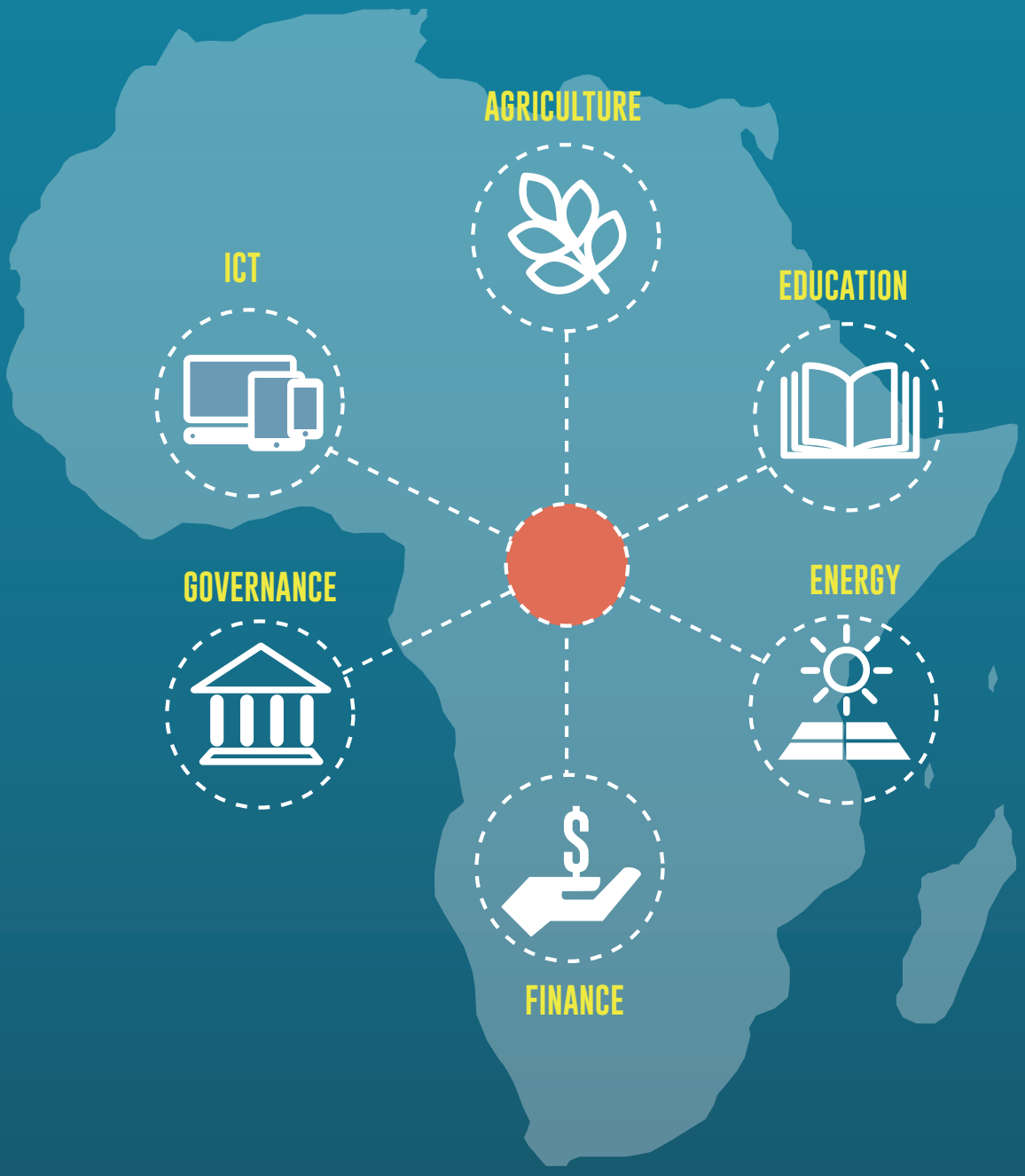
LEAPFROGGING:
THE KEY TO AFRICA'S DEVELOPMENT?

FROM CONSTRAINTS TO INVESTMENT OPPORTUNITIES



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Foreword

The purpose of this book is to explore ways to catalyze a new generation of investment opportunities in Africa that leverage the ability of many countries to leapfrog into the future. The book was born from the view that gradualism and business-as-usual will not provide the necessary solutions to the massive challenges facing the continent. Learning from economic history, the types of transformational and high-impact solutions that are needed to unlock Africa's potential for accelerated, sustained, and inclusive growth often have been driven by innovation and widespread technology adoption. Embracing and leveraging innovation and building the momentum to leapfrog will be critical for Africa to create the jobs its youth so desperately need.

Under the overarching theme of *Leapfrogging*, the book discusses the following six topics: (a) agriculture, (b) education, (c) energy, (d) finance, (e) governance, and (f) information and communications technologies. The book is predominantly forward looking and results oriented; it showcases specific projects, success stories, and innovative ideas. The six topics are the themes covered in the third Investing in Africa Forum (IAF 2017).

The IAF was established in 2015, as a global platform for multilateral cooperation and promoting opportunities to increase investment in Africa. It was first initiated by the China Development Bank, with the full endorsement of the Chinese government, and won the firm support of the World Bank Group and several African countries. The first forum focused on "Industrialization and results for Africa" and aimed to think about different strategies that would help to unlock the potential for sustainable and inclusive growth, job creation and poverty reduction in Africa. The second forum under the theme "Experience Sharing and Investment Promotion, Building Complementarities and Shared Prosperity" addressed issues pertaining to agriculture and agribusiness, infrastructure development, regional connectivity and renewable energy, skills development, and job creation.

The third IAF (IAF 2017) will bring together delegations from African countries, World Bank, China, as well as other development partners, and think tanks, to share experiences and explore opportunities for *Leapfrogging through Innovation in Africa*. While continuing to promote partnerships for accelerated investment to build complementarities and shared prosperity between Africa and China will focus on transformational and high-impact solutions driven by innovation and technology adoption.

Acknowledgments

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Abstract

Despite sustained economic growth over the past two decades, Sub-Saharan Africa faces massive challenges and significant gaps in many development outcomes. Although poverty has been declining, a recent report estimates that over two-fifths of the African population was poor in 2012. Nearly two-thirds of Africans do not have electricity. Less than one quarter of African enterprises have loans or lines of credit; the corresponding share among firms in non-African developing countries is almost half. The use of formal financial services is concentrated among the richest 20 percent of the population. Most African countries have made significant gains in access to education, but learning remains weak. The agriculture sector, which employs a large share of the labor force, exhibits low productivity. Technological change and levels, which are the drivers of productivity, are much lower compared to other parts of the world. Even simple productivity-enhancing factors like the use of fertilizers has remained flat for decades.

Africa's large infrastructure, technology, and policy gaps require disruptive solutions and thinking outside of the box. Yet, development policies have often been primarily programmatic and mostly incremental. This book argues that it is time to go back to basics of development, think big, and foster the environment for more innovation and technology adoption, to provide the chance for Africa to experience major positive transformations. This is not a new idea; to the contrary, it is what economic theory and history teach. There is no solid ground to treat Africa as an exception. The one commonality among almost all contemporary growth and development theories is that they consider technology and innovation as the primary drivers of economic growth. Historical experiences point to the same evidence. Major changes in the history of countries like the United Kingdom, the United States, or even recently developed and emerging economies can be tightly linked to increased productivity through the adoption of better technologies. The stream of inventions that began in the 18th century in the United Kingdom, from the steam engine to electricity, the power loom, and machine tools, has dramatically changed the course of human history. More recently, the phenomenal rise of South East Asian countries involved moving from low productivity agriculture (paddy fields) to manufacturing and more technology-intensive electric and electronic components. Squarely focusing on uncovering investment opportunities that could reduce the distance to the technology frontier should therefore be the starting point in thinking about African development. Equally important is the acknowledgment that Africa need not follow the same path and/or steps as other emerging regions. Vertiginous changes brought about by the digital revolution in the past 20 years (World Development Report 2016) make leapfrogging (skipping steps, charting new paths) in Africa not only a possibility but a necessity.

While it has become customary in the development practice to highlight and quantify constraints to

investing in Africa, this book argues that those constraints must be seen as and transformed into investment opportunities. Several factors, such as skills, service delivery, access to finance, energy, to name the few, are often pointed out as constraints to investment. Treating those constraints as investment opportunities, attracting the private sector, both domestic and foreign, and creating a conducive environment for technological diffusion is precisely how Africa will harness innovation toward its prosperity.

Abbreviations and Acronyms

4G	fourth-generation
ABF	Asian Bond Fund
ADIE	Agence De l'Informatique de l'Etat
AFI	Alliance for Financial Inclusion
AGRA	Alliance for a Green Revolution in Africa
AVU	African Virtual University
BRICS	Brazil, the Russian Federation, India, China, and South Africa
CAADP	Comprehensive Africa Agriculture Development Programme
CDB	China Development Bank
CEI	Center for Education Innovations
CENI	Commission Électorale Nationale Indépendante
CFAF	African Financial Community Franc
DLP	Digital Learning Program
EARP	Electricity Access Rollout Program
EGDI	United Nations E-Government Development Index
EIA	U.S. Energy Information Administration
EMEAP	Executives' Meeting of East Asia and Pacific Central Banks
eSWAp	Electricity Sector Wide Approach
FAO	Food and Agriculture Organization
FDI	foreign direct investment
GDP	gross domestic product
GISDC	Ghana Industrial Skills Development Center
GTZ	Gesellschaft für Technische Zusammenarbeit
IAF	Investing in Africa Forum
ICT	information and communications technology
ID	identification
IEA	International Energy Agency
IFC	International Finance Corporation
IIAG	Ibrahim Index of African Governance
ILO	International Labour Organization
IMF	International Monetary Fund
IPP	independent power project
ITU	International Telecommunication Union
K Sh	Kenyan shillings
KENET	Kenya Education Network

km	kilometer
KNBS	Kenya National Bureau of Statistics
MIF	Mo Ibrahim Foundation
NMCP	National Malaria Control Programme
OECD	Organisation for Economic Co-operation and Development
OER	open educational resources
OHCHR	Office of the United Nations High Commissioner for Human Rights
PASS	Program for Africa's Seed Systems
PCIP	Pacific Council for International Policy
PISA	Program for International Student Assessment
PPP	public-private partnership
PwC	PricewaterhouseCoopers
R&D	research and development
R4	Rural Resilience Initiative
RCDF	Rural Communications Development Fund
ROPL	Rwanda Online Platform Limited
SAVCA	South African Private Equity and Venture Capital Association
SDGs	Sustainable Development Goals
SMEs	small and medium-size enterprises
t/ha	tons per hectare
TMG	Telecommunications Management Group
TVET	technical and vocational education and training
UIS	UNESCO Institute for Statistics
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries
USAID	U.S. Agency for International Development
WEDP	Women Entrepreneurship Development Project
WEF	World Economic Forum
WFP	World Food Programme
WTO	World Trade Organization

Executive Summary

Enabling leapfrogging in Africa

This book strives to identify the common factors behind successful leapfrogging experiences across sectors. It also uncovers challenges that need to be overcome to spur transformational changes on the continent. The following key messages emerge:

Leapfrogging is enhanced through the proper balance between top-down and bottom-up approaches

Africa needs both push and pull to transform. Top-down initiatives are essential for creating an enabling environment for large-scale investment, building major infrastructure that triggers spillover effects, and boosting knowledge to use and adapt technology. Bottom-up innovation is essential for successfully adapting technology to local needs and challenges. Generally, the relationship has been lopsided, with more emphasis on top-down adoption strategies. Better balance can be achieved through greater effort to boost adaptation by investing in education and Research and Development (R&D) and enhancing the enabling environment for innovation-driven entrepreneurship.

Africa is not new to leapfrogging and is already leading the world in a number of innovations

Despite the significant challenges the region faces, this book presents evidence of leapfrogging experiences in Africa. They demonstrate that with the right governance, attractive business climate, and proactive policies, leapfrogging can and does occur across all sectors. Interestingly, various innovations, such as mobile money and pay-as-you-go off-grid solar, were spawned in Africa, and are spreading to other developing regions. This makes Africa very attractive as a test-bed for technological innovation and adaption.

Not all leapfrogging attempts are successful

African countries, as well as private investors, must be willing to take risks and learn from failures, which are a normal part of the innovation ecosystem. Risks can be mitigated in various ways, including the support of development partners. A testing stage is essential for refining and adapting technology to the variety of local conditions on the continent.

Failure allows technology to be refined and improved. M-PESA began as effort to use mobile phones for microfinance loans and only later evolved to mobile money. Similarly, Lighting Africa continually adapted the program based on the results of early field trials in Ghana and Kenya, and found that on-the-ground engagement needed dedicated local specialist resources in addition to global expertise.

Constraints that African economies face are investment opportunities

Challenges are what motivates entrepreneurs to find solutions. African governments need to create

the right conditions to encourage innovators to overcome constraints, and for the private sector to provide support and the necessary resources. The benefits for the private sector can be significant. In just a decade, M-PESA has become Safaricom's largest driver of revenue growth, contributing to over a quarter of its fiscal year 2017 revenue, with the mobile money service generating K Sh 55 billion (US$103 million).[1]

Having the right regulatory environment is crucial for enabling leapfrogging

A flexible regulatory environment enables innovation by allowing new business models to be tested—regulation can then scale with the innovation. This was the case with M-PESA where, other than requiring users to register, the Central Bank of Kenya imposed few restrictions during the mobile money service's early deployment. Flexibility is also required to create investment channels, such as delinking generation, transmission, and distribution, and opening energy markets to private participation.

Innovation must scale up to trigger leapfrogging

Technological innovation must be accessible in cost, the skills required to use it, availability, and meeting a widespread need. Mobile money scaled rapidly because it filled the gap in formal banking, was simple to use, worked on inexpensive basic cell phones, and answered the need for a cheap and safe way for urban Kenyans to transfer money to family in rural areas.

Public investment should prioritize skill acquisition

Education, especially foundational skills acquisition as well as science, technology, engineering, and mathematics, is fundamental to using, adapting, and triggering technological innovation that enables leapfrogging. Of all the sectors covered in this book, education has unique role in creating a conducive environment to attract private investment on the scale needed. Governments should prioritize public spending for the education sector, given the potentially high returns it can generate as a lever for transformational leapfrogging.

R&D is key to adapting technology to local contexts

R&D is an important determinant of absorptive capacity and technological progress. It enables technology to be adapted to local environments for rapid adoption. Part of Africa's lack of leapfrogging can be explained by low R&D expenditure: the lowest of any developing region and almost four times less than the world average. This report has identified several promising areas meriting research. R&D is particularly essential for two sectors that have not experienced significant leapfrogging—agriculture and education. Characterized by unique agroecology and small shareholdings, Africa's agriculture sector has remained largely unaffected by the Green Revolution. R&D is needed to investigate how to increase productivity and sustainability, given these distinctive characteristics. R&D in itself is a good investment that should be prioritized. A study from India finds that investment in research, education, and roads was the most effective for agricultural growth and reducing poverty.[2]

In education, outcomes remain constrained, meriting research into causes and solutions. Several educational technologies are being piloted across the continent. However, few have found scale despite the promise of some, such as online learning, which could help alleviate shortages of teachers. R&D is needed to explore the adaptive potential of these technologies, including impact evaluations, to determine if and how they can be scaled for Africa.

Innovation, Technology, and Development: Africa Can Leapfrog

Why Are Technology Adoption and Innovation Crucial for Africa's Future?

Despite sustained economic performance in the past two decades, Sub-Saharan Africa region still faces enormous challenges and significant gaps in many development outcomes. Although poverty has been declining, a recent report estimates that over two-fifths of the African population was poor in 2012.[3] Infrastructure is a key component that helps in promoting industrialization, raising incomes, accumulating human capital, and easing access to markets. However, the evidence shows that there are severe infrastructure gaps in Africa. There is a dire need to address these gaps, as the current state of the region's infrastructure is one of the major reasons limiting private sector expansion and investment.

Sub-Saharan Africa ranks at the bottom of all developing regions in virtually all dimensions of infrastructure performance: quantity, quality, and access.[4] The consequences of this poor infrastructure are enormous. Weak physical infrastructure not only limits the growth of potential entrepreneurs, but also restricts private sector development and the region's overall development. Many issues drive the infrastructure gap in Africa, ranging from a lack of commitment, to sustainable tariffs on infrastructure services, to poor performance of public utilities, with weak management and political interference affecting the latter.[5]

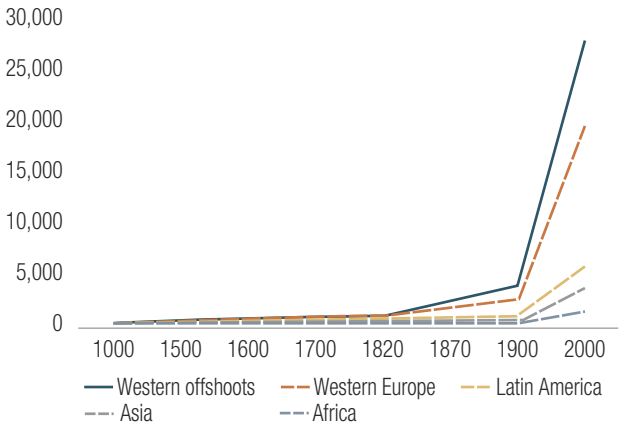
Despite these massive challenges and gaps, the development approach in Africa has often been primarily programmatic and mostly incremental. This book argues that it is time to go back to the foundation of development, think big, and enable the environment for innovation and technology adoption for Africa to have the opportunity to experience major positive transformations. This is not a new idea; on the contrary, it is what economic theory and history teach. There is no solid ground to treat Africa as an exception. The one commonality among almost all contemporary growth and development theories is that they consider technology and innovation as the primary drivers of economic growth.[6] Major changes over the course of the history of countries like the United Kingdom, the United States, and recently developed and emerging economies can be tightly linked to increasing productivity through the adoption of better technologies. The stream of inventions that began in the 18th century in the United Kingdom, from the steam engine, to electricity, the power loom, and machine tools, has dramatically changed the course of human history. If the theoretical foundations and experiences around the world concur on this point, it should also be the starting point in thinking about African development.

What Do Economic Theory and History Say about Leapfrogging?

What Does Economic Theory Say?

There is one commonality in almost all contemporary growth and development theories: they all consider technology and innovation as the most important drivers of economic growth. The role of technology and innovation and their subsequent adoption for economic growth and development is well established.[7] Research finds that the correlation between innovation (measured by the natural logarithm of total factor productivity) and the logarithm of output per worker for 98 countries in 1985 was 0.93.[8] This very high correlation suggests that, at the aggregate level, there is a large interdependence between the level of technology productivity and economic development in general. Similar results are found for productivity growth. Technology and innovation also represent the bulk of cross-country differences in productivity, compared with factor accumulation (physical and human capital), which accounts for only 10 percent.[9]

FIGURE ES.1: Evolution of per Capita GDP in Western Offshoots, Western Europe, Latin America, Asia, and Africa, 1000–2000



Source: The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.
Note: GDP = Gross Domestic Product. Values in 1990 International Geary-Khamis dollars. Western Offshoots = Australia, Canada, New Zealand and the United States.

What Does History Reveal about Technology and Development?

Very few events have dramatically changed the course of human history more than the stream of inventions that began in the 18th century in the United Kingdom. This period of unprecedented technological advancements led to a real Industrial Revolution, first gradually in Europe and later in North America. The effects of this revolution have reverberated throughout the years across the globe, from Latin America to Asia and Africa. The exact reasons for why this succession of breakthrough inventions occurred are not straightforward to explain, but perhaps were implicit in the events in the buildup toward industrialization.

Through a mix of good fortune and conscious efforts, by the early 18th century, Britain came to possess a unique combination of social needs and social resources that offered the necessary preconditions for commercially successful innovations and a social system that was capable of sustaining and institutionalizing the processes of rapid technological change once it had started. The list of sectors affected by those inventions is extensive: power, metallurgy, mechanical engineering, textiles, chemicals, agriculture, civil engineering, transport and communications, and the military, to name some.

Figure ES.1 shows that, going back in time, the income gap among countries becomes smaller, emphasizing that the big divergence took place over the past 200 years or so. The evidence suggests that there was only limited economic growth before the 18th century. The major catalyst for the momentous change was undeniably the Industrial Revolution and the incredible amount of technological developments that came along with it, which ultimately affected many sectors.

Technological Breakthrough in One Sector Can Spill over into Others

Technological spillover and innovation are well illustrated by the British textile industry during the Industrial Revolution. Not only did the textile industry capitalize on the steam engine, it also stimulated the development of the chemical industry. The Industrial Revolution bracketed the period in which the processes of cotton manufacture in Britain were transformed from a small-scale, domestic industry scattered over towns and villages, into a large-scale, concentrated, power-driven, mechanized, factory-organized, urban industry. The most far-reaching innovation in cotton manufacture was the introduction of steam power to drive the carding machines and power the looms and printing machines. The growth of the textile industry brought a sudden increase of interest in the chemical industry, because a bottleneck in the production of textiles was the length of time the process of natural bleaching techniques took, relying on sunlight, rain, sour milk, and urine. The modern chemical industry was virtually called into being to develop more rapid bleaching techniques for the British cotton industry.

Similar spillovers took place across other sectors. The metallurgy and metal trades industry benefited greatly from the power revolution. The agricultural improvements of the 18th century had been promoted by people whose industrial and commercial interests made them willing to experiment with new machines and processes to improve the productivity of their estates. Another sector that heavily benefited from the new innovations of the 18th and 19th centuries was civil engineering. Throughout this period, for large engineering works, the heavy work of moving earth continued to depend on human labor organized by building contractors. The use of gunpowder, dynamite, and steam diggers helped to reduce this dependence toward the end of the 19th century; the introduction of compressed air and hydraulic tools also contributed to the lightening of drudgery. The evolution of the railroad involved the combination of the steam locomotive and a permanent travel path of metal rails. Steamboats and ships also massively benefited from the steam engine, as it transformed marine transport forever.

Technological Innovation Has No Borders

Although the industrial revolution started in the United Kingdom, the United States is unquestionably the most technologically advanced nation. Despite having only around 4 percent of the world's population, the United States has almost 40 percent of the world's total wealth, and ranks among the top countries in productivity. Although early technology may have been adopted from the Industrial Revolution, the process that propelled the United States to the forefront of innovation was the result of more than two centuries of investments in human and physical capital.

