under the same title (Peter Cook and Felicity O'Neill, EM Compass Note 82, IFC, May 2020).

Chapter 10, *Artificial Intelligence Innovation in Financial Services,* was published previously under the same title and was expanded for this report (Margarete Biallas and Felicity O'Neill, EM Compass Note 85, IFC, June 2020).

Chapter 11, *Artificial Intelligence Investment Opportunities to Increase Complexity in Manufacturing*, was published previously under the same title (Sumit Manchanda, Hassan Kaleem, and Sabine Schlorke, EM Compass Note 87, IFC, July 2020).

Chapter 12, *Leveraging Big Data to Advance Gender Equality*, was published previously under the same title (Ahmed Nauraiz Rana, EM Compass Note 86, IFC, June 2020).

FURTHER READING

REINVENTING BUSINESS THROUGH DISRUPTIVE TECHNOLOGIES

Sector Trends and Investment Opportunities for Firms in Emerging Markets

Reinventing Business Through Disruptive Technologies: Sector Trends and Investment Opportunities for Firms in Emerging Markets

March 2019—108 pages

Technology disrupts and transforms. And disruptive technologies are critical to achieving the Sustainable Development Goals, many of which can be advanced and accelerated through technological innovations.

For a comprehensive examination of the ways these innovations alter private sector business models in emerging markets, IFC conducted a tour of the technology horizon in eight selected sectors—power, transport, water and sanitation, digital infrastructure, manufacturing, agribusiness, education, and financial services—and six selected themes, from gender and climate-smart cities to e-logistics and personal identification, among others.

This report examines each of these sectors and themes in terms of what true disruption looks like, which technologies are most likely to have a dramatic impact, and the specific opportunities they offer. It also identifies the challenges and constraints that will need to be surmounted if the private sector is to seize these opportunities. Lastly, it presents how IFC supports companies and investors in their efforts to enter into or expand in emerging markets.

Blockchain: Opportunities for Private Enterprises in Emerging Markets

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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

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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.

EM Compass Notes

About IFC and Investing in Disruptive Technologies

IFC supports early-stage ventures in developing countries that are creating new markets, transforming industries, and driving inclusive growth while realizing strong returns. By investing in best-in-class entrepreneurs and partnering with top-tier venture capital (VC) funds, we support the creation of a tech-enabled venture asset class across emerging markets that fosters private sector growth.

IFC takes a holistic approach—from ecosystem building to investing directly in ventures and VC funds—with combinations of commercial and concessional capital, and technical advisory services—to identify, incubate, and scale business models that can have significant impact. IFC's current portfolio focuses on Internet-related Business Models driving the transition to the digital economy in priority sectors—digital health, ecommerce, e-logistics, e-supply chain, edtech, and agtech—all aiming at reducing cost, increasing quality, and expanding access.

With one of the largest footprints in emerging markets, we offer growth and expansion capital, local and sector knowledge, and connections to a global network of other clients and portfolios, as well as an understanding of regulations and local domains. We aim to be a long-term partner to the ventures we support.

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