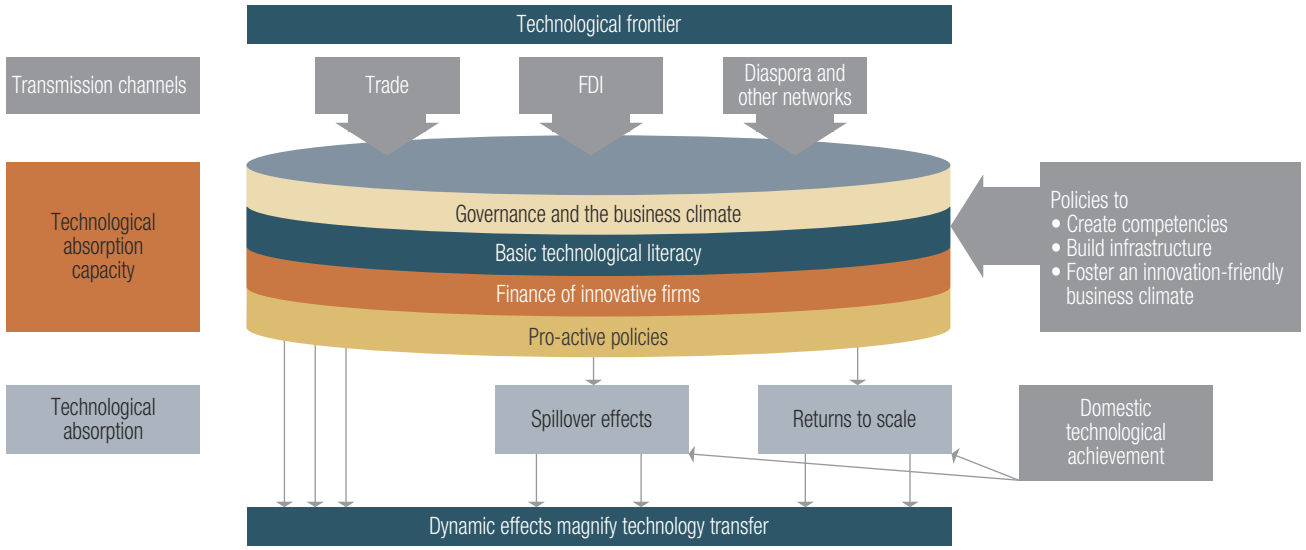
Many factors contributed to the rapid industrialization in the United States: the availability of vast land and literate labor; absence of a landed aristocracy, unlike parts of Europe at the time; high esteem for entrepreneurship; large diversity of climate; and robust free markets. The availability of capital, navigable rivers and coastal waterways, and abundance of natural resources facilitated the cheap extraction of energy, which largely contributed to fast industrialization. Thanks to the large railway and highway systems, successively built in the 19th and 20th centuries, internal markets were enlarged and shipping and production costs were reduced. In addition to physical factors, nonmaterial factors, such as the legal system, facilitated business operations and guaranteed contracts. Science also played an important role in supporting the national efforts of innovation and development. Consequently, the United States was the birthplace of almost half of *Britannica's Greatest Inventions*, spanning items such as the airplane, Internet, microchip, laser, cell phone, refrigerator, e-mail, microwave, personal computer, air conditioning, assembly line, bar code, and much more.

Africa Leapfrogging: Opportunities for Investments

It can be inferred from theory and historical evidence that Africa can leapfrog through innovation and technology. Several recent examples from the region confirm this. Leapfrogging is evidence of a quick jump in economic development and can include skipping stages. Examples of leapfrogging include a significant rise in access to electricity, a huge expansion in school enrollment, a notable improvement in financial access, and a prominent spike in agricultural production.

Technology is a transformational driver of leapfrogging. Historically, technology has been conceived in developed countries, and introduced to developing nations through trade, foreign direct investment (FDI), and other channels such as diasporas, development agencies, and academia (figure ES.2). Technology transfer is dependent on governance, advanced skills and R&D, financing, and policies for market entry. These factors have a strong influence on the adoption, adaptation, and absorption of technology in the

FIGURE ES.2: Technology Transfer, Capacity, and Absorption



Source: World Bank, 2008, *Global Economic Prospects: Technology Diffusion in the Developing World.*

economy. How quickly a technology can be absorbed in a country is affected by spillovers and scaling potential.

Several examples illustrate the technology diffusion model at work. In 2005, the Government of Ghana changed the business climate for energy through pro-active policies such as separating generation, transmission, and distribution, and opening the market to independent power producers (IPPs). This created the channel for attracting FDI from China for construction of the Sunon Asogli Power Plant, the first power plant project in Africa that was directly invested and operated by a Chinese company. Another example is the rapid diffusion of mobile communication networks on the continent. This was facilitated in many African countries through proactive policies to allow private sector investment in the telecommunications sector. Although fixed line telephone networks existed, absorption of the technology was low despite huge pent-up demand. The rapid absorption of mobile was due to contextual adaptation triggering increasing returns to scale. This included solutions such as overcoming limited grid electricity through the use of diesel-powered base stations, lower investment costs due to greenfield wireless networks, and a prepaid model that fit the region's economic circumstances.

A wave of changes that began in the 1990s are affecting the way technology is transferred, adapted, and absorbed. New technologies, such as mobile phones and the Internet, are not only diffusing more rapidly than old ones, but have transformative spillover effects. Knowledge is spreading more quickly through the Internet and supplementing traditional channels of technology transfer. New technologies are triggering innovation in finance, epitomized through mobile money and digital currencies. Cloud computing and the Internet of things extend computing power and transmit data between sensors, enlarging the scope for innovation potential.

New business models driven by digital entrepreneurs are creating a new type of innovation ecosystem. The cluster approach to innovation, epitomized by Silicon Valley, is shifting to support this change. Tech hubs are spreading, even in Africa where hundreds have sprung up to support the digital entrepreneurship ecosystem by networking entrepreneurs, designers, and potential investors. Innovative ideas are increasingly

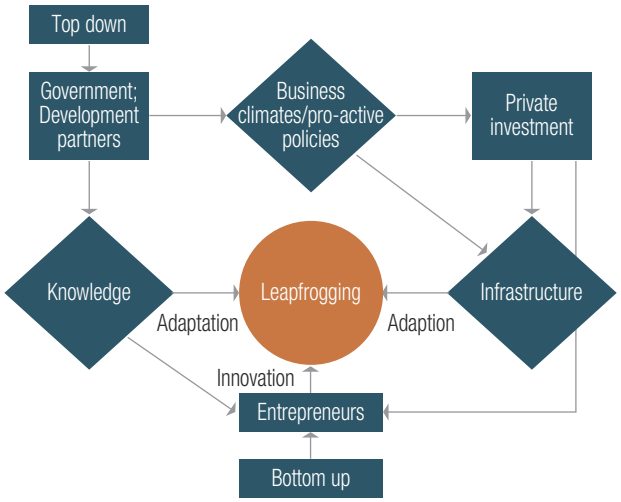
funded by private equity and, notably, risk-tolerant venture capital. Risk and failure are accepted parts of the ecosystem.

Apprehension is growing about the side effects of technology, particularly its environmental and sustainability impacts. Genetically modified seeds and pesticides, drivers of agricultural production, are coming under scrutiny. Climate change, largely triggered by fossil fuels used in power technologies, is affecting Africa's significant hydropower potential and contributing to droughts whose effects are magnified due to limited irrigation.

These three influences—technology spillovers, entrepreneur-driven innovation, and environmental and sustainability concerns—are disruptive and affecting traditional ways technology is diffused, resulting in a bottom-up type of innovation.[10] This bottom-up model is characterized by innovative adaptation, where an existing technology is leveraged to create a new product and with potential for rapid scaling. This innovative adaptation has generated the most notable recent examples of not only African leapfrogging, but also African innovation that is spreading to other parts of the world (that is, mobile money and pay-as-you-go off-grid solar).

The model of technology diffusion is evolving from top-down to include bottom-up innovation with implications for leapfrogging (figure ES.3). Governments are largely involved in the top-down model, through creating enabling business and knowledge (for example, education and R&D) environments and, along with the private sector, building large infrastructure such as roads, power generators, and telecommunications networks that are generally adopted with little if any adaptation. These projects can be leapfrogging—rapidly adding to transport, energy, and telecommunications capacity—with significant political will and investment. Other technologies often need to be adapted to scale in Africa's context of a largely rural population and low incomes. African governments have not generally had a successful record with adaptation, largely due to insufficient investment in education and R&D.

FIGURE ES.3: Top-Down and Bottom-Up Framework for Technology Diffusion



Source: World Bank.

Instead, notable adaptive leapfrogging has emanated from the bottom up, often enabled by development partners, and implemented by entrepreneurs or the private sector operating in an entrepreneurial mode. Examples include the United Kingdom's Department for International Development working with Vodafone in the case of mobile money, and the World Bank and International Finance Corporation (IFC) working with a range of actors in the case of off-grid solar. The key to leapfrogging from the bottom-up is unlocking scalability through innovative business models.

Around the world, successful entrepreneurs have come up with solutions to problems that crop up around them. In each problem, constraint, or challenge, these innovators see opportunities. Some experiences, such as mobile money and pay as you go solar, have given hope to Africa that it can also be a dynamic and innovative player.[11] While such examples offer encouragement, the promise of leapfrogging remains largely unfulfilled. In Africa, constraints are still often considered barriers rather than opportunities. Several factors, like the level of skills, service delivery, and poor infrastructure, are considered to be constraints

to attracting investment in productive sectors. To solve Africa's challenges, this report argues that those constraints must be viewed as investment opportunities. Seen in that light, Africa will witness more innovation toward prosperity. Once the constraints are turned into investment opportunities, there will be limitless win-win situations and an alignment between Africa's development requirements and investors' quest for high returns.

This report assesses the potential of technology adoption and innovation for six key sectors in the region: agriculture, education, energy, finance, governance, and information and communications technology (ICT). Agriculture is Africa's most important economic sector, employing the majority of its population and generating around one-third of its gross domestic product (GDP). Technological adoption and innovation are highly dependent on the ability of education to impart skills for absorbing technology and developing and applying innovation. The steam engine triggered the Industrial Revolution, and energy can have a similar impact for transforming Africa's economic development. Financial inclusion is important for poverty alleviation. Efficient financial markets are critical for channeling investment into Africa's infrastructure. Good governance is critical for political stability and market efficiency, strongly influencing economic development. ICT is a cross-cutting, general purpose technology that is increasingly the basis for triggering technological innovation around the world, as well as in Africa.

The selected sectors exhibit spillover effects, creating dynamic synergies between them. ICT is the best example, where digital technologies are creating leapfrogging options in finance (mobile money), education (online learning), agriculture (precision farming), energy (smart on- and off-grids), and governance (e-government). Education generates talent to imagine innovative solutions to the pressing challenges in many industries. Energy is needed for schools to enable digital technologies for online learning. Financial technology facilitates micropayments for pay-as-you-go off-grid electricity.

Following an overview of the six sectors and the challenges they face, examples of leapfrogging experiences, based on innovative practices and technology adoption, are illustrated from within and outside the region. Technological adoption, adaptation, and innovation scaling require the support of physical and institutional infrastructure.[12] Herein lies the key for unlocking leapfrogging: For each sector, the discussion describes impediments to technology adoption and innovation and how they can be ameliorated. Finally, areas of future research are identified for each sector.

Technological change can take one of two forms: Transfer of existing technologies to countries that have not yet adopted them, or addition of new technological innovations. The policy implications can differ, because in one case it is about strengthening mechanisms and removing barriers for technology transfer; in the other case, there is more of an imperative to promote homegrown innovation that is tailored to local conditions.

AGRICULTURE

The Need to Feed the Continent

More than 60 percent of Africa's population lives in rural areas, making the region's economy intrinsically dependent on agriculture. Around a third of the continent's GDP is generated by the sector. However, agricultural productivity remains far below that of other regions. Over 90 percent of African agriculture depends on rainfall, with no irrigation. The techniques used to cultivate the soil are behind those in other developing regions, lacking not only irrigation, but also fertilizers, pesticides, and high-yield seeds. Agriculture in Africa also experiences problems such as access to markets and financing. Despite its tremendous agricultural potential, Africa is a net importer of

food, due to population growth, low and stagnating agricultural productivity, policy distortions, weak institutions, and poor infrastructure.[13] These barriers are inhibiting the continent's ability to achieve food security.

There is a strong link between agricultural growth and poverty reduction. The results of a regression analysis covering 25 developing countries show that although economic growth was an important contributor to a decrease in poverty, the sector mix of growth mattered substantially, with growth in agricultural incomes being especially important.[14]

Due to the unique nature of Sub-Saharan Africa's agriculture sector—small shareholdings and distinctive agroecology—transformational changes will require solutions beyond the so-called Asian Green Revolution epitomized by the intensive application of high-yield seeds, fertilizer, pesticides, and irrigation.

Solutions for raising agricultural productivity in Africa are influenced by the shifting relationship between technology adoption and sustainable farming and the influence of interest groups. Several factors affect technology adoption, including the application of biological, chemical, and mechanical methods (that is, inputs and assets); farmer knowledge; the agriculture value chain; and technologies emerging from outside the farm sector.[15] Sustainable farming reflects the capacity to generate sufficient food in an economically efficient, socially responsible, and environmentally sound way. The aspects of the sustainability of technology depend on whether it is at the farm level, within the agribusiness sector, or from the lens of the national, regional, or global economy. Sustainability concerns are rising in areas such as food-related illness, environmental impacts, and animal welfare. Governments face challenges aligning the private interests of agricultural businesses with the public interest of small farms and concerned citizens. Added to this mix is the growing impact of climate change on weather patterns affecting Africa's agriculture sector.

Agriculture forms part of a rural ecosystem where diversification opportunities can enhance sustainability, increase incomes, and generate employment. Experience from other regions suggests that, as agricultural productivity rises, workers move to urban areas to seek jobs in other sectors. Given the low proportion of manufacturing and industry on the continent and challenges with rapidly growing urbanization, an alternative strategy is to enhance the rural economy. This includes widening the product mix of single-crop farmers, expanding agriculture value chains, and developing rural tourism. High-value, nontraditional crops can supplement farmers' income with significant potential for exports. Links between informal value chains in rural areas and agribusiness generate jobs and opportunities for smallholder farmers. Rural tourism has significant diversification potential for the rural economy. A survey among the indigenous population living in the Ngorongoro Conservation Area in Tanzania, where livestock is the primary economic activity, found that 39 percent of the population was also involved in tourism.[16] The respondents reported that tourism was a reliable source of income compared with other activities, and provided extra income for food and education expenses.

Digital technologies, such as mobile phone applications, sensors, satellites, radio-frequency identification, big data, and drones, have emerged with notable effects on agriculture and rural livelihoods. Unlike direct inputs, such as seed, irrigation, fertilizers, or pesticides, digital technologies raise agricultural productivity and rural incomes through their effects in areas such as finance, crop and weather monitoring, animal control, markets, and farmer education.[17] The cost of digital technologies has dropped, making them increasingly feasible for African farming. An analysis of social enterprises operating across East Africa finds that technology was a key enabler for entrepreneurs involved in agriculture, lowering transaction costs and enabling scale through the provision of information and finance, collectivizing smallholders, and providing market linkages.[18]

The Comprehensive Africa Agriculture Development Programme (CAADP) is Africa's framework for agriculture sector transformation. Ratified in 2003 in Maputo, Mozambique, the resulting declaration[19] called for at least 10 percent of government spending to be allocated to agriculture and rural development, and for sector growth to reach an annual average rate of 6 percent. Although most countries have increased funding for agriculture since then, only five reached the CAADP target during 2008–14. Agriculture sector growth in Africa increased at 3.8 percent per year between 2003 and 2008. Several countries surpassed the 6 percent target during different periods, and 15 did so during 2008–14.

Micro Jumps

Agricultural leapfrogging examples are difficult to quantify at the macro level. This is because a notable improvement in productivity is often related to a specific crop or technology (such as irrigation; see box ES.1) and not necessarily translated into nationwide agricultural advances. Similarly, a rise in agricultural output may not affect overall incomes in the rural sector (for example, subsidies received by large farms). Bearing those limitations in mind, there are several examples of rapid productivity gains that have positively affected welfare.

One area of notable success is the Alliance for a Green Revolution in Africa (AGRA) program for seeds, which are particularly relevant, given their impact in raising agricultural productivity. AGRA has invested US$100 million in African seed businesses, working with more than 100 companies, representing about a third of the market. They produced around 125,000 tons of improved seed in 2015, up almost 400 percent from 2010. As a result, corn yields have doubled in the 18 African countries in which AGRA works. According to AGRA, the 57,000 tons of improved seed produced in 2012 catalyzed yields of 5.7 million metric tons of additional food, enough to feed 34 million people.[20] AGRA plans to invest US$500 million over the next five years in seed businesses, adopting principles similar to startup ecosystems, by acting as an angel investor with investments in the range of $150,000, and working closely with entrepreneurs.

Côte d'Ivoire has generated interest because its cereal yields have increased, surpassing two metric tons per hectare in 2010. This is perceived as evidence of a Green Revolution, given that, historically, yields of more than two tons per hectare mark a threshold that is followed by sustained agricultural productivity.[21] Cereal yields in the country increased by more than a third between 2007 and 2014. The rise coincided with the end of civil war in the country. The resulting political stability expanded the area under cultivation. Another factor was a large increase in government spending, resulting from the 2010–15 National Agricultural Investment Program. Government agriculture expenditures rose from 2 percent of total spending in 2007, to a peak of 6 percent in 2014. This included funding for rural infrastructure and farmer training programs, in addition to better seed and greater availability of fertilizer. Rice is a popular food item in the country, accounting for over half of domestic cereal production. The rise in rice yields has made rural areas self-sufficient.

Other African countries have surpassed cereal yields of two metric tons. In two countries, Ethiopia and Rwanda, agricultural growth has been a main driver of poverty reduction. Rwanda focused agricultural production on staple crops to replace imports and enhance food security. The government's crop intensification program reduced seed and fertilizer costs for farmers. Fertilizer use more than doubled, from 18 percent in 2005–06, to 38 percent in 2010–11, and average sales of agricultural output rose from 18 to 25 percent. According to the World Bank, 45 percent of poverty reduction in Rwanda over that period can be attributed directly to agriculture.[22]

Cereal production tripled in Ethiopia between 2000 and 2014. According to the World Bank, poverty in

Box ES.1: Irrigation Project in Western Kenya

Lack of irrigation is often cited as one of the shortcomings of African agriculture. Western Kenya is responding with a water conservancy and irrigation project located in Homa Bay County beside Lake Victoria. The densely populated region, home to many small-scale cereal farmers, has unreliable rainfall, experiencing frequent crop failures. The aims of the Kimira Oluch Small Holder Farm Improvement Project are to reduce reliance on rainfall, improve agricultural productivity, decrease poverty, and improve the living standards of small-scale farmers. The Government of Kenya and the African Development Fund jointly funded the project. Sino Hydro, a Chinese construction firm, was contracted by the Ministry of Regional Development Authorities to build gravity-fed irrigation channels along two rivers. Because of the project, farmland is now under irrigation and there is a reliable source of drinking water for local people and livestock. The irrigation scheme also offers an opportunity for farmers to diversify production, by providing water for grain, fruit, and vegetable cultivation; fish breeding; and other activities.

Ethiopia has dropped by 33 percent since 2000, with agricultural GDP growth of nearly 10 percent per year.[23] An analysis of the cereal growth reveals that it was mainly driven by acreage expansion rather than inputs.[24] One exception was teff, a grain that is a main ingredient of the country's popular injera bread. The rapid spread of teff is attributed to a range of factors, including demonstration plots, seed loans, and training; informal networking to share information about production techniques was also important.

An analysis of sustainable agricultural processes across 20 African countries between the 1990s and 2000s finds productivity gains via two pathways.[25] *Multiplicative* increases result from the use of new and improved varieties and improved management practices. *Additive* benefits accrue by diversifying into new crops and livestock. These techniques and practices have resulted in increased yields. The analysis also finds that the adoption of more than one practice produced cumulative gains through synergies, resulting in higher yields compared with single applications, such as just fertilizer or irrigation. For instance, decision makers often view increased irrigation as a general panacea for boosting crop production in dry lands, but restoring soil health while ensuring the effective use of rainwater may be a more cost-effective and sustainable option.

Conditions for Agricultural Leapfrogging

Several areas require attention to create the necessary preconditions for agricultural leapfrogging in Africa.

Research and development is essential for developing and adapting new technologies, and positively associated with high returns.[26] Although investment in agricultural R&D tripled in China and India over the past 20 years, it increased by barely a fifth in Sub-Saharan Africa (and declined in about half the countries in the region). In 2011, public and private agricultural investment in Sub-Saharan Africa was just 4 percent of the world total, down from 6.1 percent three decades earlier.[27] In small African countries, it is difficult to benefit from economies of scale in R&D, making regional collaboration essential. International technology transfer is limited, due to the unique African agroecological environment, placing even more importance on national R&D efforts. Shortages of skilled researchers are exacerbated by retirements and departures of experienced scientists; more resources need to be devoted to capacity building. The volatile nature of African funding for agricultural R&D is a reflection of limited government funding and dependence on irregular development partner assistance. African governments need to design coherent R&D

programs and commit sufficient funding while ensuring that donor funding is aligned with strategies.

Similar to other sectors, a growing number of advances in African agriculture are emerging from *entrepreneurial innovation ecosystems*. A new breed of young "agripreneurs" is emerging, applying digital technologies and principles from startup ecosystems to enhance agricultural processes. Local entrepreneurs have a better understanding of their rural context, giving them an advantage over large multinationals, and they are more suited for surmounting challenges such as fragmented markets, lack of scale, illiteracy, and native traditions.[28] This can be facilitated by an enabling environment that includes incubators, information exchange networks, and funding. Collaborative and efficient links are also essential along the agriculture supply chain, from farmers, to agribusinesses, to consumers. Policy makers should involve all these groups when developing sector strategies and plans.

Investment is needed in *rural infrastructure*, particularly transportation, electricity, telecommunications, and irrigation. The impact of such investment can be significant. One study finds that access to all-weather roads reduces poverty by 6.9 percentage points.[29] Lower costs and innovative business models are spurring the take-up of off-grid electricity, providing power to hundreds of thousands of rural homes in the past 18 months, but still a tip of the iceberg, given that half of Sub-Saharan Africa is without power. Irrigation is essential for crop production, yet less than 5 percent of cultivated land in Africa is irrigated. Mobile infrastructure has spread the furthest, with the proportion of cell phones in many rural African households higher than the availability of electricity. This is largely due to private investment, a model that could be more widely applied in other infrastructure sectors through licenses and public-private partnerships. Governments need to prioritize public funding for agricultural infrastructure, recognizing the trade-offs between where the investment is made (for example, roads, irrigation, extension services, R&D, and so forth) and economic growth and poverty reduction.

Skills and education are needed at all levels, including policy making, research, the application of technology, and the farmers themselves. Although new digital technologies have emerged with demonstrated impacts for the rural sector, skills in government agriculture offices are often limited, affecting their application. Extension agents need to be trained in the utilization of new technologies, so they can transmit that knowledge to farmers. There are also resource constraints for spreading knowledge, because there are insufficient numbers of agricultural extension agents and experienced technical staff members are nearing retirement. These examples are largely applicable to many African countries, reinforcing the need to enhance capacity-building initiatives for technical experts. The knowledge capacity of farmers also needs to be raised, so they can leverage inputs, machinery, and digital technologies to enhance productivity. Ineffective user interfaces and lack of digital literacy are cited as reasons for the lack of success of some ICT in agriculture projects.[30]

Despite the importance of agriculture in the African economy—18 percent of GDP in 2016—its potential remains unrealized due to chronic *underinvestment*. This is reflected by low productivity and characterized by limited mechanization, non-optimum inputs, and uneven application of new technologies. African governments spent only 3 percent of their budgets on agriculture in 2010, seven years after committing to spend at least 10 percent in the CAADP Maputo Declaration. Investment per agricultural worker has been flat or declining over the past 30 years. The region's agriculture sector receives less than 5 percent of lending from formal financial institutions, starving agricultural businesses of capital. There are several factors behind this, including the riskiness of small landholding farms, low returns, uncertain property rights and land tenure, and inadequate policy and regulatory frameworks. Nevertheless, there are indications that funding is available from development partners if pro-growth conditions can be met. In addition, private sector initiatives for funding are growing, including banks, private equity funds and venture

capital, impact investors, and microfinance institutions. The African countries that are most likely to benefit are those that prioritize agriculture, including a sound sector strategy and plan; have an inclusive implementation process at the country level; offer attractive investment incentives; and demonstrate commitment to necessary reforms.

Education

Some Gains, but Falling Behind

It is well established that advances in education are associated with long-term improvements in economic performance.[31] Education links with economic development in three broad ways:[32] First, it improves the skills of the workforce, leading to greater productivity. Second, it influences the capacity of the economy to develop new ideas and technologies. Third, it serves as a means of spreading the knowledge needed to apply innovative ideas and new technologies.

Developing countries, especially those in Africa, are lagging behind in education outcomes. A recent analysis argues that there is a 100-year gap in education levels between the developed and developing worlds.[33] At this pace, it will take more than 100 years for developing world students to catch up. Addressing the massive challenges facing Africa's education sector will mean taking bold and innovative approaches.

Sub-Saharan Africa has made great strides in boosting primary school attendance, and gross enrollment ratios are almost 100 percent. Much of the recent increase was driven by donor support to achieve the Millennium Development Goal of universal primary education by 2015. It will be more difficult for the region to achieve the new Sustainable Development Goal (SDG) of free universal secondary education by 2030. In 2014, Sub-Saharan Africa's gross secondary enrollment rate was 43 percent, 22 percentage points below the next lowest region and 34 percentage points below the world average. This is a much bigger gap to close than achieving near universal primary education, yet there are relatively few initiatives to deal with the expansion of secondary school coverage. The region's gross tertiary enrollment is just 8.6 percent; some experts reckon it needs to be almost double that to sustain current levels of economic development. There is an urgent need for radical change.

Africa faces challenges in increasing the number, motivation, and quality of its teachers. Nearly 42 percent of all instructional time in Kenya is lost because of teacher absenteeism; just over a third of public school teachers display mastery in the subjects they teach.[34] The limitations of teachers will implicitly be reflected in learners' performance. Across the region, only three in four adults who completed six years of schooling can read. There are wide differences among countries, suggesting that in many, the quality of student learning in primary school needs to be improved before increasing the school cycle.

The composition of education attainment in Sub-Saharan Africa has changed substantially over the past 60 years, during which the share of the population ages 15 and older who attended secondary school rose over fivefold, from 5 to 26 percent. However, around a third of those ages 15 and older are still without education. Efforts need to be devoted to educating those who never went to school or dropped out, and a culture of lifelong learning needs to be instilled.

Given these diagnostics, it is not overstated to affirm that Africa's education system needs a rapid fix, in quantity and quality. Education in Africa also needs to leap forward to catch up with the transformation of labor markets. The changing nature of jobs and life in the 21st century means that, although traditional ways of educating children may have worked in the past, there is no guarantee that it will continue in the future. The employment landscape is rapidly evolving. In many countries, the most in-demand occupations did not exist a decade ago. As such, there is a pressing

need to transform Africa's education system and equip students with the right skills that will reflect the needs of tomorrow's labor market.

One of the ways Africa's education system can be transformed is through innovation and technology. The Internet is a cross-cutting enabler for education, providing unparalleled access to information, and facilitating connections to educational resources, virtual labs, ideas, and people. It opens a way for exponentially expanding the physical limits of the school, giving students and teachers access to online learning resources from around the world.

There are a growing number of innovations and digital interventions in education. The challenge for Africa will be to know which are worth adopting and which can scale. A major constraint the region faces is a lack of infrastructure to avail educational technologies. Electricity availability, essential as a prerequisite for computers and Internet access, varies widely in African schools. There is also wide variation in school availability of digital technologies, such as Internet access and computers.

Leapfrogging School Enrollment, Educational Technology, and Outcomes

Examples from other regions and within Africa show that rapid jumps in outcomes, teacher training, school enrollment, development of online learning content, and the availability of electricity and ICT in schools can be achieved. An example is Vietnam's level of progress in education over the past 20 years. Despite having the lowest GDP per capita among the countries that participated in the Program for International Student Assessment, Vietnam scored higher than the OECD average, outperformed many developed economies, and its score was more than 100 points greater than the average of other developing countries taking the test.[35] The government recognized education as a national priority and invested early in schools and teacher quality, developing and enforcing minimum quality standards for schools and professionalizing its teaching force, setting standards around content knowledge, skills, and behavior. Vietnam was an early adopter of standardized assessments of literacy and numeracy. The country also has an outward-looking approach of adapting the best practice in developed countries.

In Bhutan, a project was launched to provide trainee teachers with skills in ICT. The country has two teacher education institutions; prior to 2000, neither offered ICT training. Bhutan's Ministry of Health and Education worked with a Singaporean foundation to train teachers in integrating ICT into education, to close the gap between the low ICT skills among pupils and the growing adoption of ICT technology in the workplace. The project led to a tremendous increase in ICT skills among teachers, who went from knowing nothing about computers to being able to design web pages.[36] The project benefited from being designed in two phases, so the lessons from the first could be incorporated into the second.

China has long recognized that it must rapidly deliver skills that are crucial for its economic development. For almost four decades, China's education system has experienced stages of exploration, innovation, reform, and development. The Chinese experience in the transformation of its education system can be summarized in five major thrusts. First, it modified models to accommodate economic changes. In the early days of economic reform, major industries were underdeveloped, and professional talent was in high demand. Instead of sticking to the traditional education model, the central government invested in the development of skills in key areas to accommodate the course of economic development. Second, it learned from other countries to make higher education oriented to global demands. Experts from developed countries, such as the United Kingdom, France, Germany, the United States, and Japan, and the experiences of other countries in higher education were introduced to accelerate reform of the tertiary sector in China. Third, it coordinated market demand and supply, restructuring and innovating the education

industry. Fourth, it channeled more fiscal and social resources into education and increased investment in rural areas. Fifth, it promoted educational investment as a prerequisite for economic development. Evidence from China finds that education development is the prerequisite for rapid economic development and not vice versa. Education and economic development are interdependent, which means that economic development provides resources for education and education provides intellectual support for economic development. China's experience indicates that investments in education and economic transformation should be made simultaneously.

The African Virtual University (AVU) has been at the forefront of online learning in the region. AVU connects 27 institutions across Anglophone, Francophone, and Lusophone African countries, offering degree, diploma, and certificate programs delivered online, face-to-face, and through blended modes. One of the AVU's flagship projects was the launch of Open Educational Resources in 2011. AVU is the largest creator of online higher education content in Africa, with more than 200 Open Educational Resources courses that are used on the continent and overseas. More than 63,000 African students have benefited from the AVU since its inception. Distance education offers an attractive supplement for boosting Africa's higher education training, given the inability of universities in Africa to increase physical infrastructure rapidly.

Kenya provides an example of how quickly electricity and Internet access can be deployed, even to remote rural schools, to enable online learning. As a precursor to facilitating digital learning in public primary schools, the National Public Primary Schools Electrification Project was launched in July 2013. Over the next three years, more than 12,000 mainly rural primary schools were connected to electricity using grid or off-grid solutions, raising the proportion of schools with electricity from 43 percent in 2013 to 95 percent by June 2016. Primary schools were also provided with Internet access through a range of initiatives and technologies, including fiber optic, mobile broadband, and satellite. In a separate program, all secondary schools are being provided with Internet access financed by the universal service fund of the Communications Authority of Kenya. The Kenya Education Network, which was previously responsible for connectivity of the country's higher education system, has seen its mandate expanded to coordinate the various public and private sector initiatives for providing Internet access in primary and secondary schools. More than 90,000 teachers have been trained in delivering digital learning; e-learning has been introduced in more than 18,000 primary schools.

São Tomé and Príncipe provides an example of rapidly leapfrogging secondary education enrollment to above world levels. The government developed a plan outlining strategies for the education sector, with one objective being 12 years of free education to all children. It had already achieved universal primary enrollment, with a significant number of children then going on to secondary. This was manifested through an increase of almost 50 percentage points in gross secondary education enrollment between 2003 and 2016. This increase was stimulated by government prioritization of the education sector, establishing the preconditions through an increase in resources: the proportion of public expenditure for education increased from 2.7 percent of GDP in 2002 to 8.8 percent by 2010.

Establishing the Preconditions for Leapfrogging Education Outcomes and Skills

Although education in Africa faces challenges, the leapfrogging examples present potential for the continent to improve outcomes and skills quickly. To enable rapid educational transformation, the region needs to create the necessary preconditions in several areas.

Partnerships are features in all the leapfrogging examples, including intergovernmental agreements such as the

AVU as well as bilateral cooperation, whether formalized as projects or for one country to learn from other nations' successful experiences in education. This points to the need for African governments and education ministries to collaborate more closely with each other and with other countries outside the region, to share scarce resources and learn innovative educational practices and how to apply them on a large scale. Another promising area is private sector partnerships, whether for the introduction of technology or collaboration on industry skills training. The private sector could play a key role by investing in education and infrastructure, facilitating digital learning over the continent. This will entail reducing regulatory barriers that constrain private sector investment in the sector. Although this challenge must start with governments' efforts to reform, there is much for the private sector to gain by investing in support of the public sector in delivering skills.

ICT applications in education require digital equipment, Internet access, and regular and reliable electricity. There are many gaps in the region in the provision of electricity, computers, and the Internet, as well as significant differences in availability across different levels of education. Although governments need to invest resources in digital infrastructure for schools, there are various options for tapping funding. This includes drawing on the resources of the private sector for school connectivity projects, such as leveraging the corporate social responsibility programs of telecommunications operators and universal service funds to which telecommunications operators contribute. Several African countries have successfully adopted these strategies for funding school ICT infrastructure. The cost of the Internet can be made more affordable for schools by subsidizing service charges, another practice adopted in many countries. African countries can also tap the expertise of national education and research networks, which were initially created for higher education, to assist with primary and secondary school connectivity.

Labor markets are rapidly evolving and many new skills are in demand. In Africa, there is a considerable imbalance between the demand for and supply of people with appropriate qualifications. To improve matchmaking between jobs and skills, the public and private sectors need to work closely together. Labor ministries need to seek the input of industry to forecast labor and occupation requirements. Ministries of education need to draw up sector plans to ensure that proper skills are developed to meet this demand. There also needs to be emphasis on the sources of innovation, by encouraging entrepreneurship through the creation of digital hubs and close collaboration between higher education and startups.

Good students require good teachers. More effort is needed to train teachers and ensure that they are appropriately allocated throughout the education system. The success in the use of ICT in education is contingent on teachers' abilities and skills in integrating these technologies into the teaching process. Therefore, if teachers are not provided with ICT skills, it is highly unlikely that digital interventions will be effective.

Innovative ideas and digital technologies will not scale and reach success without a robust education sector policy, strategy, and plan. A clear government vision of the education sector is required, identifying how it fits in with national goals, the initiatives for the sector to achieve those goals, and the expected outcomes. This provides clarity on how innovation and digital technologies fit into education goals and outcomes, and enhances the chances of scaling up successful pilots while minimizing initiatives that are driven by donors or the private sector and stop when funding runs out. Strategies should be developed along a multi-stakeholder approach, including among ministries, to reduce educational technology silos. And the approach should include the inputs of teachers, parents, students, donors, and the private sector. Monitoring and evaluation are critical to track the implementation of digital technologies in an effort to reduce inequities, as well as to assess what works in improving outcomes.

A culture of ongoing skills development needs to be instilled across the continent. This is essential with constantly evolving economies and demand for new skills. Online learning platforms ease the task of continuous skill development and improvement. This requires access to digital technologies and development of relevant local content. At the same time, over half of Africa's adults never attended school or have only a primary school education. Effort is needed to reach this group, through formal and informal training initiatives, including teaching basic computer skills, so they are not left further behind.

Energy

Abundant Resources but Insufficient Capacity

Energy capacity and use in Africa are the lowest in the world. Although the continent's power generation capacity grew 32 percent between 2010 and 2016, at 175 gigawatts it is the lowest among all developing regions. Although Africa accounts for 16 percent of the world's population, it only has 2.8 percent of the power generation capacity.

Household connections to the power grid are scarce in Sub-Saharan Africa. Although the share is slowly rising, only 37 percent of the population had access to electricity in 2014, far less than any other developing region. As a result, more than 600 million people in Sub-Saharan Africa—almost two-thirds of the population—live without electricity. Most of them are in rural areas where there is no grid electricity, and expansion is financially and logistically impractical. Without radically increased energy production, the region will find it difficult to achieve the SDGs for energy, including meeting the goal that sets out to "ensure universal access to affordable, reliable and modern energy services" by 2030.

The lack of grid and off-grid electricity results in increased use of kerosene, candles, wood, and coal for cooking and lighting in Africa. This has serious health, safety, environmental, and socioeconomic consequences and disproportionally impacts women and children. More than 3.5 million Africans die yearly due to pollutants or fires from liquid fuels for lighting and cooking.[37]

The weakness of the African energy sector constrains economic growth and development. Electricity is a critical concern for businesses in Sub-Saharan Africa, and after access to finance, is listed as the second largest problem for enterprises in the region. Although Sub-Saharan Africa is improving in some areas of its business environment, it is performing poorly in electricity. It takes an average of 130 days to get a new electricity connection, and African consumers and businesses have the highest duration of outages in the world.[38] Relative electricity prices are by far the highest among all regions, equivalent to almost 4,000 percent of GDP per capita.

Although Sub-Saharan Africa faces an energy crisis, it has abundant low-carbon and low-cost energy resources. The greatest potential energy source is water. Over 90 percent of Africa's economically viable hydropower potential, equivalent to about one-tenth of the world total, is unexploited. Hydroelectric accounted for 13 percent of primary energy consumption in the region in 2016.[39] The largest sources of energy consumption in the region are oil and gas. Although most Sub-Saharan African countries have thermal power stations, only a few use local oil and gas resources. Instead, most countries rely on imports, with a few exceptions (for example, Nigeria and Angola). The continent has abundant renewable energy resources, particularly solar and wind. Due to declining equipment costs, greater efficiency, and innovative business models, solar is rapidly expanding as an attractive solution for providing off-grid power in rural areas throughout the region. Solar and wind renewables are the fastest-growing sources of primary energy consumption on the continent.

Africa needs huge investments to increase energy production. Compared with other sectors, the power

sector's investment needs are high: they are 4.5 times larger than in the ICT sector, and approximately double the investment needs in each of the water, sanitation, and transport sectors.[40] It is estimated that Sub-Saharan Africa needs to invest US$41 billion a year to meet the needs of its power sector, equivalent to over 6 percent of GDP.[41] Although public utilities have traditionally been the largest source of power generation in Sub-Saharan Africa, the investment required exceeds their funding capacity, making private investment critical for expanding energy supplies. Private sector investment in the sector is increasingly channeled through IPPs, which have spread throughout the continent and are present in 17 countries.

Africa needs to follow a different trajectory to boost its energy sector. Four trends have emerged recently that are noticeably increasing the potential for leapfrogging, based on the confluence of technological change that is dramatically (a) reducing the cost of renewable energy, (b) improving the efficiency of appliances, (c) increasing the intelligence of power infrastructure through digital technologies, and (d) enabling decentralized service provision. Combining these factors with technology customization and innovative financing can radically effect socio-technical transitions to energy solutions.[42] Applying spatial-economic analysis to the intense changes that energy technologies have experienced can help identify the least-cost rural grid, mini-grid, and off-grid electrification options to end energy poverty in Sub-Saharan Africa.[43] This will require complementary institutional, regulatory, and financial innovation.

Power Leaps

Some African countries are experiencing significant leaps in electricity production and access through a regionwide initiative deploying off-grid electricity, an IPP in Ghana, and Rwanda's accelerated electrification initiatives. Leapfrogging was triggered by innovations in technology, project design, and regulation.

Lighting Africa is a World Bank/IFC initiative that was launched in Kenya in September 2007. Lighting Africa aimed at supporting the global lighting industry to catalyze a market for off-grid lighting products tailored to the needs of African consumers. The program's mission was to make affordable, environmentally sustainable, durable, and safe lighting available to the masses. The project design incorporated lessons from earlier IFC and donor grant-based solar lighting projects. Lighting Africa was innovative on two levels: From a market development perspective, the project transformed the solar lamp market in Kenya by making modern, good quality, and affordable lighting products available to the very poor. It also demonstrated the commercial viability and sustainability of the approach to address the lighting needs of the base of the pyramid, in contrast to donor subsidized lending for the purchase of solar lamps. To achieve this, Lighting Africa considered constraints along the entire supply chain (including market intelligence; business development support to manufacturers and distributors; development of international quality standards in product design, product quality testing, and certification; and consumer education and financing). The pilot provided valuable lessons that were used to adapt the design and implementation of the initiative.

By 2016, the project had been deployed in 11 Sub-Saharan African countries, affecting almost 21 million people (4 percent of those with access to electricity). The project aims to reach 250 million more people by 2030 (equivalent to 42 percent of those without access to electricity). The project has also had important health, safety, and environmental benefits, such as reducing toxic fumes from kerosene lamps and paraffin, enabling children to study and do homework at night; and it saved money for households and small businesses by reducing kerosene purchases.[44] The success of Lighting Africa has spawned Lighting Global, to spread off-grid, solar-based electricity to other regions. Innovation has also been triggered by solar startups using mobile networks to manage generators, and

mobile money for consumers to make micro payments. There are over half a dozen of these new solar utilities; they raised venture capital of more than US$200 million in 2016, up from US$19 million in 2013.[45]

In 2005, the Government of Ghana promulgated an amendment to the Act governing the country's main electricity utility, the Volta River Authority. The amendment, made in the context of the government's power sector reforms, largely restricted the Volta River Authority to the generation of electricity. This created the opening for attracting private sector investment into the energy sector through IPPs. Sunon Asogli Power Plant is one of the IPPs that was created by the reform. It was the first power plant project in Africa that was directly invested and operated by a Chinese company, jointly financed by the China Africa Development Fund and Shenzhen Energy Group. In 2010, the gas-fired generating units for phase I were put into commercial operation. Phase II started generating power in March 2017, after construction of less than a year, the fastest ever for a similar size project in Africa. Sunon Asogli plays an important role in meeting Ghana's power demands, with the potential to supply nearly a fifth of the country's power needs. The US$560 million project was the seventh largest private sector investment in the country, demonstrating that, with the right conditions, significant private sector funding is available for infrastructure in Africa.

Electricity access in Rwanda grew over 300 percent between 2005 and 2014. The impressive growth is tied to the adoption of a new Electricity Sector Wide Approach (eSWAp) by the government in 2009. eSWAp had several novel features, including joint coordination, a specific time bound target (16 percent access to electricity by 2013), a prospectus to attract investment, and strategies to reduce electricity costs through technical standards and geospatial analysis. eSWAp was operationalized through the Electricity Access Rollout Program (EARP), coordinated by the national electricity utility, and supported by several development partners. The electrification rate target was reached a year early, rising to 20 percent by 2014. The second phase of EARP has an even more ambitious target, aiming for electrification of 70 percent by 2018, using a combination of grid and off-grid solutions. A key leapfrogging condition has been the effective coordination among stakeholders in planning, financing, and implementation.[46]

Preconditions for Powering Africa

With abundant energy resources, there is considerable potential for increasing power generation in Africa. More so than for other sectors, policy and regulatory challenges are the main impediments to leapfrogging. Enabling leapfrogging in the African energy sector will require modernization of institutions, regulations, and finance.

Market reforms are crucial for creating an attractive environment for investment. This includes a sector *regulatory agency* for oversight and instilling a transparent framework to attract investment. The regulator needs to create an enabling *competition* environment to establish routes for investment in the sector. The lack of funding for the power sector in Africa is often because investment options are nonexistent rather than a shortage of capital. Market entry in the sector can be facilitated through the structural separation of generation, transmission, and distribution. Another aspect of competition relates to the procurement of power projects. Competitive procurement increases transparency and lowers costs. Tenders or auctions can be complex to design compared with unsolicited or directly negotiated contracts; however, the latter tend to have more drawbacks over time (for example, higher prices, contract disputes, and opaqueness).

Energy sector *planning* is critical to ensure that investment sustains economic growth on the continent and to factor in the consequences of climate change and the emerging potential of off-grid electricity. This requires expertise in forecasting demand and determining

optimal supply options, within the time constraints for identifying projects, obtaining funding, and deploying energy capacity. Ongoing updates are needed for planning software to ensure that it is relevant for changing demand and costs; the plans need to be revised on a regular basis to adjust to market conditions. Plans should be flexible, with multiple options, given that the African nations that have attracted the most investment into their energy sectors have a range of policies and structures. Appropriate skills are needed for planning that cross a range of disciplines, such as engineering, law, meteorology, finance, economics, and data analytics.

Improving the financial sustainability of *public utilities* in Sub-Saharan Africa is critical. This is particularly important for the success of private sector investment through IPPs since they rely on the "off-taker," typically a public utility, to get the power transmitted and distributed. Improvements are needed in areas such as governance, efficiency, and billing and collection. Better collection, transparency, and dissemination are needed for metrics measuring electric utility performance for objective diagnosis of weaknesses. *Tariff policy* is critical not only for the viability of power utilities, but also for attracting new investment in the sector. The challenge is finding a model that balances affordability and access with investment needs. If subsidies are required, they need to be well designed. Energy subsidies account for a significant portion of government resources in the region and often benefit the richest and create disincentives for maintenance and investment.[47]

FINANCE

A Sector in Need of Change

It is widely recognized that access to finance is key for inclusive economic growth. First, an effective financial system reduces the cost of intermediation, enhancing the efficiency of transforming savings into investment. Second, a developed financial system increases households' savings rates, by providing attractive risk-return combinations, which should induce households to save more and, in turn, stimulate investment and consequently higher economic growth. Third, a well-functioning financial system improves financial intermediation, leading to a better allocation of resources across investment projects, as it provides economic agents with a mechanism that allows for hedging, trading, and pooling risk, thereby raising the level of investments and economic growth.

Financial markets in Africa are considerably less developed than elsewhere in the world, according to virtually all indicators of financial development. In Sub-Saharan Africa, only 34 percent of those ages 15 years and older have an account at a formal financial institution. Most African stock markets are quite thin, with low levels of liquidity, and there is relatively low private equity penetration.

Currency markets in many Sub-Saharan African countries remain risky and are devoid of liquid, long-term investment instruments. Institutional investment in local-currency debt in these countries tends to be disadvantaged due to volatile exchange rates and the risk of currency depreciation, and inadequate market infrastructure, among others. Thus, international investors command greater returns to compensate for taking these risks, which often makes local-currency financing prohibitively expensive. Consequently, governments and private sector participants are constrained to borrow in foreign currencies from donors or through the capital markets, thereby exposing them to currency risk.

The African banking sector is characterized by high spreads, short tenure, and general risk aversion, and does not offer adequate products, with its lending activities being concentrated in certain sectors. This culminates in scenarios where banking systems tend to have high levels of liquidity, but provide a small amount of lending to small and medium-size enterprises (SMEs). The absence of credit bureaus in most countries and the concomitant effect on interest rates further hinders SMEs from gaining access to finance. The lack of access

to credit for SMEs in Sub-Saharan Africa is further reflected in the data on bank and domestic credit to the private sector. Based on data for 2015, Sub-Saharan Africa trails other developing regions when considering both indicators of financial development.

A key characteristic of the financial system in the region is the crowding-out of private sector financing by the public sector. Financially constrained governments tend to offer high real interest rates on government bonds, which become more attractive to banks compared with providing credit to SMEs. This crowding-out can be direct when the banking sector purchases a substantial share of bonds, or indirect when the government bond rates set the risk-free floor for private sector financing, which serves as a disincentive to borrowing. Therefore, banking is very expensive in Africa, reflected by high interest spreads and margins compared with other regions in the world. Moreover, extremely low returns on deposits have discouraged savings and limited the ability of the banking sector to perform its intermediary role. This has been a contributory factor in limiting the development of the financial system, which remains narrow and illiquid, with limited access to long-term financing and, consequently, a hindrance to local debt financing. The financial systems also lack innovative financial instruments, especially those geared toward SMEs, which constitute most businesses in the region and tend to be confined to informal sector financing because of inadequate financial services.

Several factors have served as impediments to the development and efficiency of the financial system in African countries. The institutions required for building an efficient financial system, including robust contractual and informational frameworks and incentive-compatible regulation and supervision, are weak.[48] The inadequacy of the regulatory framework in these countries has produced a concentrated banking sector, very low intermediation rates, and inefficient collateral registry systems that further hinder access to credit for businesses and individuals.

Innovation can provide opportunities for leapfrogging in financing and make capital more efficient, risk management more targeted, hedging better matched, and trading less costly. It should also contribute to the unbundling of risk, improved liquidity, broader access to capital, and optimal portfolio diversification. However, financial innovation is not without dangers, as risk often drives it and, in return, incentivizes at the level of the individual, structured financier or institution. The financial incentives of individuals, coupled with advancements in technology and financial engineering skills, can result in situations where new instruments outpace the existing market and regulatory infrastructure.

Nevertheless, there is an advantage for emerging markets more generally, and particularly for Sub-Saharan African countries in pursuing financial innovation, to trigger the transformation for leapfrogging in the financial sector. Conventional financial services have room to be more inclusive and innovation can offer viable services to those at the bottom of the pyramid. Moreover, development of the formal financial services industry will expand access to finance, and innovation in the financial sector is very critical in this regard.

Leapfrogging Finance

There has been a paradigm shift in the financial sector across the globe over the past decade, as the ecosystem was created for disruptive innovation. This includes country experiences in financial innovation, and its impact on financial inclusion and access to financing. Access to finance has been made easy and affordable via the use of mobile phones, the best example of financial leapfrogging in Africa. Other financial leapfrogging examples include the relatively rapid take-up of risk index insurance in some African countries, including innovative payment and collateral options and lowering the time to develop local currency denominated bonds.

M-PESA, which was launched in 2007 by Safaricom in Kenya, ignited the mobile money revolution in

Africa. The service allows customers to use a mobile phone to undertake deposit, withdrawal, and money transfer activities; pay bills; and purchase airtime. M-PESA's initial innovation was leapfrogging the lack of financial services by exploiting existing telecommunications infrastructure and network subscriptions in Kenya, circumventing the expenses associated with storefronts and in-cash transactions. The service has expanded to include more advanced offerings, including ATM cash withdrawals, savings accounts, on-site retail payments, mobile ticketing for events, and corporate banking accounts. M-PESA spawned competing mobile money services. By 2016, 75 percent of the country's adult population had a mobile money account, with transactions amounting to the equivalent of 4.5 percent of annualized GDP per day.[49] M-PESA was a disruptive innovation that transformed banking in other countries, leading to an explosion of mobile money services across Africa, enhancing financial inclusion.

A responsive retail banking model with innovations aimed at the African context has proven successful in Kenya, as the example of Equity Bank demonstrates. Equity specializes in the provision of high-volume small loans at low interest rates. Micro-loans are available from as little as K Sh 500 (US$5.81).[50] Other innovations include waiving property-ownership requirements for opening an account, flexible forms of collateral including personal belongings, and trucks with a satellite dish and a bank manager to go to places where there were no branches. Equity also provides free financial literacy programs. By 2011, Equity had provided US$750 million in loans to almost 300,000 SMEs.[51] Consequently, Equity's deposit accounts have increased to more than nine million, making it the second largest bank in the country.[52]

The World Bank and IFC are issuing local currency bonds, aiming at strengthening domestic capital markets by working with governments, regulators, capital market institutions, investors, and local financial institutions. The instruments include offshore bond sales in local currencies aimed at international as well as domestic investors, as well as domestic bond issues. The World Bank has issued about US$8.5 billion in bonds in 19 currencies since 2011, including in several African currencies, such as the Uganda shilling. Since 2002, IFC has issued bonds in 14 emerging market currencies around the world, including Rwanda. Given that a local currency bond issue takes several years to develop, IFC aims to reduce the time by standardizing the process. It notes that in Africa: "...there is a great desire to catch up. Some countries are impatient enough they want to leapfrog—they don't want to wait another 20 years to develop the market."[53]

Agricultural risk schemes have emerged to avoid situations where farmers resort to selling off valuable assets, such as livestock and equipment, due to climatic events beyond their control. To address this challenge, index-based risk financing hedging against specific climate-related events has been developed. Data are tracked and payouts triggered by instances, such as a significant drop in rainfall that deviates from historical averages and reaches a pre-set level. The first government-level, index-based insurance was piloted in Ethiopia in 2006, spearheaded by the United Nations' World Food Programme, with 26 weather stations monitoring rainfall throughout the country daily. The experience led to the Rural Resilience Initiative (R4), which was launched by the World Food Programme and Oxfam in 2011.[54] R4 currently reaches more than 43,000 farmers (about 200,000 people) in Ethiopia, Senegal, Malawi, Zambia, and Kenya. The initiative has introduced several innovations for rural insurance, including allowing poor farmers to pay for crop insurance with their own labor and using the insurance policy as collateral for better credit terms. R4 found that insured farmers in Ethiopia saved more than twice as much as those without any insurance, and invested more in inputs and assets. In Senegal, after two years of bad harvests, insured farmers were able to maintain food security compared with others exposed to the same risks. R4 is aiming to reach 500,000 farmers in the region by 2020.

The objective of the Women Entrepreneurship Development Project (WEDP) is to increase earnings and employment for women-owned enterprises in Ethiopia. It created the first women entrepreneur–focused line of credit in Ethiopia in 2013 and, as of the end of 2015, more than 3,000 women entrepreneurs have taken loans, 64 percent of them first-time borrowers. The WEDP microfinance institutions improved their ability to appraise, which resulted in a decline in collateral requirements from an average of 200 percent of the value of the loan to 125 percent. WEDP is recognizing new forms of collateral, such as vehicles, personal guarantees, and even business inventory. WEDP is introducing innovative credit technologies to lenders, such as psychometric tests, which can predict the ability of a borrower to repay a loan and reduce the need for collateral. This technology allows entrepreneurs who do not have collateral to take an interactive test on a tablet computer, predicting the likelihood of repayment.

The Asian Bond Fund (ABF) is an example of a regional initiative designed to protect economies from damaging currency speculation while at the same time enhancing bond market development. It is one of the first initiatives in the world where a regional organization contributed financial resources to setting up a bond fund. The 11 members of the Executives' Meeting of East Asia and Pacific Central Banks (EMEAP) launched the ABF in June 2003. The 11 central banks pooled US$1 billion to invest in dollar bonds issued by the sovereign and quasi-sovereign borrowers in the EMEAP countries.[55] This was followed by ABF2, launched in 2005, which invested US$2 billion in local currency bonds. The bonds had the desired effect of drastically reducing currency speculation, and helped develop the bond and local currency bond markets in the region. Equally important was the catalytic role of the ABF in collaboration and building trust among the region's central banks.

During the years following the 2008 global financial crisis, two financial innovations were developed in China. These solutions comprise a development financing model supporting China's urbanization and digital inclusive finance aimed at providing financial services to groups with limited financial options. China Development Bank (CDB) has served as the facilitator of development financing. CDB has devised major development strategies for the economy through medium- and long-term credits, investment, and other financial services. In its development financing role, CDB has built a bridge between the government and the market, through use of public credit to attract social funds for urbanization, economic transition, and stable development. Development financing has been a key instrument in China's urbanization strategy. For example, from 2004 to 2014, CDB issued loans amounting to 54 percent of the fixed asset investment of China's public infrastructure, providing a capital guarantee for over half of city construction projects.

Inclusive finance aims to provide services to groups with unfavorable economic circumstances and limited financial options. The ultimate objective is to facilitate the economic growth of enterprises and families, eliminate poverty and inequality, and incorporate all persons needing financial services into the financial system. Alipay, a third-party mobile and online payment platform, is an example. Alipay was established in February 2004. In 2010, China's central bank issued licensing regulations for third-party payment providers and a separate set of guidelines for foreign-funded payment institutions. Alipay, which accounts for half of China's nonbank online payment market, was restructured as a domestic company to facilitate the regulatory approval for the license. In the fourth quarter of 2016, Alipay had over half the market share of China's US$5.5 trillion mobile payment market, by far the largest in the world. Alipay provides an escrow service, where consumers can verify their satisfaction with purchased merchandise before releasing money to the seller. Internationally, more than 300 worldwide merchants use Alipay to sell directly to consumers in China.

Alipay has progressed with several recent innovations in digital finance. Quick Payment, launched in 2011,

aimed to solve the problem of the low success rate and poor experience caused by complicated payment steps on online shopping platforms. Quick Payment introduced a one-click solution, streamlining the process. Market response was favorable, and Quick Payment soon became a standard product for all payment institutions, including Tenpay and Chinabank Payments, significantly improving the degree of inclusive digital finance in payments. Alipay also experimented with various technologies for offline small and micro businesses without Point-of-Sale machines. It implemented a Quick Response solution, where merchants can scan a customer's payment details using a smartphone, providing a convenient payment solution for many small and micro businesses in rural areas. Alipay is also providing payment platforms for other types of services, including in the medical field, where hundreds of institutions have access to Alipay. For example, Alipay is connected to insurance providers in the city of Shenzhen, establishing the first medical insurance mobile payment platform in the world.

Changes to Transform the Financial System in Africa

African countries will need to undertake several reforms to exploit the potential for leapfrogging. Moreover, the leapfrogging experiences provide examples of policy measures that underpin innovation in and development of the financial system. The experiences of leapfrogging in finance also serve as the basis for the options available to African countries to circumvent the challenges presented by underdeveloped financial markets through various instruments (box ES.2).

Regulatory bottlenecks can be tackled by establishing and enforcing laws and creating facilities that enable smoother credit flows. Investor confidence can be enhanced through the creation of credit bureaus that oversee repayment records. One of the major impediments to borrowing in Africa is the lack of collateral due to inefficient registration systems. Reliable credit registries, effective cadaster systems, and effective land title transfers are critical for the performance of financial intermediaries, particularly for assisting SMEs.

The banking system needs to be reorganized by opening the sector to competition, reviewing prudential ratios, and putting in place innovative savings and borrowing instruments adapted to local needs. A typical characteristic of the banking sector in African countries is the high concentration ratio; at an aggregate level, the World Bank's estimate of the average market share of the three largest banks in Africa is 73 percent. This oligopolistic structure has negative consequences, among which are high interest rate spreads that crowd out credit to the private sector by making loans too costly. Mobilization of domestic resources is vital to investment; the sustainable growth and banks, as the primary channels of financial intermediation, has a key role to play in this regard. Thus, the banking sector needs to be reformed to increase competition, and to accommodate effectively the demand for credit from the public and the private sectors, so that savings and resources can be channeled toward productive investment.

The gap between the informal and formal financial sectors needs to be bridged by formalizing microfinance institutions, to help them scale up activities while developing financial products geared toward SMEs. The emergence of microfinance as a tool for financing the informal economy coincides with the growing understanding between nongovernmental organizations, development experts, and policy makers that a significant proportion of the population in developing countries has no access to financial services. Microfinance, which at first seemed to be a panacea, has demonstrated its limitations in scaling up operations. Thus, formal financial institutions need to adapt their products to local demand. Specifically, innovative financial tools that use technology, such as mobile banking, can also help leapfrog traditional financial services and reach a larger population.

Box ES.2: Financial Options for Leapfrogging

There are several areas of finance that present opportunities for African countries to leapfrog:

Agriculture financing relates to how effectively such financing can be aligned to the agricultural production cycle. *Commodity collateralized finance* uses commodities or, more broadly, inventories as collateral for lending. The use of digital technologies enhances the tracking of commodities, and the emergence of collateral management companies provides an additional level of comfort for financiers. Agriculture financing also *links value chains to financial institutions*. As agriculture value chains in Africa become better organized, opportunities increase to introduce digital payments and collect information by anchor firms that could be used by providers of finance to facilitate the efficient allocation of credit.

Agricultural index insurance provides protection against climate shocks like drought, flooding, and irregular rainfall. Because of the need for on-site farm visits, the traditional agriculture insurance market largely fails to meet smallholder farmers' demand for affordable insurance. Satellite-based index insurance, when combined with mobile technology for registration and claims settlement purposes, has huge potential to meet the needs of these farmers.

Financial inclusion can be enhanced via measures such as making government payments through electronic channels; establishing or accelerating universal coverage of national identification systems, which facilitates opening bank accounts; and strengthening education programs to deliver financial and digital skills and literacy.

Local currency financing in Africa has been constrained by the lack of incentives, policy coordination, and affordable solutions. A tailored solution can be developed combining technology and experience based on lessons learned in other countries in (a) clearing and settlement technology used to integrate markets; (b) implementation of trading platforms; (c) design of market-making systems and alternative trading arrangements, such as call markets; (d) design of local currency indexes; and (e) participation of multilateral development banks as conveners in the development of investment products.

Infrastructure finance can be leapfrogged by developing unconventional financing solutions that do not need to wait for full-fledged capital markets. For example, the World Bank is supporting an approach in Kenya to mobilize long-term local institutional investors into infrastructure financing through alternative financing vehicles, such as debt funds and hybrid-financing featuring long-term institutional investors and local bank co-financing. Another feature is a World Bank guarantee, which enhances projects to acceptable risk-return profiles. This financing solution provides the flexibility needed in markets that are not yet fully functional, as is the case across Sub-Saharan Africa, and leverages the benefits of a private-equity fund structure, but modified to accommodate features like those of fixed-income debt. Through an intensive training process, when the pipeline projects reach their financing phase, investors would be prepared and made to feel comfortable enough to invest in these infrastructure projects through a suitable investment vehicle to pool their funds. Credit risk guarantees are also useful for long-term financing, specifically when issuing local-currency debt. Most importantly, through domestic debt issuance, countries can use and recycle their savings toward their investment needs rather than increase their external debt.

GOVERNANCE

Digital Technologies: The Foremost Change

The World Bank defines governance as "…the process through which state and nonstate actors interact to design and implement policies within a given set of formal and informal rules that shape and are shaped by power." Power is "the ability of groups and individuals to make others act in the interest of those groups and individuals and to bring about specific outcomes."[56] Good governance is critical for government and market efficiency, and this strongly influences economic development. The United Nations Development Programme believes that governance and human development are indivisible and good governance is a primary means of reducing poverty.[57] The potential of good governance to improve economic and social development outcomes is of utmost relevance to Sub-Saharan Africa, which has the lowest per capita income and human development of any region in the world.

The foremost change affecting governance since 2000 is advances in the use of ICT. The Internet, mobile communications, and social networking have facilitated the transformation of public administration in some countries and triggered a shift in the relationship between citizens and governments in others.[58] Potential impacts include "enlarging the democratic space, enhancing dialogue, facilitating inclusiveness, and by providing governments the tools to better perform their administrative and management functions."[59] However, the digital divide between Africa and the rest of the world is a major barrier to the applications of digital technologies for governance.

A study points out that African governments have been using information technology for over four decades and progress in the use of ICT for governance should be seen as evolutionary rather than revolutionary.[60] Nevertheless, the emergence of computer networking in the 1990s is a key innovation transforming the processing and communication of government data. Three impacts from the use of e-government include improving the internal workings of the public sector and reducing costs; improving communications with the public as voters/stakeholders or as users of public services; and improving relationships between public agencies and other institutions, such as other public agencies, the private sector, and civil society institutions. Stakeholders need to understand the large gaps between project design and the reality of the African public sector. These "design-reality gaps" underlie failure. They arise due to the origin of e-government concepts and designs in developed countries that are considerably different from Africa. Some best practices may help to improve project success, but only if they are appropriate to the contexts of African countries.

Corruption is a major, and some argue the greatest, obstacle to social and economic development. Digital technologies can lead to more transparency, reducing corruption among public officials. One study finds a connection between corruption and e-government, with a statistically significant link between the United Nations E-Government Development Index (EGDI) and the Transparency International Corruption Perception Index, suggesting that as the use of e-government increases, corruption decreases.[61] The impact of e-government on reducing corruption is higher in developing countries than in developed ones. This is of particular significance for Sub-Saharan Africa, which ranks lowest in the perception of corruption.

Digital technologies can improve registration processes for citizens in areas such as births and passports. An important area is the national ID card. The lack of official identification prevents citizens from exercising their rights and isolates them socially and economically. For example, they may not have access to voting, legal action, receipt of government benefits, banking, and borrowing. Digital IDs, combined with the broad spread of mobile devices in developing nations, offers a transformative solution to the problem. Not only is it a simple means for capturing official identification

that can reach far more people, a digital ID creates innovative and efficient ways for governments and businesses to serve citizens.

Experiences Implementing Innovation and Technology to Make Government More Effective

African countries are implementing innovation and technology to make government more effective in several ways. These include standardizing government data architectures and databases to make back-office work flows more productive, connecting government offices to enhance information sharing and reduce costs, and providing information online or through mobile phones with various stages of interactivity. Ninety-two percent of the countries in Sub-Saharan Africa have established at least a central portal providing some information about the government and, in some cases, links to procedures and forms as well as some interactive services.[62] Examples of notable practices in innovation and leapfrogging in the application of digital technologies to government include top-ranked Mauritius. The country has one of the oldest histories of applying computerization to the public sector, as well as the continent's best digital infrastructure. Other examples include Tanzania's creation of a dedicated agency for electronic government and Rwanda's success in connecting government agencies and deploying online public e-services. Kenya and Burkina Faso are notable for innovative deployment and use of open data; Côte d'Ivoire has had the largest improvement in governance indexes.

According to the EGDI,[63] Mauritius is top ranked in Africa by some margin. Its score is 23 percent above the second highest-ranking country in the region, Tanzania. On reason is the long experience Mauritius has had with the computerization of government, dating back to the 1990s. The country also has the best-developed ICT infrastructure in Africa. There are more than 60 major multi-user systems implemented and operational in the public administration. Mauritius has assisted several other African countries with implementing systems. A recent impetus has been more focus on services for citizens. Households across the country were surveyed to solicit their views to inform the citizen-centric e-Government Strategy 2013–2017. The strategy has already had an impact; by July 2017, almost 70 e-services were available online, with 10 mobile applications also under development.[64]

Tanzania's Electronic Government Agency is an innovative example of a dedicated entity charged with handling government computerization for the country. Established in 2012, the Electronic Government Agency assists government departments with various activities, including designing websites so they have a consistent look and feel, managing the government's domain name (.gov.tz), and helping agencies develop mobile applications.

Rwanda has made notable use of its own resources, assistance from the development community, and public-private partnerships (PPPs) to link government offices, provide civil servants with digital skills, computerize back-office processes, and deploy electronic public services for citizens and businesses. The government used proceeds from the sale of its incumbent telecommunications operator to construct a national fiber optic network that enabled connections of government offices. In 2013, the government entered into a 25-year PPP with Rwanda Online Platform Limited for the provision of online government services. Services are provided over the Irembo (Kinyarwanda for gate) platform, which is accessible via the web and mobile. More than 30 services are available, ranging from birth certificates to driving tests, with plans to expand to more than 100. More than 200 service centers are spread throughout the nation for citizens to learn how to use the system or have an intermediary carry out the transaction for them.

Open data provides unstructured government data available online to the public, to enhance

accountability and transparency. The 2010 Kenyan Constitutional revision included a new section calling for citizens' right to government information. This was one of the factors leading to the establishment in 2011 of the Kenya Open Data Initiative, the first in Sub-Saharan Africa. Several enhancements have been introduced since then, including a program providing training to journalists and civil society organizations interested in using open data. Code for Kenya assigns them computer experts and data analysts. Several tools have been developed, such as Open Budget, replacing unstructured budget data with an intuitive, interactive tool. Data Lens is a new, visual way to explore data that makes it easy for citizens to get answers to their questions in a visual, intuitive way without getting lost in the data.

Burkina Faso provides an innovative illustration of how open data was used to disseminate the results of the 2015 presidential election, moving from unstructured, static data to real-time, formatted data. A consensus emerged that rapid dissemination of the election results would increase transparency and encourage confidence in the results. There was close collaboration between the country's electoral commission and government, civil society, and international partners. The electoral commission worked to secure political support for rapid processing and publication of the election results, which was unprecedented in Burkina Faso and almost unheard of in Sub-Saharan Africa: just one day. This was achieved by publishing the results in real time, enabling citizens to access the results instantly as they were validated on election day.

Côte d'Ivoire is a case where governance leapfrogging is supported by statistical measurement. Over the past decade, it was the most improved African country in the Ibrahim Index of African Governance, with its score rising 13 points between 2006 and 2015. Anti-corruption efforts are cited as one reason behind improved business procedures. The High Authority for Good Governance was established in 2013 as part of the government's national anti-corruption plan. It is an independent authority responsible for preventing and combating corruption and related offenses, and part of the Network for Integrity, whose members include similar institutions from 13 other countries.

Prerequisites for Contextual Leapfrogging

Most African governments have made some progress in applying digital technologies within the public administration. This ranges from simply putting up a few websites, to interactive processes for the delivery of services. Leapfrogging in the sense of catching up with developed countries in the short run is unlikely, given the resources and state of connectivity required. A contextual type of leapfrogging is necessary, where appropriate application of digital technology is made available within the African environment. E-governance interventions also need to be cognizant of the region's absorption capability, with grandiose projects having a poor record compared with an evolutionary approach. Leapfrogging requires certain prerequisites to enable success.

The main factor for enabling leapfrogging in the application of digital technologies to governance is *high-level government support*. Political will and leadership are a prerequisite for successful e-government. Without strong government commitment, there will be bureaucratic resistance and a lack of coordination among ministries. A common attribute of successful instances of e-government in Africa is a *strategy*. This was found to be the case for example in Mauritius and Tanzania. A strategy provides a concrete reference to goals and often a schedule for implementation. Strategies also ensure that there is a whole-of-government approach to using digital technologies, rather than individual silos in ministries. This can be further strengthened through the establishment of an *agency* that is responsible for e-government to coordinate with information officers in all ministries. *Sensitization and training* are also needed for successful implementation of e-government initiatives. There is often limited expertise

and a lack of incentive among government officials to use ICT. Therefore, e-government projects should have a substantial training component to enhance the potential for success.

In the absence of a strategy, and often where there is bureaucratic resistance to e-government, a *quick win* approach can be considered. Quick wins are often innovative and applied to leapfrogging in a particular area. They are particularly relevant where there is not much digital expertise in government or it varies across ministries. Quick wins help to gain experience that can then be used to develop bigger projects. They provide proof of concept that could then attract deeper political buy-in and are often perceived as nonthreatening. There is often a thin line between bottom-up activities that can be scaled up as opposed to one-off interventions that fade when funding runs out. Therefore, a good understanding is needed of how quick wins fit into a long-term strategy for sustainable e-governance.

Governments also need to have a *citizen-centric* approach, especially when devising e-services. This is particularly relevant in Africa, where most citizens do not have access to the Internet. Citizens need to be involved in designing digital initiatives for governance. Low-cost and non-Internet–based ICT tools should be included, because technical accessibility and affordability and awareness campaigns should be conducted to let citizens know about the existence of and how to use the tools.[65] The use of public centers to teach citizens how to use e-services or provide intermediary services is also important.

Limited resources often deter governments from adopting digital technologies, due to the high cost involved in connecting agencies and developing e-services. This can be ameliorated through progressive implementation over time as well as assistance from development agencies and the use of PPPs. Although Africa lags behind in wired broadband deployment, there is widespread mobile phone availability; e-services need to be deployed that target cell phones. Government services may require payment, so it is essential to make them truly interactive in collaboration with mobile money providers. This also requires the adoption of laws that recognize the legality of electronic transactions. Some wired broadband networks and supporting infrastructure, such as data centers, are critical for connecting government offices and delivering cloud services. These can be encouraged through PPPs and infrastructure sharing. Government data need to be standardized through common architectures to reduce duplication and facilitate sharing.

Information and Communications Technologies

The Mobile Revolution

ICT is revolutionizing the world. Not only is ICT an important sector in its own right, it affects every other sector in the economy. As ICT evolves in speed, from narrowband to broadband, and in scope, from connecting just humans to machines, it is having even greater effects.

The rapid decline in the cost of digital technologies, particularly the Internet, has dramatically reduced transaction costs. This benefits economic development in three ways.[66] First, the Internet helps overcome information asymmetry by better linking sellers and buyers. Second, lower transaction costs enabled by the Internet raise productivity in businesses. Third, the Internet triggers innovation associated with the so-called "new economy" characterized by innovative business models, the customization of services, and industry disruption.

ICT and particularly mobile networks have grown rapidly in Africa. The speed of mobile evolution, policy reforms, and the ways of financing investment are distinct among infrastructure sectors in Africa.[67] The availability and quality of service have increased

and prices have gone down. Sector reform has driven this radical change. Markets have been opened and regulatory agencies created. This has resulted in competition spurring investment. Cell phones are used for more than basic voice communications in Africa. Mobile networks are generating innovation and boosting incomes, with farmers using cell phones to check market prices and traders accepting payments in mobile money. However, there remains a large digital divide in Sub-Saharan Africa, due to the high costs of deploying infrastructure in rural areas.

The international development agenda stresses the cross-cutting importance of ICT infrastructure for achieving the SDGs. SDG Target 9c makes a call to: "significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020." Although the target refers specifically to the least developed countries, it is highly relevant for Africa, since 33 of the 47 least developed countries are on the continent.

Although Sub-Saharan Africa has made impressive progress in expanding digital infrastructure over the past decade, there is still further to go to expand broadband infrastructure, lower costs, and leverage benefits more fully. Despite the steady gains, the region continues to lag all others in access to ICT. This is partly due to the link between per capita income and ICT access. However, in many cases, the market is not functioning as well as it could—sometimes linked to exogenous factors such as poor governance, lack of electricity, the high cost of doing business, and a low level of digital skills. Other factors are internal to the sector, including imperfect competition, the lack of open access to key facilities, and constrained spectrum allocation. Government strategies to narrow the digital gap between urban and rural areas through universal service funds have been largely ineffective throughout the region. Solutions are needed to these challenges to lift the region's ICT sector to a higher level.

Rapid Progress through Substitution and New Approaches

Africa has several noteworthy leapfrogging experiences in ICT. The region as a whole has experienced rapid growth of mobile networks and, more recently, the deployment of a growing number of submarine cables. Some Sub-Saharan African countries stand out for mobile connectivity on par with developed nations, for the application of mobile communications in other sectors, and for innovative approaches to mobile broadband network deployment. Leapfrogging has often been stimulated from ICT serving as a substitute for inadequate alternatives (for example, the lack of fixed telephone lines or limited formal banking services); in other cases, leapfrogging has been driven by a new approach, such as PPPs.

Mobile communications are the one ICT where Africa has been closing the gap with the rest of the world. Although fixed telephone networks have been around since the early 1900s, access was always limited in Sub-Saharan Africa, at less than 2 percent of the population. Once the first mobile networks launched in the region in 1989, they grew rapidly. The gap between Sub-Saharan Africa and the rest of the world dropped from 99 percent in 1989 to 23 percent by 2015. The reason for the popularity of mobile in Africa is largely contextual: ineffective monopoly landline operators that did not pose a strong competitive threat to new mobile operators, lower investment costs of greenfield wireless networks, huge pent-up demand due to a lack of landlines, and the prepaid model that fit the region's economic circumstances.

The rapid growth of submarine cables in Sub-Saharan Africa is another area where there has been astounding leapfrogging. Before 2009, there was only one monopoly-controlled cable on Africa's west coast and only a handful of countries were connected. The deployment of cables on Africa's east coast in 2009 led to a surge of undersea fiber optic networks. By 2016, all sea-facing African countries, except Eritrea and Guinea-Bissau,

were connected to submarine cables. Growth has been stimulated by several factors, including rising Internet use on the continent necessitating greater international capacity, a race to deploy between different cable systems, rising demand for Internet capacity, and the involvement of development agencies, particularly in a policy role of encouraging open, cost-based access to submarine cables.

South Africa is notable as one of the first countries in Sub-Saharan Africa to introduce competition in its mobile sector. Today, cell phones are as common in South Africa as they are in the United States, with 89 percent of adults having a cell phone. Although South Africa had an analogue mobile network in the 1980s, it was essentially restricted to the well-off, due to high costs and low coverage. The launch of second-generation mobile and introduction of competition between the two private companies, MTN and Vodacom, in 1994, transformed the industry. Today, there is widespread mobile broadband coverage, with a 3G signal reaching 99 percent of the population and 4G/LTE covering over 75 percent of the country's inhabitants, the highest levels in Sub-Saharan Africa and significantly above world averages. Additional competition through the market entry of Cell C in 2001 and the incumbent fixed line operator Telkom in 2010 has sustained growth. MTN and Vodacom have also been instrumental in introducing cell phones to other Sub-Saharan African countries, with subsidiaries in 19 markets in the region.

Kenya provides examples of ICT policy and technical innovations. Although the East African nation faces the sea, it long relied on expensive satellite connectivity, due to the lack of access to submarine cables. The government saw this as a major obstacle to the country's becoming an ICT hub. The government created a PPP to build an open access undersea fiber optic cable to the United Arab Emirates, which became operational in 2009. The country is now connected to three submarine cables and this will double by the end of 2018. Kenya has emerged as the leading bandwidth hub in East Africa, providing international Internet capacity for landlocked countries, including Ethiopia, Rwanda, Uganda, and soon South Sudan. Kenya is also a trendsetter for the application of mobile to the financial sector. In 2007, mobile operator Safaricom launched M-PESA, the first mobile money service in Africa. The lack of or the cost of formal banking quickly stimulated take-up, as did a relaxed regulatory framework to allow the service to develop. The percentage of the population ages 15 and older with an account rose from 42 percent in 2011 to 75 percent in 2014, one of the highest rates of mobile money penetration in the world, strengthening financial inclusion in the country. Mobile money has spawned add-on applications, such as links to savings and insurance and payment for online shopping.

Although Rwanda is a landlocked, least developed country, this has not stood in the way of government aspirations for the ICT sector. An innovative government-led initiative is the world's first wholesale-retail model for a fourth-generation (4G) wireless network. A PPP was established in 2013 to build the network; it acts as a wholesaler, selling capacity to retail Internet service providers. The 4G network was launched in 2014, with the target of covering 95 percent of the population by 2018. One reason for this model is that the government wanted to accelerate the rollout of superfast mobile technology.

The experiences of China illustrate how the adoption of digital technologies has triggered economic and social changes (box ES.3).

Enhancing Conditions for Digital Leapfrogging

ICT is an important sector in its own right and in cross cutting with impacts across other sectors. Leapfrogging within the sector is dependent on a proper regulatory environment to stimulate competition, investment, and innovation. Its impact on other sectors is

Box ES.3: Leapfrogging by China's Digital Economy

The past two decades have witnessed the rapid development of China's Internet-based industry. Internet enterprises have made great progress in technical expertise, business models, and changes brought to the economy and society, and even assumed a leading position in the world in some respects. The main experiences include the following:

I A robust e-commerce platform and network has been established. The development of credit, payment, and other new finance infrastructure has been boosted to provide inclusive financial services for individuals and small and micro businesses. Financial technology enterprises have been supported to construct a global payment network, making online and mobile payment more convenient. China's digital payment companies have become the largest in the world. Shopping websites have broken the constraints of time and space, providing convenient low-cost channels for linking buyers and sellers, and promoted the development of small enterprises.

II Various platforms have been established to enhance access to local content. The ratio of Internet users using instant messaging has reached 91 percent. Several online platforms have emerged for people to communicate and obtain information through the Internet and spawned a self-media era, making the Internet a source for user-generated content and an important channel for transmission.

III In areas such as customer-oriented businesses, cloud computing, big data, and recognition technology, China's Internet enterprises have reached and, in some cases, even exceed the world's top level. The development and utilization of up-to-date technologies by financial enterprises have been promoted for increasing efficiency, optimizing user experience, and maintaining market competitiveness. The annual online "11 Day Global Festival" held on November 11, 2016, is an example. Some 120,000 payment transactions were processed per second during peak times.

IV The new economy represented by the Internet has developed rapidly, brought about huge social and economic benefits, and provided new energy for China's economic development. In fiscal year 2016, the total online sales on the Alibaba platform exceeded Y 3 trillion (US$4.5 billion), more than the total sales of Walmart, historically the world's largest retailer. The 18-year development of Alibaba has surpassed the 54-year development of Walmart.

V With the transformation of urban development and evolution of smart cities, advanced e-government services have accelerated. Network information technology has created a new pattern of economic and social development, where the relations between people and services, people and cities, people and society, people and resources, and people and the future are transformed. In 2015, Alipay launched the "City Service" smartphone app, allowing users to carry out a range of tasks related to urban living, including paying for traffic tickets as well as utility bills, making medical appointments, and accessing information about traffic and public transportation. Another example is "Sesame Credit," where users of the Alipay digital payment service generate real-time credit scores; those with high scores accrue rewards, such as avoiding car rental deposits or quick airport security checks. Ant Forest, an app from Ant Financial, is a game that tracks users' behavior to help them reduce their carbon footprint. Around a fifth of China's population signed up for the app in nine months. The lifestyle changes the app induced are estimated to have avoided 150,000 tons of carbon emissions.[a]

[a] Green Digital Finance Alliance. 2017. *Scaling Citizen Action on Climate: ANT Financial's Efforts Towards a Digital Finance Solution.*

dependent on regulations as well as knowledge of how to apply ICT to areas such as finance, agriculture, health, and so forth. Other necessary preconditions include a clear sector strategy, human capacity development, and innovation support. Once these preconditions are in place, there are several potential technological options for leapfrogging, such as the Internet of things, drones, new spectrum sources (for example, analog broadcasting and white space), and jumping straight to 4G and 5G networks.

African countries need the right *enabling framework*, including an independent sector regulator, competition, and openness to private sector investment. *Competitive safeguards* are needed to check anticompetitive behavior such as cross-subsidization and control over key bottleneck facilities. The price for exchanging traffic between different competing networks should be transparent and cost-based. Universal service funds could be established to reduce the gulf between ICT access in urban and rural areas, but need to be designed so they are transparent and effective. Contributions to universal service funds combined with other sector-specific taxes are burdensome in some countries, diverting money from investment and raising prices for consumers. Clear rules about *licensing* requirements for market entry are another principle. This includes distinguishing between types of licenses, when they are needed, and publicly available information about licensing criteria (that is, the period required to reach a decision, terms and conditions, and so forth). One challenge is pricing licenses correctly to attract strong players while at the same time not charging so much as to discourage market entry. Finally, there need to be efficient mechanisms for the assignment of *scarce resources*. This is particularly important in the African context, where most access is through wireless networks that require frequency spectrum. Transparent procedures are needed for the allocation of scarce resources, such as frequencies, numbers, and rights of way.

An ICT sector strategy is vital for providing guidance and accountability and describing how digital technologies fit in with overall national development plans. Ongoing, multi-year plans offer some predictability about the government's direction for the sector, providing reassurance for investment from the private sector.

The strength of telecommunications operators, their involvement in other countries, and scale make a difference. Governments should award major telecommunications licenses based on a variety of criteria, including the operator's experience, particularly in other African countries; its proven technical expertise; its financial depth; and its willingness to engage in a significant way with the social and economic goals of the country.

Skills across various domains are essential for Sub-Saharan Africa to exploit ICT opportunities successfully. Governments need the right skills to create policies and regulate the sector. Technical skills are needed across sectors to develop ICT applications and services. Digital literacy is essential for citizens to make productive use of the Internet. The transition to broadband and the Internet is often constrained because it requires a higher level of skills than using a mobile phone.

The need to stimulate *innovation* is critical for triggering new uses for ICT that benefit the economy and society. Governments need to encourage ICT-based disruptive innovation that challenges traditional industries. Thousands of digital entrepreneurial innovators have clustered in tech communities across the continent that merit support and incentives.[68]

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Innovation and Development: Why Africa Needs to Leapfrog?

1

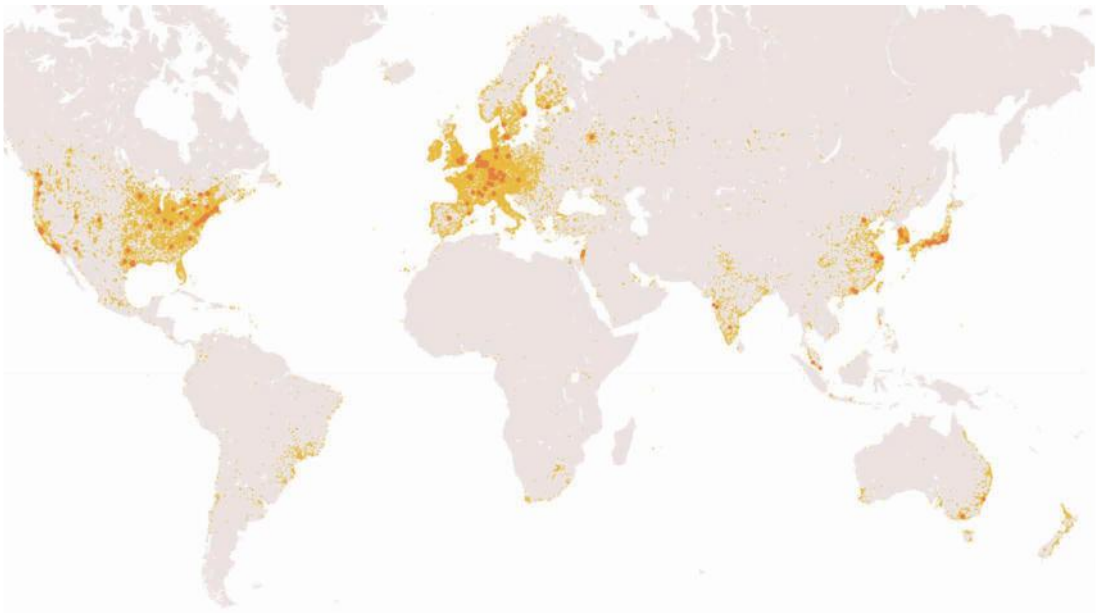
I. Why Are Technology Adoption and Innovation Crucial for Africa's Future?

Despite sustained economic performance in the past two decades, the Africa region still faces enormous challenges and significant gaps on many development outcomes. A recent World Bank report estimates that around 43 percent of the African population was still living in extreme poverty in 2012 (World Bank 2016). Additionally, the region's infrastructure is underdeveloped. Infrastructure is a key component that helps in promoting industrialization, raising incomes, accumulating human capital, and easing access to markets. However, evidence shows that there are severe infrastructure gaps in Africa. There is a dire need to address these gaps, as the current state of the region's infrastructure is one of the major reasons limiting private sector expansion and investment.

According to the latest *Africa's Pulse*, Sub-Saharan Africa ranks at the bottom of all developing regions in virtually all dimensions of infrastructure performance, which are quantity, quality, and access (World Bank 2017a). In the quantity of transport infrastructure, it is reported that Sub-Saharan Africa stands as the only region where road density (measured as kilometers (km) per square km of surface area) has deteriorated over the past 20 years. The report estimates that Sub-Saharan Africa recorded a road density network of 0.002 km per square km of surface area in 2014, compared with 0.016 in South Asia. Similarly, Sub-Saharan Africa is still the weakest performing region in road quality, with a score of 3.3 in 2015, compared with 4.5 for East Asia and the Pacific. The consequences of this poor infrastructure are enormous. Weak physical infrastructure not only limits the growth of potential entrepreneurs, but also restricts private sector development and the region's overall development. Many issues drive the infrastructure gap in Africa, ranging from a lack of commitment to sustainable tariffs on infrastructure services, such as electric power, transport, and water, to poor performance of public utilities, with the latter being affected by weak management and political interference (World Bank 2017b).

Moreover, nearly two-thirds of Africans lack of access to electricity; and an even larger share relies on biomass as the main fuel for cooking (World Bank 2017b). In access to finance, only 23.1 percent of African enterprises have loans or lines of credit; the corresponding share among firms in non-African developing countries is 46.1 percent (Beck et al. 2011). In the Africa region, the use of formal financial services is concentrated among the richest 20 percent of the population (Beck et al. 2011). Most countries in the region have made significant gains in access to education, but learning remains poor. The agriculture sector, which employs a significant share of the labor force, exhibits low productivity. These large gaps require disruptive solutions and out-of-the-box thinking.

MAP 1.1: Top 100 Innovation Clusters Worldwide



Source: Dutta, Lanvin, and Wunsch-Vincent 2017.

The level of innovation in Africa is low, as highlighted in the latest evidence provided by the Global Innovation Index 2017 Report (Dutta, Lanvin, and Wunsch-Vincent 2017). Since 2012, the increase in innovation achievers from the continent has been steady. On a scale of 100 and in a sample of 127 economies, the top African country in 2017, South Africa, ranks 57th, with a Global Innovation Index score of 35.80. South Africa is followed by Kenya (60th), Mauritius (64th), Botswana (89th), Botswana (89th), Tanzania (96th), Namibia(97th), Rwanda (99th), and Senegal (100th). Most of the continent's innovation achievers performed better in institutions, infrastructure, and market sophistication. However, although the region's relatively high performance in innovation signals strengths, innovation levels across countries in the region still show large disparities. Therefore, it is crucial for the less-developed economies of the continent to continue to improve their innovation performance, to maintain the momentum of the region's innovation standings.

Looking at innovation from other perspectives (mainly clusters), Africa is very far behind. The region's innovation activities often tend to be geographically concentrated in specific clusters linked to a single city or a set of neighboring cities. Adopting a cluster perspective opens the door to a better understanding of the determinants of innovation performance that do not necessarily operate at the country level. Clusters of inventive activities are often identified and classified based on the number of patent filings. Patent data offer rich information on the location of innovative activity. Map 1.1 displays the top 100 major research and innovation clusters in the world in 2017. As shown on the map, most of the innovation activities take place in Western Europe and the United States. The distribution of clusters across countries is highly uneven: the United States has 31; Germany, 12; Japan, 8; China, 7; and France, 5. The top 100 do not include any cluster from Latin America and the Caribbean, Sub-Saharan Africa, Northern Africa, or Western Asia.

Despite these massive challenges and gaps, the development approach in Africa has often been primarily programmatic and mostly incremental.

FIGURE 1.1: Research and Development Expenditures and Economic Growth (%)

Source: Dutta, Lanvin, and Wunsch-Vincent 2017.
Note: GDP = gross domestic product; R&D = research and development.

This book argues that it is time to go back to the foundation of development, think big, and enable the environment for more innovation and technology adoption for Africa to have the opportunity to experience major positive transformations. This is not a new idea; to the contrary, it is what economic theory and history teach. There is no solid ground to treat Africa as an exception. The one commonality among almost all contemporary growth and development theories is that they all consider technology and innovation as the primary drivers of economic growth (Aghion and Howitt 2009). Historical experiences point to the same evidence. Major changes over the course of the history of countries like the United Kingdom, the United States, or even recently developed and emerging economies can be tightly linked to increasing productivity through the adoption of better technologies. The stream of inventions that began in the 18th century in the United Kingdom, from the steam engine, to electricity, the power loom, and machine tools has dramatically changed the course of human history. If the theoretical foundations and experiences around the world concur on this point, it should also be the starting point in thinking about African development.

II. What Do Economic Theory and History Say about Leapfrogging?

What Does Economic Theory Say?

There is one commonality in almost all contemporary growth and development theories: they all consider technology and innovation as the most important drivers of economic growth (Aghion and Howitt 2009). The role of technology and innovation and their subsequent adoption for economic growth and development is well established (Romer 1990; Aghion and Howitt 1992). The correlation between research and development expenditures and economic growth is robust, as illustrated in figure 1.1 for a sample of 127 countries between 2005 and 2015. Klenow and Rodriguez-Clare (1997) find that the correlation between innovation (measured by the natural logarithm of total factor productivity) and the logarithm of output per worker for 98 countries in 1985 was 0.93. This very high correlation suggests that, at the aggregate level, there is a large interdependence between the level of technology/productivity and economic development in general (Comin and Hobijn 2004). Similar results are found for productivity growth. Klenow and Rodriguez-Clare (1997), as well as Easterly and Levine (2001), suggest that the cross-country correlation between total factor productivity growth and the growth of output per worker is about 0.9. Technology and innovation also represent the bulk of cross-country differences in productivity, compared with factor accumulation (physical and human capital), which accounts for only 10 percent (Klenow and Rodriguez-Clare 1997; Clark and Feenstra 2003).

The neoclassical models, for example, are in many ways capital-based theories of economic growth. They focus more on modeling the accumulation of physical and human capital. However, these theories emphasize the crucial importance of technology. For instance, they do not generate economic growth in the absence of technological progress, and productivity differences help to explain why some countries are rich while

others are poor. In this way, neoclassical growth theory highlights its own shortcoming: although technology is a central component of the neoclassical theory, it is left unmodeled. Technological improvements arrive exogenously at a constant rate, and differences in technologies across economies are unexplained.

Four leading paradigms explain economic growth: the Solow model, the AK model, the product-variety model, and the Schumpeterian model.

Solow Model

Known also as the neoclassical growth model, the Solow (1956) model is the first most comprehensive model of how we approach not only economic growth, but also the entire field of macroeconomics. Building on the assumptions of the neoclassical production function and the evolution of the three inputs into the production function (capital, labor, and knowledge) over time, the Solow model ultimately identifies two possible sources of variation in output per worker: differences in capital per worker and differences in the effectiveness of labor, also understood as technology. However, the Solow model shows that only growth in the effectiveness of labor can lead to permanent growth in output per worker and that, for reasonable cases, the impact of changes in capital per worker or output per worker is modest. Consequently, only differences in the effectiveness of labor (or technology) have any reasonable hope of accounting for the vast differences in wealth across time and space. Specifically, the central conclusion of the Solow model is that the returns that capital commands in the market are a rough guide to its contributions to output for a significant part of worldwide economic growth or cross-country income differences.

AK Model

The AK model was the first version of the endogenous growth theory. AK models, as their name indicates, do not make an explicit distinction between capital accumulation and technological progress. The models lump together physical and human capital, whose accumulation is studied by neoclassical theory, with the intellectual capital that is accumulated when technological progress is made. When this aggregate of shades of capital is accumulated, there is no reason to think that diminishing returns will drag the marginal product of capital down to zero, because part of that accumulation is the very technological progress that is needed to counteract diminishing returns. According to the AK paradigm, the way to sustain high growth rates is to save a large fraction of the national income, some of which will find its way into financing a higher rate of technological progress and thus result in faster growth. Formally, the AK model is the neoclassical model without diminishing returns, and it presents a one-size-fits-all view of growth dynamics.

Product-Variety Model

The second wave of growth theories consists of innovation-based growth models, or endogenous models, which belong to two parallel branches, the product-variety model and Schumpeterian growth theory. In Romer's (1990) product-variety model, innovation causes productivity growth by creating new, but not necessarily improved, varieties of products. This paradigm grew from the new theory of international trade and emphasizes the role of technology spillovers. Per this model, the degree of product variety determines an economy's aggregate productivity, and the growth rate is the economy's long-run growth rate of per capita output. More product variety raises the economy's production potential, because it allows a given capital stock to be spread over many uses, each of which exhibits diminishing returns. Thus, increased product variety is what ultimately sustains growth in this model. New varieties, that is, new innovations, result from research and development investments by researchers—entrepreneurs who are motivated by the prospect of monopoly rents if they successfully innovate. The endogenous product-variety model, despite its limitations, can be used in various contexts where competition and turnover considerations are not paramount.

Schumpeterian Growth Theory

The final of the four main paradigms of economic growth is the other branch of innovation-based growth theory, developed by Aghion and Howitt (1992). This latest paradigm was born from modern industrial organization theory. It is commonly referred to as the Schumpeterian growth theory, because it focuses on quality-improving innovations that render old products obsolete, and hence involves the force that Schumpeter rightly called creative destruction. The first implication of the Schumpeterian model is that faster growth generally implies a higher rate of firm turnover, because the process of creative destruction generates the entry of new innovators and the exit of former innovators. Although the theory focuses on individual industries and explicitly analyzes the microeconomics of industrial competition, the assumption that all industries are ex ante identical gives it a simple aggregate structure. There are two main inputs to innovation in this model: private expenditures made by the prospective innovator, and the stock of innovations that have already been made by past innovators. The latter input represents the publicly available stock of knowledge to which current innovators are hoping to add. The theory is flexible enough in modeling the contribution of past innovations. It encompasses the case of innovation that leapfrogs the best old technology. It also encompasses the case of innovation that catches up to a global technology frontier, which represents the stock of global technological knowledge available to innovators in all sectors of all countries. In the former case, the country is making a leading-edge innovation that builds on and improves the leading-edge technology in its industry. In the latter case, the innovation is just implementing technologies that have already been developed elsewhere.

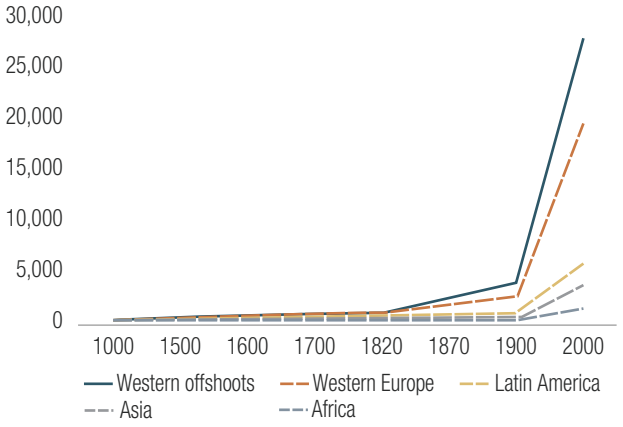
What Does History Reveal about Technology and Development?

Very few events have dramatically changed the course of human history more than the stream of inventions that began in the 18th century in the United Kingdom, from the steam engine, to electricity, the power loom, machine tools, and so forth. This period of unprecedented technological advancements led to a real Industrial Revolution, first gradually in Europe and later in North America. The effects of this revolution have reverberated throughout the years across the whole globe, from Latin America to Asia and Africa. The exact reasons for why this succession of breakthrough inventions occurred are not straightforward to explain, but perhaps were implicit in the events in the buildup toward industrialization.

Through a mix of good fortune and conscious efforts, by the early 18th century, Britain came to possess a unique combination of social needs and social resources that offered the necessary preconditions for commercially successful innovations and a social system capable of sustaining and institutionalizing the processes of rapid technological change once they had started. The list of sectors affected by those inventions is quite impressive: power technologies, metallurgy, mechanical engineering, textiles, chemicals, agriculture, civil engineering, transport and communications, military, and so forth. Figure 1.2 extends the income differences back to 1000 A.D. The figure shows that, going back in time, the gap among countries becomes smaller, emphasizing that the big divergence among countries took place over the past 200 years or so. Much evidence suggests that there was only limited economic growth before the 18th century. The major catalyst for the momentous change was undeniably the Industrial Revolution and the incredible amount of technological developments that came along with it, which ultimately affected many sectors.

Undoubtedly, the flagship feature of the entire Industrial Revolution was the fascinating advancement in power technologies. Prior to this period, the major sources of power available to industry were animate energy and the power of wind and water, with the only exception being the atmospheric steam engines that had been installed for pumping purposes, mainly

FIGURE 1.2: Evolution of per Capita GDP in Western Offshoots, Western Europe, Latin America, Asia, and Africa, 1000–2000



Source: The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.
Note: GDP = Gross Domestic Product. Values in 1990 International Geary-Khamis dollars. Western Offshoots = Australia, Canada, New Zealand and the United States.

in coal mines. It is important to stress that this use of steam power was exceptional and remained so for most industrial purposes until well into the 19th century. Steam did not simply replace other sources of power; it completely transformed them.

The same amount of scientific inquiry that led to the development of the steam engine was equally applied to the traditional sources of inanimate energy, with the consequence that waterwheels and windmills were drastically improved in design and efficiency. A legion of engineers contributed to the refinement of waterwheel construction. By the middle of the 19th century, new designs made possible increases in the speed of revolution of the waterwheel, thus paving the way for the emergence of the water turbine, which remains to date a very efficient device for converting energy.

Although the qualification of older sources of energy power is important, steam became the characteristic and ubiquitous power source of the British Industrial Revolution. Few developments took place previously until 1769, when James Watt patented a separate condenser. From that point onward, the steam engine underwent almost continuous improvements for more than a century. The Watt machine had an unparalleled impact in spearheading the early process of industrialization.

Perhaps the only other technology that had an impact that was equivalent to that of the steam engine was electricity. Electricity was developed by an international collection of scientists, including Benjamin Franklin of the United States, Alessandro Volta of Italy, and Michael Faraday of Britain. Later, French, German, Belgian, and Swiss engineers evolved the most satisfactory forms of the armature and ultimately produced the dynamo, which eventually made the large-scale generation of electricity commercially feasible. However, electricity does not constitute a prime mover, because however important it may be as a form of energy, electricity must be derived from a mechanical generator powered by water, steam, or internal combustion. The first successful internal combustion engine was invented by Etienne Lenoir in Paris, in 1859. The engine emerged as a result of greater scientific understanding of thermodynamics and a search by engineers for a substitute for steam power in certain circumstances.

Technological Breakthrough in One Sector Can Spill Over to All Sectors of the Economy

An industry that benefited greatly from the power revolution was that concerned with metallurgy and the metal trades. The development of new techniques for working with iron and steel was one of the outstanding British achievements of the Industrial Revolution. The main characteristic of this achievement was that changing the fuel of the iron and steel industry from charcoal to coal enormously increased the production of these metals. It also provided another incentive for coal production and made available the materials that were indispensable for the construction of steam engines and every other sophisticated form

of machines. All these innovations resulted from the fact that the British iron and steel industry was freed from its reliance on the forests as a source of charcoal and encouraged to move toward the major coalfields.

Abundant and cheap iron thus became an outstanding feature of the early stages of the Industrial Revolution in Britain. Cast iron was available for bridge construction, the framework of fireproof factories, and other civil engineering purposes. Closely linked with the iron and steel industry was the rise of mechanical engineering, brought about by the demand for steam engines and other large machines. Mechanical engineering took shape for the first time in Birmingham, where the skills of the precision engineer, developed in manufacturing scientific instruments and small arms, were first applied to the construction of large industrial machinery. The engineering workshops that matured in the 19th century played a vital part in the increasing mechanization of industry and transport. They not only delivered looms, locomotives, and other hardware in steadily growing quantities, but also transformed the machine tools on which these machines were made.

Perhaps more than any other, the industry that gave its character to the Industrial Revolution was the cotton-textile industry. The traditional dates of the Industrial Revolution bracket the period in which the processes of cotton manufacture in Britain were transformed from those of a small-scale domestic industry scattered over the towns and villages of the country into those of a large-scale, concentrated, power-driven, mechanized, factory-organized, urban industry. The transformation was dramatic for contemporaries and posterity, and there is no doubt about its immense significance in the overall pattern of British industrialization. The most far-reaching innovation in cotton manufacture was the introduction of steam power to drive carding machines, power looms, and printing machines.

In Britain, the growth of the textile industry brought a sudden increase of interest in the chemical industry, because one bottleneck in the production of textiles was the length of time the process of natural bleaching techniques took, relying on sunlight, rain, sour milk, and urine. The modern chemical industry was virtually called into being to develop more rapid bleaching techniques for the British cotton industry. For example, John Roebuck's invention of a method permitting the mass production of sulfuric acid in lead chambers effectively met the requirements of the cotton-textile industry. Thereafter, the chemical industry turned its attention to the needs of other industries, and particularly to the increasing demand for alkali in soap, glass, and a range of other manufacturing processes.

The agricultural improvements of the 18th century had been promoted by people whose industrial and commercial interests made them willing to experiment with new machines and processes to improve the productivity of their estates. Under the same sort of stimuli, agricultural improvement continued into the 19th century and was extended to food processing in Britain and elsewhere. The steam engine was not readily adapted for agricultural purposes, yet ways were found to harness it to threshing machines and even plows, by means of a cable between powerful traction engines pulling a plow across a field. In the United States, the mechanization of agriculture began later than in Britain, but, because of the comparative labor shortage, it proceeded more quickly and more thoroughly. The combine harvester was developed in the United States, as were barbed wire and the food-packing and canning industries. Later, the introduction of refrigeration techniques in the second half of the 19th century made it possible to convey meat from Australia and Argentina to European markets. The same markets encouraged the growth of dairy farming and market gardening, with distant producers such as New Zealand able to send their butter in refrigerated ships to wherever in the world it could be sold.

Another sector that heavily benefited from the new innovations of the 18th and 19th centuries was civil engineering. Throughout this period, for large engineering works, the heavy work of moving earth

continued to depend on human labor organized by building contractors. The use of gunpowder, dynamite, and steam diggers helped to reduce this dependence toward the end of the 19th century, and the introduction of compressed air and hydraulic tools also contributed to the lightening of drudgery. The latter two inventions were important in other respects, such as in mining engineering and the operation of lifts, lock gates, and cranes. The use of tunneling shields and the introduction of the iron bell and other inventions helped civil engineering achieve some monumental successes, especially in the design of dams, which improved considerably in the period, and in long-distance piping and pumping.

Other prominent sectors of the Industrial Revolution were transport and communications and, to a large degree, the military. The former represents an example of a revolution within the Industrial Revolution, so completely were the modes transformed during 1750–1900. The first improvements in Britain occurred in building roads and canals in the second half of the 18th century. The evolution of the railroad involved the combination of the steam locomotive and a permanent travel path of metal rails. The first fully timetabled railway service with scheduled freight and passenger traffic relying entirely on the steam locomotive for traction was opened in 1830, between Liverpool and Manchester. The opening of this line may fairly be regarded as the inauguration of the railway era, which continued until World War I. During this period, railways were built across all the continents, opening vast areas of the markets of industrial society.

Locomotives rapidly increased in size and power and laid the ground for spurring trade. Steamboats and ships also massively benefited from the steam engine, as it transformed marine transport forever. The first commercial success in steam propulsion for a ship was that of the American Robert Fulton, whose paddle steamer was equipped with a Boulton and Watt engine. By the end of the 19th century, steamships were well on the way to displacing the sailing ship on all the main trade routes of the world. In communication technologies, printing, photography, telegraphs, and telephones inexorably drew the world into a closer community by the spread of instantaneous communication. Finally, the military was also largely influenced by the new innovations, albeit not as dramatically as transport or communication. Although armies increased in size between 1750 and 1900, there were few innovations in techniques, except at sea, where naval architecture rather reluctantly accepted the advent of the iron steamship and devoted itself to matching ever-increasing firepower with the strength of the armor plating on the hulls. The quality of artillery and firearms improved with the new high explosives that became available. Railroads and the electric telegraph were put to effective military use but, in general, the 19th century put remarkably little of its tremendous and innovative technological effort into devices for war.

Technological Innovation Has No Border

Experiences from the United States

Although the industrial revolution started in the United Kingdom, the United States is unquestionably the most technologically advanced nation. Despite having only 4.3 percent of the world's population, Americans hold almost 40 percent of the world's total wealth and rank among the highest in productivity. Although early technology may have been adopted from the Industrial Revolution, the process that propelled the United States to the forefront of innovation was the result of more than two centuries of investments in human and physical capital.

Many factors contributed to the rapid industrialization in the United States: the availability of vast lands and literate labor, the absence of a landed aristocracy unlike in parts of Europe at the time, the high prestige of entrepreneurship, the large diversity of climate, and the upscale free markets. The availability of capital, development of navigable rivers and coastal waterways,

and abundance of natural resources facilitated the very cheap extraction of energy, which largely contributed to fast industrialization. Thanks to the large railway and highway systems, successively built in the 19th and 20th centuries, internal markets were enlarged, and shipping and production costs were sensibly reduced. In addition to physical factors, nonmaterial factors, such as the strict legal system, facilitated business operations and guaranteed contracts. Science also played an important role in supporting the national efforts of innovation and development. Consequently, the United States was the birthplace of almost 50 percent of *Britannica's Greatest Inventions*, spanning items such as the airplane, Internet, microchip, laser, cell phone, refrigerator, e-mail, microwave, personal computer, air conditioning, assembly line, bar code, and much more.

The early technological and industrial development in the United States was facilitated by a unique confluence of geographical, social, and economic factors. After the American Revolution, the new government continued the strong property rights established under British rule and established the rule of law necessary to protect those property rights. The idea of issuing patents was incorporated into the Constitution, authorizing the promotion of the progress of science and useful arts, by securing for limited times to authors and inventors the exclusive right to their respective writings and discoveries. An American's invention of the cotton gin made cotton a cheap and readily available resource in the United States for use in the new textile industry. Modern productivity researchers have shown that the period in which the greatest economic and technological progress occurred in the United States was between the last half of the 19th century and the first half of the 20th century. During this period, the nation was transformed from an agricultural economy to the foremost industrial power in the world, with more than a third of global industrial output.

The American colonies gained independence in 1783, as profound changes in industrial production and coordination were beginning to shift production from artisans to factories. The growth of the nation's transportation infrastructure, with internal improvements and a confluence of technological innovations before the Civil War, facilitated an expansion of the organization, coordination, and scale of industrial production. Around the turn of the 20th century, American industry had superseded European industry. Science, technology, and industry have not only profoundly shaped America's economic success, but also contributed to its distinct political institutions, social structure, education system, and cultural identity.

Experiences from Emerging Countries

Brazil and India belong to a group of five major emerging economies, often labeled by the acronym BRICS for Brazil, the Russian Federation, India, China, and South Africa. All five countries are leading developing or newly industrialized countries. As of 2015, the five BRICS countries together accounted for over 40 percent of the world's population, with a combined gross domestic product (GDP) of US$16.6 trillion, the equivalent of 22 percent of the world's GDP. Among the BRICS, Brazil and India share many historical and climate similarities with the African continent.

India

India was colonized, like most of the African countries. Although British colonial rule created an institutional environment that stabilized law and order, the colonial episode in India is commonly seen as having been mostly detrimental to the country. The infrastructure the British created (railways, telegraphs, and a modern legal system) was primarily geared toward the exploitation of resources, just like in most of Africa. Per Angus Maddison (2006), India's share of the world's income went from 27 percent in 1700 to 3 percent in 1950. Many modern economic historians blame colonial rule for the dismal state of India's post-independence economy.

After independence, India, like many developing countries, adopted a socialist-inspired economic model. The economy was heavily centralized and regimented by five-year plans. This approach hindered growth and development for several decades, while neighboring countries (the Republic of Korea; Taiwan, China; and others) were flying with double-digit growth rates. Around the early 1990s, India started embracing deep and structural economic reforms, with the objective of making the country more market- and service-oriented while expanding the role of private and foreign investment. The Indian government massively cut import tariffs, deregulated markets, reduced corporate taxes, and robustly attracted more foreign direct investment (FDI). Thus, the country embarked on an unprecedented path of growth and development, with the peak of the GDP growth reaching 9.6 percent in 2006. Today, the Indian economy is the seventh largest by nominal GDP and third largest by purchasing power parity.

Brazil

Brazil followed a course that was different from India's. A former Portuguese colony, Brazil gained full independence in 1822. The real structural transformations of the country's economy took place in the 20th century, around 1930. In the 19th century, slavery was still in full effect and was only abolished in 1888. Most of the slaves, originally from West Africa, were used in the sugar industry (plantations and factories).

Until the early 17th century, the Portuguese and Dutch held a virtual monopoly over Brazil's sugar exports to Europe. Initially, the Caribbean sugar boom reduced that monopoly. But at the same time, it brought about a steady decline in sugar prices globally, forcing Brazil to reduce its overreliance on a single export commodity. Exports moved from cattle to coffee, in an effort at diversification spanning several decades. Brazil was among many countries to experiment with import substitution industrialization after World War II, with mixed results. The performance of the export sector, for example, improved only modestly.

A degree of industrialization was achieved, but growth was not always sustained and consistent, often disrupted by social and political tensions. However, the industrial sector grew more rapidly than the agriculture sector, and traditional industries such as textiles, food products, and clothing declined, while the transport equipment, machinery, electric equipment and appliances, and chemical industries expanded. The strategy left behind a plethora of problems. The kind of growth it promoted resulted in a substantial increase in imports, notably of inputs and machinery, and the foreign-exchange policies of that period meant inadequate export growth. Moreover, a large influx of foreign capital in the 1950s resulted in a large foreign debt. The subsequent decades alternated between periods of steady stagnation and periods of spectacular growth, with some episodes of deep crises. Currently, following a boom at the end of the previous decade, the Brazilian economy is perhaps at the end of many episodes of contractions and recessions. Nonetheless, Brazil is the ninth largest economy by nominal GDP, and the eighth largest by purchasing power parity, and is somehow much more inward-oriented than the rest of the BRICS countries.

III. Africa Leapfrogging through Innovation: Opportunities for Investments

It can be inferred from theory and historical evidence that Africa can transform through innovation and technology adoption. However, the change will require major disruption in the way business is conducted across various sectors.

All around the world, the most successful entrepreneurs have come up with solutions to problems that crop up around them. In each problem, constraint, or challenge, these innovators see opportunities. Unfortunately, the same constraints in Africa are often pointed out as the reasons why many things are stalling. Several factors, like the level of skills, service

delivery, and poor infrastructure, are considered to be constraints to attracting investments in productive sectors. To solve Africa's challenges, this book argues that those constraints must be viewed as investment opportunities. This is precisely how Africa will gradually see more innovation toward prosperity.

Technological upgrading absolutely requires a set of preexisting physical and institutional infrastructure to support it (Acemoglu 2009). Both of those have been and continue to be in short supply in Africa, and must be the focus for innovative investment. Incidentally, research shows that FDI and trade are two of the most important channels for international diffusion of knowledge and technologies (Keller 2004). Trade embodies the mobility of new goods that are horizontally or vertically differentiated with embedded technologies (Aghion and Howitt, 2009; Romer 1990). Various studies show the relationship between the speed of technology diffusion and the overall volume of goods and services exchanged. Markusen (1989), Verspagen and Wakelin (1997), and Keller (1998) analyze the impact of technology diffusion on imports of intermediary goods. Syrquin and Chenery (1989) and Sachs and Warner (1997) find a positive and significant impact of trade on technology diffusion and economic growth.

With FDI, three types of effects on local economies are often mentioned: improvement of local firms' technical efficiency by observing the best practices of foreign multinationals; renewed competitiveness, as a direct result of the competition between local firms and foreign multinationals; and mobility of the skilled labor force from foreign multinationals to local economies (Gorg and Strobl 2001). Branstetter (2000) provides further evidence for the knowledge transfer from multinationals to local economies. Often overlooked is the role of international collaboration between upstream innovating firms from developed countries and downstream adopting firms in developing economies. Such collaboration could take various forms, including subsidiaries, joint ventures, mergers, and licensing. Buying licenses represents a particularly efficient approach in knowledge transmission (Branstetter 2006; Kortum 1997).

Once constraints are turned into investment opportunities, there would be potentially countless win-win relations and an alignment between Africa's development and investors' quest for high returns. This book illustrates this point with a brief assessment of the following six key sectors.

Energy

According to the World Bank, altogether the countries of Sub-Saharan Africa generate roughly the same amount of power as Spain. Nearly two-thirds of the people in Sub-Saharan Africa live without electricity, and an even larger share must rely on biomass as the main fuel for cooking (World Bank 2017b). Without radically increased energy production, it will be difficult for Sub-Saharan Africa to achieve the Sustainable Development Goals for energy, including to "ensure universal access to affordable, reliable, and modern energy services" by 2030. The lack of grid and off-grid electricity results in increased use of kerosene, candles, wood, and coal for cooking and lighting. This has serious health, safety, environmental, and socioeconomic consequences and disproportionally impacts women and children (Mills 2016).

The paradox in Sub-Saharan Africa's energy sector is that there are abundant low-carbon and low-cost energy resources (Eberhard et al. 2011). The biggest potential energy source is water. Over 90 percent of Africa's economically viable hydropower potential, equivalent to about one-tenth of the world total, is unexploited (Eberhard et al. 2011). Per BP's estimation, hydroelectric accounted only for 13 percent of primary energy consumption in the region in 2016.[1] The energy sector in Africa demonstrates huge investment opportunities for unlocking the potential of the sector and contributing to the development of the continent.

Finance

Another area where Africa seriously lags is the constraint to credit and financial resources (Stein 2013). Financial development is rightly regarded as a centerpiece in the debate on how to foster growth in developing countries and reduce stark poverty levels. There is ample evidence over the past couple years to confirm the notion that financial development is indeed growth enhancing, especially in developing countries. Improving access to credit and financial deepening help especially those industries that are more dependent on external finance, and help to reduce financing constraints, particularly for smaller firms. Financial deepening has a transformative effect on economies, shaping the industrial structure, firm size distribution, and even organizational structures.

Given the crucial importance of credit and finance for economic development, the staggering superficiality of African finance is an understatement. African financial sectors are very small in absolute and relative terms. With a few exceptions, such as Mauritius, South Africa, and a handful of offshore financial centers, financial systems in Sub-Saharan Africa are among the smallest in the world. A small financial system is often correlated with productivity and skill shortages, and prevents banks from exploiting economies of scale that otherwise would have been possible. Additionally, small size deters many banks from undertaking large investments in technology and innovation. The opportunities for innovative investment in the financial sector in Africa are numerous, and should account for the local context.

The success of M-Pesa in Kenya demonstrates how innovative investment can help the continent to leapfrog in the sector. The continent's national and regional financial systems are characterized by limited outreach, with less than one in five households having access to any formal banking service, from savings to payments and credit. Seven in 10 adults in Kenya use M-Pesa, making millions of transactions daily. The service has become a popular alternative to cash for many businesses and government agencies, and has contributed to drastically improving financial inclusion in Kenya.

Education and Skills

Together with the infrastructure deficit and poor financial development, shortcomings in education, skills, and knowledge transmission constitute an obstacle to sustained growth and technological development in Africa. The importance of human capital in fostering growth, empirically and theoretically, cannot be overemphasized. Generations of engineers and skilled journeymen from Britain to China made the Industrial Revolution possible and helped innovation and economic development become a universal reality. Although school enrollment has greatly improved in Africa in recent years, it remains the lowest by any measure compared with the rest of the world. In 2014, only 57 percent of African children were enrolled in primary schools, with a great gender imbalance in favor of boys (UNESCO 2014). There is much hope in Africa that the fourth goal of the Sustainable Development Goals, which aims at ensuring inclusive, quality education and promoting lifelong learning opportunities for all, could bring about more success than all previous attempts. Equally, investing in more vocational training, revamping educational systems to adapt them to the countries' needs, and giving a greater role to local languages, at least in primary education, are all needed to improve knowledge creation and skills transmission in Africa.

Agriculture

Other constraints on technological development and adoption in Africa result from the attitudes of local entrepreneurs, consumers, farmers, and others toward risk and uncertainty (Adesina and Baidu-Forson 1995; Adhvaryu 2014; Fafchamps and Soderbom 2013; Lambrecht et al. 2014). These attitudes come from

the high degree of risk aversion and highlight the crucial importance for national governments to provide enough financial guaranties to push farmers and others to adopt new technologies. Insurance schemes are very poorly developed in Africa, suggesting that to adopt new technologies many entrepreneurs on the continent rely on their own private resources. In agriculture, a sector plagued by potential droughts and other natural risks, a coherent and comprehensive insurance mechanism would boost the adoption of improved technologies, as recently shown by Carter, Cheng, and Sarris (2016).

As Africa grapples with the challenges of sustaining high levels of economic growth, plunging commodity prices, and the effects of climate change, revitalizing key economic sectors (especially agriculture) must become a top priority. A dynamic, vibrant, sustainable, and resilient agriculture sector is vital for Sub-Saharan Africa's economic future, as the sector has been shown to be two to four times more effective than other sectors in raising the incomes among the poorest people (Kijima, Otsuka, and Sserunkuuma 2011; Benin 2016). Agriculture in Sub-Saharan Africa stands at the cusp of transformational change, and the evidence is compelling. Farming represents the primary source of income for food for people and provides up to 60 percent of all jobs on the continent (ILO 2013). The continent is bursting with untapped potential: with 200 million hectares, Sub-Saharan Africa is home to nearly half of the world's uncultivated lands that can be effectively tapped for production. Africa only uses 2 percent of its renewable water resources, compared with 5 percent globally.

Together with abundant resources, including a resourceful, enterprising youth population, strategic investments in agriculture can unleash virtuous growth cycles. Farmers in Africa especially need new technologies (such as higher-yielding, more resilient food crops) that could deliver bountiful harvests. They also need more access to electricity, more irrigation, and better physical infrastructure linking them to lucrative food markets. The agriculture sector in Africa equally needs to account for women. Women produce much of the food on the continent, and yet they are largely locked out of land ownership, access to credit, and productive farm inputs, such as fertilizers, pesticides, and farming tools.

Information and Communications Technology

Despite the many challenges ahead, there are a few examples of technological adoption in Africa. Prominent among them is the exponential growth of mobile phones in recent years. Mobile phones will account for almost one-tenth of Africa's GDP by the end of this decade, which underscores how the explosive growth in the telecom industry is having major economic, social, and even political transformational effects. The extraordinary rate at which the mobile phone industry has grown across the continent over the past decade and a half is almost unique, and this growth is expected to be even faster through 2020 and beyond. As handsets and data become more affordable, greater accessibility to mobile phones (which have by far outpaced other forms of communications infrastructure on the continent) is changing the way in which public services are delivered, and how business and politics are being conducted. In part, because the old state-run, fixed-line telephone companies were inefficient monopolies, many in Africa took up mobile phones with great enthusiasm at the start of the past decade. There are now more mobile phones than adults in most African countries. In recent years, the rise of mobile phone access has acted as a new game-changer, bringing many online who do not have access to desktop machines or fixed-line broadband. This exponential growth has fueled a parallel expansion in the number of innovators and entrepreneurs looking to ride the mobile wave, and opened an array of uses for mobiles in areas such as business, health care, and education. The spillover effects of the use of mobile phones on other sectors have been substantial, and the best may be yet to come.

The continent now needs to improve digital literacy and increase Internet penetration by making it more accessible, better, and more affordable. The combination of reliable and cheap Internet with the already strong phone base could help propel the continent to new heights, as well as reduce the digital divide with the rest of the world.

Governance

The potential of digital technologies for improving governance has been recognized for quite some time. Information and communications technology (ICT) may affect democratization and democratic governance, macroeconomic and public-sector management, and agriculture and environmental management. However, the digital divide between Africa and the rest of the world has been identified as a major barrier to the application of digital technologies for governance. The impact of ICT on governance will be limited without the consideration of human factors. Heeks (2002) points out that African governments have been using information technology for more than four decades and progress in the use of ICT for governance should be seen as evolutionary rather than revolutionary.

The digital divide across and within countries can result in those better provisioned with ICT having a greater influence on and use of e-government (World Bank 2017b). Designing public services for a wide audience and a variety of ICT can mitigate this. In Kenya, for example, the government partnered with mobile operators to support an application that works on older model cellphone to communicate with citizens living in remote areas without access to the latest technologies (Turianskyi and Gruzd 2016). In governance, there are many investment opportunities that could be implemented through public-private partnerships, and deploy electronic public services for citizens and businesses.

Endnote

1 http://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/downloads.html.

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AGRICULTURE

2 AGRICULTURE

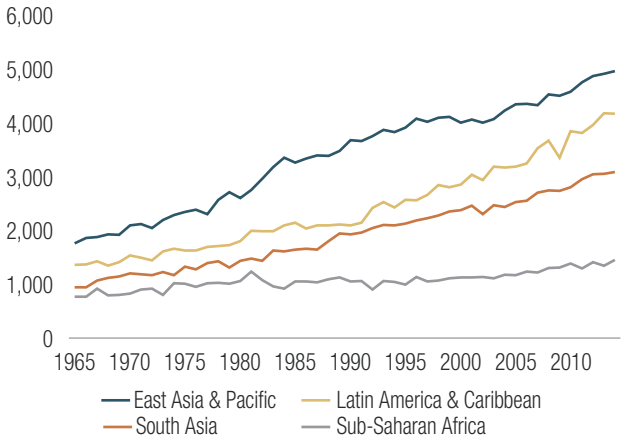
I. THE NEED TO FEED THE CONTINENT

More than 60 percent of Africa's population lives in rural areas, making the region's economy intrinsically dependent on agriculture. Around a third of the continent's gross domestic product (GDP) is generated by the sector. However, agricultural productivity remains far below that in other regions (figure 2.1). Over 90 percent of African agriculture depends on rainfall with no irrigation. The techniques used to cultivate the soil are behind those in other developing regions, lacking not only irrigation, but also fertilizers, pesticides, and high-yield seeds. Agriculture in Africa also experiences problems such as access to markets and financing. Despite its tremendous agricultural potential, Africa is a net importer of food due to population growth, low and stagnating agricultural productivity, policy distortions, weak institutions, and poor infrastructure (Rakotoarisoa, Iafrate, and Paschali 2011). These barriers are inhibiting the continent's ability to achieve food security.

There is a strong link between agricultural growth and poverty reduction.[1] A regression analysis covering 25 developing countries finds that although economic growth was an important contributor to a decrease in poverty, the sector mix of growth mattered substantially, with growth in agricultural incomes being especially important (Cervantes-Godoy and Dewbre 2010).

Most Sub-Saharan African agriculture consists of small shareholdings (figure 2.2) (FAO 2012).[2] Due to the unique nature of the region's agriculture sector—small shareholdings and distinctive agroecology—transformational changes will require solutions beyond the so-called Asian Green Revolution[3] epitomized by the intensive application of high-yield seeds, fertilizer, pesticides, and irrigation (World Bank 2008). Further, the application of Green Revolution principles may not always be pro-poor, and should be subject to rigorous impact assessments that take into account land tenure, agricultural practices, and social differences (Dawson, Martin, and Sikor 2016).

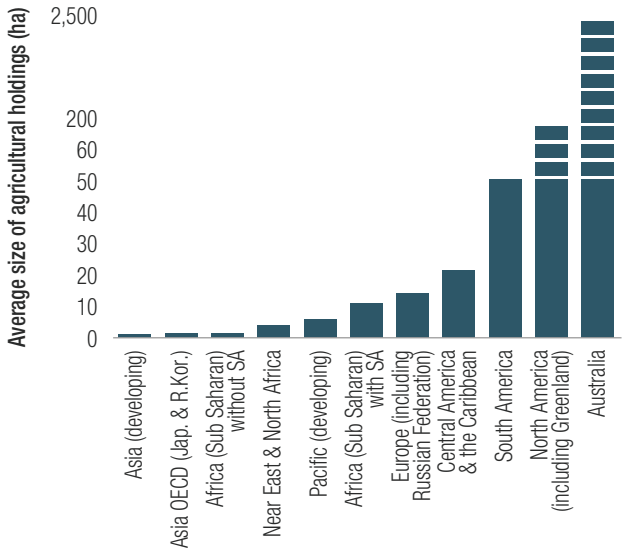
FIGURE 2.1: Cereal Yield (kilograms per hectare)



Source: World Bank.

Solutions for raising agricultural productivity in Africa are influenced by the shifting relationship between technology adoption and sustainable farming and the influence of various interest groups. Several factors

FIGURE 2.2: Average Size of Agricultural Holdings (hectares)



Source: FAO 2012.

affect technology adoption, including the application of biological, chemical, and mechanical methods (such as inputs and assets); farmer knowledge; the agriculture value chain; and technologies emerging from outside the farm sector (OECD 2000). Sustainable farming reflects the capacity to generate sufficient food in an economically efficient, socially responsible, and environmentally sound way.

There are various perspectives on the sustainability of technologies, depending on whether it is at the farm level, within the agribusiness sector, or from the lens of the national, regional, or global economy. Sustainability concerns are rising in areas such as food-related illness (including genetically modified organisms), environmental impacts (for example, pesticide use), and animal welfare (Tanentzap et al. 2015). Increased use of food crops for biofuel can have serious implications for food security (FAO 2009). Governments face challenges in aligning the private interests of agricultural businesses with the public interests of small farms and concerned citizens. Added to this mix is the growing impact of climate change on weather patterns affecting Africa's agriculture sector.[4]

In Zambia, drought magnified by climate change has dried up dams, severely affecting hydroelectric power in the country (Onishi 2016) and contributing to crop failure and rising food prices (Kaunda 2017). With the right supportive environment, sustainable intensification of agriculture in Africa can produce higher yields, boost income for farmers, and regenerate natural capital (GO-Science 2014).

Agriculture forms part of a rural ecosystem where diversification opportunities can enhance sustainability, increase incomes, and generate employment. Experience from other regions suggests that as agricultural productivity rises, workers move to urban areas to seek jobs in other sectors. Given the continent's low proportion of manufacturing and industry and challenges with rapidly growing urbanization, an alternative strategy is to enhance the rural economy. This includes widening the product mix of single-crop farmers, expanding agriculture value chains, and developing rural tourism.

High-value, nontraditional crops can supplement farmers' income, with significant potential for exports (Temu and Temu 2005). Kenya's horticulture subsector is a leading foreign exchange earner, generating around US$1 billion a year, and it is the top flower exporter to the European Union; production increased from 10,946 tons in 1988 to 133,658 tons in 2016.[5] An entrepreneur benefitting from the Mali Agricultural Competitiveness and Diversification Project was able to acquire two high-capacity mango processors that tripled output, which enabled the business to export to Europe (World Bank 2015a).

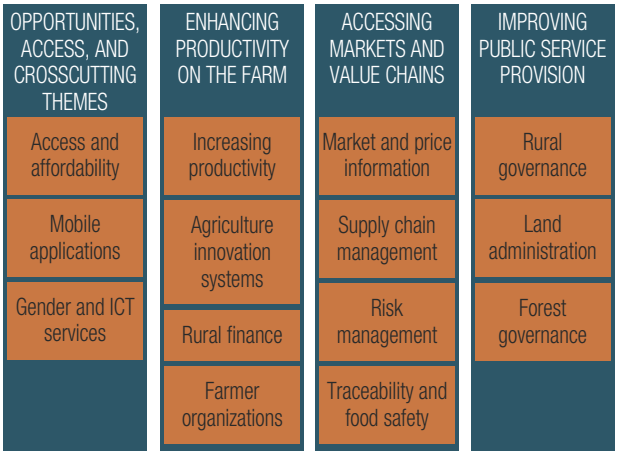
Links between informal value chains in rural areas and agribusiness generate jobs and opportunities for smallholder farmers (Byerlee et al. 2013). South Africa launched a rural tourism strategy to promote equal access to tourism opportunities, noting that the country's prime tourist attractions were not located in cities, but rather in rural areas, including poverty-stricken areas with world heritage sites (South Africa

Department of Tourism 2012). A survey among the indigenous population living in the Ngorongoro Conservation Area in Tanzania, where livestock is the primary economic activity, found that 39 percent of the population was also involved in tourism (Melita and Mendlinger 2013). The survey respondents reported that tourism was a reliable source of income compared with other activities, and provided extra income for food and education expenses.

Digital technologies have emerged with notable impacts on agriculture and rural livelihoods. Unlike direct inputs, such as seed, irrigation, fertilizers, or pesticides, digital technologies raise agricultural productivity and rural incomes through their effects in areas such as finance, crop and weather monitoring, animal control, markets, and farmer education. Digital technologies include mobile phone applications,[6] sensors,[7] satellites,[8] radio frequency identification devices,[9] big data,[10] drones,[11] and so forth. The application of these tools can be categorized across four domains critical for rural livelihoods: opportunities, access, and cross-cutting themes; enhancing productivity on the farm; accessing markets and value chains and improving public service provision (figure 2.3). The cost of digital technologies has dropped, making them increasingly feasible for African farming (Ekekwe 2017). An analysis of social enterprises operating across East Africa finds that technology is a key enabler for entrepreneurs involved in agriculture, lowering transaction costs and enabling scale through the provision of information and finance, collectivizing smallholders, and providing market links (Intellecap 2016).

The Comprehensive Africa Agriculture Development Programme (CAADP) is Africa's framework for agriculture sector transformation.[12] Ratified in 2003 in Maputo, Mozambique, the resulting declaration[13] called for at least 10 percent of government spending to be allocated to agriculture and rural development, and sector growth to reach an annual average rate of 6 percent. Although most countries have increased

FIGURE 2.3: ICT Applications in Agricultural Domains



Source: World Bank 2017.
Note: ICT = information and communications technology.

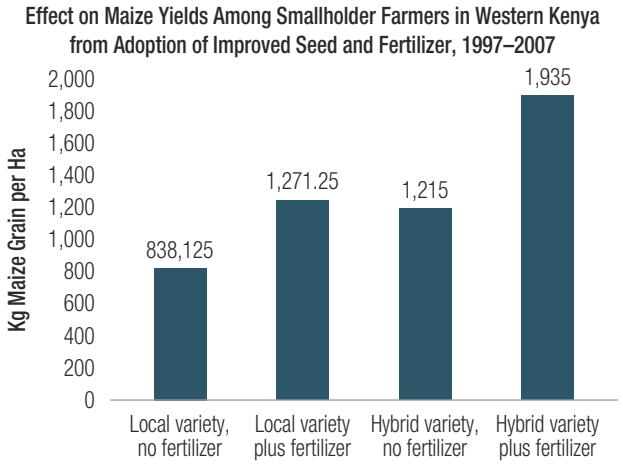
funding for agriculture since then, only five reached the CAADP target during 2008–14. Agriculture sector growth in Africa increased at 3.8 percent a year between 2003 and 2008. Several countries surpassed the 6 percent target during different periods and 15 did so during 2008–14 (AGRA 2016).

II. Micro Jumps

Agricultural leapfrogging examples are difficult to quantify at a macro level. This is because a notable improvement in productivity is often related to a specific crop and not necessarily translated into nationwide agricultural advances. Similarly, a rise in agricultural output may not affect overall incomes in the rural sector. For example, although the value of crops in Zambia has risen over 50 percent in the past decade, the increase was mainly due to subsidies received by large farms.[14] Bearing those limitations in mind, several examples of rapid productivity gains have positively affected welfare.

The Alliance for a Green Revolution in Africa (AGRA), a partnership between the Rockefeller Foundation

FIGURE 2.4: Maize Yields in Western Kenya



Source: AGRA's Program for Africa's Seed Systems (PASS): Strengthening Public Crop Genetic Improvement and Private Input Supply Across Africa.
Note: ha = hectare; kg = kilogram.

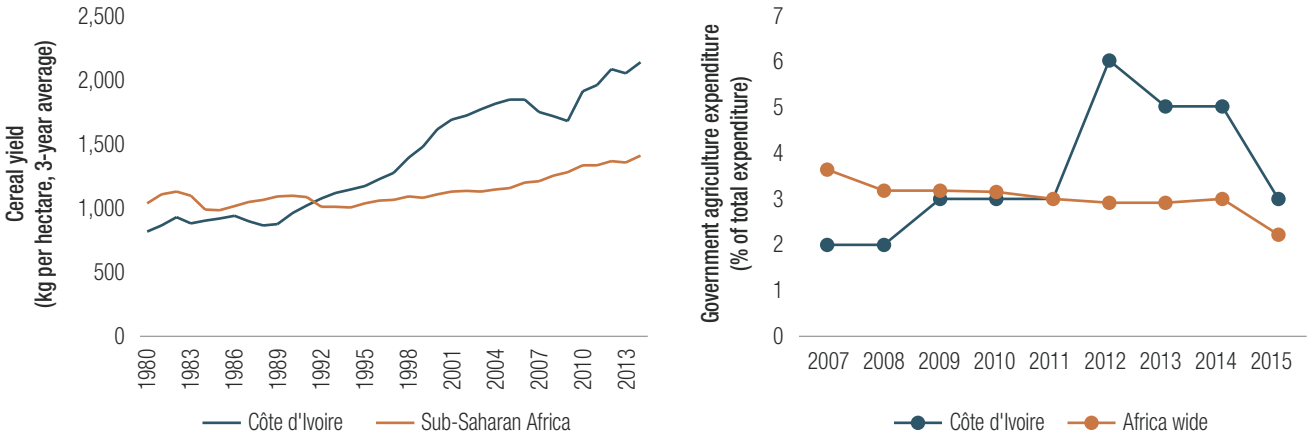
and the Bill & Melinda Gates Foundation founded in 2006, has supported hundreds of initiatives to help small shareholding farmers. One area of notable success is AGRA's program for seeds, which is especially relevant given the impact (along with fertilizer) of seeds on agricultural productivity (figure 2.4). AGRA has invested US$100 million in African seed businesses, working with more than 100 companies, representing about a third of the market. They produced around 125,000 tons of improved seed in 2015, up almost 400 percent from 2010. As a result, corn yields have doubled in the 18 African countries where AGRA works (Gebre 2016.) According to AGRA, the 57,000 tons of improved seed produced in 2012 catalyzed yields of 5.7 million metric tons of additional food, enough to feed 34 million people.[15] AGRA plans to invest US$500 million over the next five years in seed businesses, adopting principles similar to startup ecosystems by acting as an angel investor with investments in the range of US$150,000 and working closely with entrepreneurs.

Côte d'Ivoire has generated interest because its cereal yields have increased, surpassing two metric tons per hectare (t/ha) in 2010.[16] This increase is perceived as evidence of a Green Revolution, given that historically yields over 2 t/ha mark a threshold followed by sustained agricultural productivity (McArthur and McCord 2017). Cereal yields in the country increased by more than a third between 2007 and 2014. The rise in yields coincided with the end of civil war in the country in 2007 (although there was a second outbreak in 2011, it lasted less than six months). The resulting political stability expanded the area under cultivation. Another factor was a large increase in government spending, resulting from the 2010–15 National Agricultural Investment Program. Government agricultural expenditures rose from 2 percent of total spending in 2007 to a peak of 6 percent in 2012 (figure 2.5). The increase included funding for rural infrastructure and farmer training programs; there was also better seed and greater availability of fertilizer. Rice is a popular food item in the country, accounting for over half of domestic cereal production. The rise in rice yields has made rural areas self-sufficient; urban areas continue to rely on rice imports to supplement domestic production.[17, 18]

Other African countries have surpassed cereal yields of two metric tons; in two countries—Ethiopia and Rwanda—agricultural growth has been a main driver of poverty reduction (Veras 2017). Rwanda focused agricultural production on staple crops to replace imports and enhance food security in the country. The government's crop intensification program reduced seed and fertilizer costs for farmers.[19] Fertilizer use more than doubled, from 18 percent in 2005–06 to 38 percent in 2010–11; average sales of agricultural output rose from 18 to 25 percent. This helped drive GDP growth, raising per capita income by 62 percent, from US$333 to US$540 during the period and driving the poverty rate down from 57 to 45 percent (Kalibata and Roy 2015). According to the World Bank, 45 percent of poverty reduction in Rwanda over that period can be attributed directly to agriculture (World Bank 2013).

Cereal production tripled in Ethiopia between 2000 and 2014 (*The Economist* 2016). According to the

FIGURE 2.5: Cereal Production and Government Agricultural Expenditure, Côte d' Ivoire



Source: Adapted from World Bank and ReSAKSS (Regional Strategic Analysis and Knowledge Support System).
Note: kg = kilogram.

World Bank, poverty in Ethiopia has dropped by 33 percent since 2000, with agricultural GDP growth near 10 percent per year (World Bank 2015b). An analysis of the cereal growth reveals that it was mainly driven by acreage expansion rather than inputs (Taffesse 2008). One exception was teff, a grain that is a main ingredient of the country's popular injera bread. Teff's rapid spread is attributed to a range of factors, including demonstration plots, seed loans, and training; informal networking to share information about production techniques was also important (GO-Science 2014).

TABLE 2.1: Summary of Productivity Outcomes from Case Studies

Thematic focus	Area improved (ha)	Mean yield increased (ratio)	Net multiplicative increase in food production (1,000 tonnes/year)
Crop variety and system improvements	391,060	2.18	292
Agroforestry and soil conservation	3,385,000	1.96	747
Conservation agriculture	26,057	2.20	11
Integrated pest management	3,327,000	2.24	1,418
Horticulture and very small-scale agriculture	510	n.d.	n.d.
Livestock and fodder crops	303,025	n.d.	n.d.
Novel regional and national partnerships and policies	5,319,840	2.05	3,318
Aquaculture	523	n.d.	n.d.
Total	12,753,000	2.13	5,786

Source: GO-Science 2014.
Note: ha = hectare; n.d. = no data.

Box 2.1: Irrigation Project in Western Kenya

Lack of irrigation is often cited as one of the shortcomings of African agriculture. This is being overcome in western Kenya through a water conservancy and irrigation project located in Homa Bay County beside Lake Victoria. The densely populated region, home to many small-scale cereal farmers, has unreliable rainfall, experiencing frequent crop failures. The aims of the Kimira Oluch Small Holder Farm Improvement Project are to reduce reliance on rainfall, improve agricultural productivity, decrease poverty, and improve the living standards of small farmers (African Development Fund 2006).

The Government of Kenya and the African Development Fund jointly funded the project. Sino Hydro, a Chinese construction firm, was contracted by the Ministry of Regional Development Authorities to build gravity-fed irrigation channels along two rivers. Phase I was completed in 2011. Because of the project, farmland is now under irrigation and there is a reliable source of drinking water for local people and livestock. The irrigation scheme also offers an opportunity for farmers to diversify production by providing water for grain, fruit, and vegetable cultivation; fish breeding; and other activities.

An analysis of sustainable agricultural processes across 20 African countries between the 1990s and the 2000s finds productivity gains via two pathways (GO-Science 2014). *Multiplicative* increases result from the use of new and improved varieties and improved management practices. *Additive* benefits accrue by diversifying into new crops and livestock. These techniques and practices have resulted in increased yields (table 2.1). The analysis also finds that the adoption of more than one practice produced cumulative gains through synergies, resulting in higher yields compared with single applications such as just fertilizer or irrigation. For instance, decision makers often view increased irrigation as a general panacea for boosting crop production in dry lands, but restoring soil health alongside the effective use of rainwater may be a more cost-effective and sustainable option (FAO 2011). Box 2.1 presents an example of an irrigation project in Western Kenya.

III. Conditions for Agricultural Leapfrogging

Several areas require attention to create the necessary preconditions for agricultural leapfrogging in Africa.

Research and development (R&D) is essential for developing and adapting new technologies and is positively associated with high returns (Stads and Bientema 2015). While investment in agricultural R&D tripled in China and India over the past 20 years, it increased by barely a fifth in Sub-Saharan Africa (and declined in about half the region's countries) (World Bank 2007). In 2011, public and private agricultural investment in Sub-Saharan Africa was just 4 percent of the world total, down from 6.1 percent three decades earlier (Pardey et al. 2016). Around 40 percent of African countries spent less on agricultural R&D in 2011 than they did in 1980. In small African countries, it is difficult to benefit from economies of scale in R&D, making regional collaboration essential. International technology transfer is limited due to the unique African agroecological environment, placing even more importance on national R&D efforts. Shortages of skilled researchers are exasperated by the retirement and departure of experienced scientists. More resources need to be devoted to capacity building (Nienke and Stads 2011). The volatile nature of African funding for agricultural R&D reflects the limited government funding and dependence on irregular development partner assistance. African governments need to design coherent R&D programs and commit sufficient

funding while ensuring that donor funding is aligned with strategies.

Similar to other sectors, a growing number of advances in African agriculture are emerging from *entrepreneurial innovation ecosystems*. A new breed of young "agripreneurs" is emerging, applying digital technologies and principles from startup ecosystems to enhance agricultural processes.[20] Local entrepreneurs have a better understanding of their rural context, giving them an advantage over large multinationals. Further, local entrepreneurs are more suited for surmounting challenges such as fragmented markets, lack of scale, illiteracy, and native traditions (Ekekwe 2017). Their efforts can be facilitated by an enabling environment that includes incubators, information exchange networks, and funding. Collaborative and efficient links are also essential along the agriculture supply chain from farmers, to agribusinesses, to consumers. Policy makers should involve all these groups when developing sector strategies and plans.

Investment is needed in *rural infrastructure*, especially transportation, electricity, telecommunications, and irrigation. The impact of such investment can be significant. One study finds that access to all-weather roads reduces poverty by 6.9 percentage points (Dercon et al. 2009). In Niger, the expansion of mobile cellular networks led to grain traders intrinsically using cell phones to reduce search costs, decreasing information asymmetries and improving consumer and trader welfare (Aker 2010). Lower costs and innovative business models have spurred the take up of off-grid electricity, providing power to hundreds of thousands of rural homes in the past 18 months, which is still a tip of the iceberg, given that half of Sub-Saharan Africa is without power (McKibben 2017). Irrigation is essential for crop production, yet less than 5 percent of cultivated land in Africa is irrigated. Solar power is emerging as an attractive option for irrigation. In 2016, Rwanda launched a US$13 million solar-powered irrigation scheme in the Ngoma District, enabling some 1,000 farmers to grow rice, vegetables, and fruits year-round.[21]

Stimulating investment in rural infrastructure is essential to improve the livelihoods of farmers and reap productivity gains. Mobile infrastructure has spread the furthest, with the proportion of households with cell phones in many rural areas in Africa being higher than the availability of electricity. This situation is largely due to private investment, a model that could be more widely applied in other infrastructure sectors through licenses and public-private partnerships. Another lesson that can be applied from the telecommunications sector is the use of universal service funds to finance investment in uneconomical rural areas. Governments also need to prioritize public funding for agricultural infrastructure, recognizing the trade-offs between where the investment is made (for example, roads, irrigation, extension services, R&D, and so forth) and economic growth and poverty reduction (Pauw and Thurlow 2013).

Skills and education are needed at all levels, including policy making, research, application of technology, and the farmers themselves. Although new digital technologies have emerged with demonstrated impacts for the rural sector, skills in government agriculture offices are often limited, affecting their application. Extension agents need to be trained in the utilization of new technologies, so they can transmit that knowledge to farmers.

There are also resource constraints for spreading knowledge. For example, in Ghana, the ratio of agricultural extension agents to farmers is 1:1,500, compared with a recommended ratio of 1:400 (Ministry of Food and Agriculture 2015). This is a key factor deterring the adoption of technology among farmers. In Senegal, a notable number of experienced technical staff is nearing retirement (Ministry of Agriculture and Rural Equipment 2014). These examples are largely applicable to many African countries, reinforcing the need to enhance capacity-building initiatives for

technical experts. The knowledge capacity of farmers also needs to be raised, so they can leverage inputs, machinery, and digital technologies to enhance productivity. Ineffective user interfaces and lack of digital literacy are among the reasons cited for the lack of success of some information and communications technology in agriculture projects (Aker, Ghosh, and Burrell 2016).

Despite the importance of agriculture in the African economy—18 percent of GDP in 2016[22]—its potential remains unrealized due to chronic *underinvestment*. This is reflected by low productivity and characterized by limited mechanization, non-optimum inputs, and uneven application of new technologies. African governments spent only 3 percent of their budgets on agriculture in 2010, seven years after committing to spend at least 10 percent in the CAADP Maputo Declaration.[23] Investment per agricultural worker has been flat or declining over the past 30 years. The region's agriculture sector receives less than 5 percent of lending from formal financial institutions, starving agricultural businesses of capital (Snyder 2016). There are several factors behind this, including the riskiness of small landholding farms, low returns, uncertain property rights and land tenure, and inadequate policy and regulatory frameworks (AGRA 2016).

Nevertheless, there are indications that funding is available. A watershed event was the sixth African Green Revolution Forum in 2016, where leading development partners and businesses pledged more than US$30 billion for African agriculture over the next 10 years,[24] the largest-ever financial package for the sector. In addition, private sector initiatives for funding are growing, including banks, private equity funds and venture capital, impact investors, and microfinance institutions. The African countries most likely to benefit are those that prioritize agriculture, including a sound sector strategy and plan, have an inclusive implementation process at the country level, offer attractive investment incentives, and demonstrate commitment to necessary reforms.

IV. Future Research

It is questionable whether classic theories about agricultural economic transformation remain relevant today, including debates about whether development should be agriculture driven or export led (McArthur and McCord 2014). This question is particularly relevant in the African context, given that the region remains the most dependent on agricultural livelihoods and the rapid changes affecting the sector. Some economists question whether the development literature and various national and regional contexts are relevant for agricultural transformation and economic restructuring in Africa (Breisinger and Diao 2008). Classic economic development models are also under strain from new trends that have emerged, such as globalization, digital technologies, and climate change. A revised framework is needed that revisits solutions for the transformation of agriculture in light of previous experience, new trends, the need for sustainability, and the socioeconomic realities of the African continent. The revised framework could revisit the agriculture-led versus export-led debate by considering a new theory of agribusiness-led growth, including regional trade, for which export potential might be considerable.

Better understanding is needed of successful interventions and challenges for scaling up. There is growing research about the impacts of inputs and technologies in the African agriculture sector, but it is typically based on small pilots. Further, the evidence is often mixed. More insight is needed on the specific causes of agricultural productivity gains. For example, the dramatic rise in cereal yields in Côte d'Ivoire is still subject to much speculation as to the causes. A better understanding is needed about the impact of technologies, including analysis of the share of productivity gains due to inputs (seeds, fertilizer, and so forth) versus the application of digital technologies. Equally, there is not a clear picture of how new techniques are absorbed by farmers and translated into higher output. Another challenge is disentangling income effects from interventions. For example, a study shows that

banana farmers in Kenya who used mobile money had higher productivity, but they were also wealthier to begin with, suggesting a higher propensity among high-income groups to adopt new tools (Kikulwe, Fischer, and Qaim 2014).

The more widespread digital technology interventions in Africa's rural sector are low-tech, in that they revolve around narrowband mobile networks and voice, text messaging, and USSD-based mobile money. Their success is explained by widespread 2G mobile network coverage and straightforward applications that run on plain and inexpensive cell phones.

Agriculture is entering a new phase of technology characterized by big data applications and the Internet of things which promises to trigger huge productivity gains (Lohr 2015). The new phase includes cheap sensors and drones monitoring plants, livestock, water supplies, and weather, to provide detailed, real-time information. These precision farming technologies are highly relevant for Africa's agriculture sector (Dlodlo and Kalezhi 2015) and are being used in various pilots and small-scale implementations (Kariuki 2016). Precision farming offsets some of the negative side effects of inputs through environmentally friendly techniques. The widespread deployment of mobile networks in Africa is a plus, since the Internet of things transmits data using wireless communications. However, more advanced Internet of things applications are based on sophisticated data analytics, trigger many more bits, and are tied to cloud computing platforms. These advances will require investment in faster and higher-capacity 5G wireless networks, a robust national Internet infrastructure, and widespread availability of smartphones. The steps to adoption of the Internet of things in African agriculture merit deeper analysis, given its potential impact.

ENDNOTES

1 Although there is a strong link between agricultural growth and decreases in poverty, there are exceptions. For example, Zambia experienced a large increase in maize yields from 2006 to 2011, but did not see a reduction in poverty. Underlying inequalities and government policy explain the discrepancy (Veras 2017). Zambian productivity gains were mainly the result of fertilizer subsidies to large farms. Small farms, less than one hectare in area, received only an average of 7 percent of the subsidy.

2 Although small shareholdings pose productivity challenges, they have other benefits: "While 75 percent of the world's food is generated from only 12 plants and 5 animal species, making the global food system highly vulnerable to shocks, biodiversity is key to smallholder systems who keep many rustic and climate-resilient varieties and breeds alive" (FAO 2012).

3 The Asian Green Revolution refers to the application of high-yielding varieties of wheat and rice in the region beginning in the 1960s. Within two decades, around 90 percent of wheat farms in Asia were growing modern varieties, and plantings of high-yielding rice increased by a factor of five. The use of high-yield seeds was accompanied by increased use of mineral fertilizers, pesticides, and irrigation. These rapid gains avoided a food crisis in Asia and provided the foundations for rapid economic growth in China, Southeast Asia, and South Asia (http://www.fao.org/docrep/x0262e/x0262e06.htm).

4 The World Bank announced a new multibillion U.S. dollar funding initiative for the region in 2015, noting: "Sub-Saharan Africa is highly vulnerable to climate shocks, and our research shows that could have far-ranging impact—on everything from child stunting and malaria to food price increases and droughts." See World Bank (2015c).

5 See Kenya Flower Council, "Floriculture in Kenya" at: http://kenyaflowercouncil.org/?page_id=92.

6 An initiative in Ghana, Kenya, and Tanzania will benefit 500,000 farmers through a range of financial services linked to cell phones. The initiative includes buying inputs on credit using mobile money, selling produce through the mobile phone, and obtaining insurance against risks through scratch cards in seed packages. https://agra.org/2016AnnualReport/milestones-2016/.

7 Sensors are used in Nigeria to analyze soil data so that farmers apply the right fertilizer and optimally irrigate their farms (Ekekwe 2017).

8 Satellite images are used in Sudan to provide information about flooding. This information is then conveyed to farmers using mobile phones. https://wle.cgiar.org/thrive/2014/03/25/connecting-farmers-sudan-real-time-flood-management-information.

9 Botswana's Livestock Identification Trace-back System tags cattle with radio frequency identification devices. Information is transmitted to a central database. The database enables EU certification for the country's beef exports, and is a key repository of information for livestock farmers, as well as for state veterinary services and health authorities. https://cgspace.cgiar.org/handle/10568/57650.

10 Researchers in Senegal combined satellite data, national statistics, the road network, and mobile data to form a big data set that was analyzed to predict the price of millet-enhancing food security initiatives. See UCLouvain (2016).

11 In Nigeria, drones are used to map the potential for expanding rice cultivation. For example, the United Kingdom–based GrowMoreX Consultancy Company operates drone-based farming services. The company conducted a survey of 3,000 hectares of land suitable for irrigated rice farming in New Bussa, Niger State. The area has limited access to roads, electricity, clean water, and other amenities. https://agra.org/news/important-wins-were-notched-up-for-african-agriculture-in-2016/.

12 http://www.un.org/en/africa/osaa/peace/caadp.shtml.

13 http://www.nepad.org/resource/au-2003-maputo-declaration-agriculture-and-food-security.

14 https://www.africaresearchinstitute.org/newsite/blog/agricultural-subsidies-in-zambia/.

15 See: "AGRA's Program for Africa's Seed Systems (PASS): Strengthening Public Crop Genetic Improvement and Private Input Supply Across Africa." http://www.fao.org/fileadmin/user_upload/drought/docs/AGRA%20Seed%20Systems%20and%20the%20future%20of%20farming.pdf.

16 An article noted that Côte d'Ivoire had passed 3 t/ha. The data have since been revised downward, but the analysis remains roughly the same (McArthur 2015).

17 See: Food Fortification Initiative, "Côte d'Ivoire." http://ffinetwork.org/about/stay_informed/releases/images/Rice_Cote_dIvoire.pdf .

18 Vagaries in weather, government support, and market conditions can trigger a rapid downturn in agricultural production. Poor rainfall combined with recent market changes, such as reduced funding, low seed supplies, and falling market prices, caused rice production in Côte d'Ivoire to drop by 27 percent in the 2016/17 growing year. https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Dakar_Senegal_4-11-2017.pdf.

19 One dilemma, however, is that the plants grown from improved seeds do not produce the same seeds, requiring Rwandan farmers to purchase seeds again for the next crop (Veras 2017).

20 See: "The Agripreneur: A New Breed of Young Entrepreneurs Combining Their Love of Farming and Agriculture with an Acquired Professional Business Approach," at: http://www.ypard.net/testimonials/agripreneur-new-breed-young-entrepreneurs-combining-their-love-farming-and-agriculture-.

21 Ministry of Agriculture and Animal Resources, "A Solar-Powered Irrigation Scheme Unveiled in Ngoma District." http://www.minagri.gov.rw/index.php?id=469&tx_ttnews%5Btt_news%5D=1430&cHash=9ea6ad33ebc1ccfcd109caaf6f358203.

22 This figure refers to Sub-Saharan Africa. See: http://data.worldbank.org/indicator/NV.AGR.TOTL.ZS.

23 http://www.ifpri.org/blog/public-expenditure-agriculture-trends-"black-boxes"-and-more.

24 Most of the funding was pledged by three organizations: the African Development Bank (US$24 billion), Bill & Melinda Gates Foundation (US$5 billion), and International Fund for Agricultural Development (US$3 billion). See: "More Than US $30 Billion In Commitment To African Agriculture." Press Release, September 8, 2016. https://www.agrf.org/stories-of-impact/more-than-us-30-billion-in-commitment-to-african-agriculture/.

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EDUCATION

3 Education

I. Some Gains, but Falling Behind

It is well established that improvements in education are associated with long-term improvements in economic performance (Barro 2001; Arias, Santos, and Evans 2017). Education links with economic development in three broad ways (OECD 2010). First, it improves the skills of the workforce, leading to greater productivity, and thus contributing to economic growth. Second, it influences the capacity of the economy to develop new ideas and technologies. Third, it serves as a means of spreading the knowledge needed to apply innovative ideas and make use of new technologies. Having a more educated workforce enables public and private firms to take advantage of new economic opportunities, leading to improved performance (Jones 2001). Economic growth leads to higher national wealth, which increases resources and opportunities for education. The goal of any education system is to equip youth with the numeracy, literacy, and wider skills needed to unlock their latent potential, which will be required to generate economic growth and jobs.

Developing countries, and specifically in Africa, are lagging in their education outcomes. A recent analysis argues that the gap in education levels between the "developed" and "developing" worlds can be closed only with disruptive changes. Winthrop (2016) estimates that on basic literacy and numeracy measures, the average student in the developing countries scores on par with the lowest 8 percent of students in the developed countries, illustrating how large the gap is. Accordingly, addressing these massive challenges facing Africa's education sector will mean taking bold and innovative approaches. In Africa, only about one-third of young people make it to secondary school.

Sub-Saharan Africa has made great strides in boosting primary school attendance; gross enrollment ratios are almost 100 percent (table 3.1). Much of the recent increase was driven by donor support to achieve the Millennium Development Goal of universal primary education by 2015.[1] It will be more difficult for the region to achieve the new Sustainable Development Goal of free universal secondary education by 2030.[2] In 2014, Sub-Saharan Africa's gross secondary enrollment rate was 43 percent, 22 percentage points below the next lowest region and 34 percentage points below the world average. This is a much bigger gap to close than achieving near universal primary education, yet there are relatively few initiatives to deal with the expansion of secondary school coverage (Majgaard and Mingat 2012). Most dire is the region's gross tertiary enrollment, which is 8.6 percent. Some experts reckon it needs to be almost double that to sustain current levels of economic development (Diallo 2013). This has serious ramifications for producing sufficient college educated teachers, and has implications for innovation in the region, given the strong link between university education and innovative entrepreneurship (Mayhew et al. 2016). There is an urgent need for radical change (Elletson and Burgess 2015).

TABLE 3.1: School Enrollment (% of gross)

	Primary					Secondary					Tertiary				
Region	1980	1990	2000	2010	2014	1980	1990	2000	2010	2014	1980	1990	2000	2010	2014
Sub-Saharan Africa	76.9	72.5	81.6	96.6	98.4	18.7	23.4	26.3	40.2	42.7	2.1	3.2	4.4	7.9	8.6
World	96.9	99.9	98.5	105.3	104.1	49.6	51.4	60.1	70.8	76.4	12.4	13.7	19.0	29.3	35.0
East Asia & Pacific	108.5	118.8	105.9	109.4	105.4	46.0	44.4	63.0	81.5	87.9	5.4	7.4	15.5	27.8	39.1
Europe & Central Asia	103.4	103.5	102.9	102.4	103.3	87.0	90.9	94.6	97.9	106.0	27.7	32.4	45.1	61.5	65.1
Latin America & Caribbean	115.0	114.5	119.2	112.4	108.4	71.7	76.1	85.3	89.8	94.1	13.3	16.8	22.6	40.5	44.7
Middle East & North Africa	87.0	93.4	96.3	105.9	105.3	42.6	56.7	68.5	75.7	79.4	10.1	12.8	20.4	30.8	37.9
South Asia	77.9	87.0	91.4	107.5	109.1	26.9	35.9	43.1	58.9	64.8	4.5	5.4	8.2	15.9	20.8

Source: World Bank.

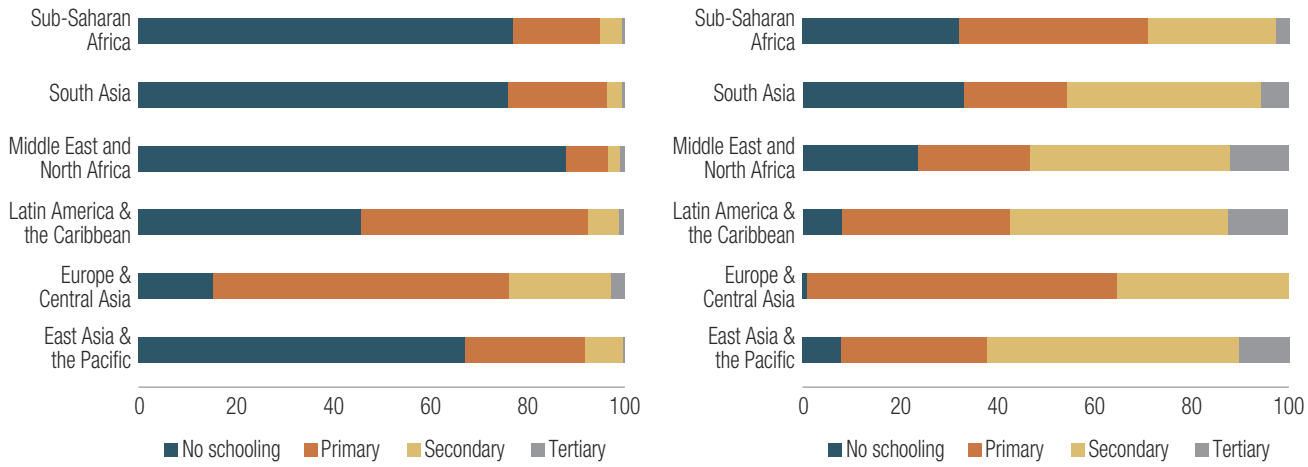
The education systems in Africa face enormous challenges in increasing the number, motivation, and quality of teachers. For example, nearly 42 percent of all instructional time in Kenya is lost because of teacher absenteeism from the classroom (WEF 2015). Further, there is a skill shortage, with about 35 percent of public school teachers displaying mastery in the subjects they teach. The limitations of teachers will implicitly be reflected in learners' performance. Across the region, only three in four adults who completed six years of schooling can read. There are wide differences among countries, suggesting that in many, the quality of student learning in primary school should be improved before increasing the school cycle (Majgaard and Mingat 2012).

The composition of educational attainment has changed substantially over the past 60 years. The share of the population ages 15 years and older who attended secondary school increased more than fivefold, from 5 to 26 percent (figure 3.1). However, around a third of those ages 15 and over are still without education. Overall progress in Africa has been marked by lower levels of secondary and tertiary attainment compared with other regions. Efforts need to be devoted to educating those who never went to school or dropped out, and a culture of lifelong learning should be instilled.

Given these diagnostics, it is not overstated to affirm that Africa's education systems need a rapid fix in quantity and quality. Education in Africa must leap forward to catch up with the transformation of labor markets. The changing nature of jobs and life in the 21st century means that, although traditional ways of educating children may have worked in the past, there is no guarantee that it will continue in the future. The employment landscape is rapidly evolving. In many countries, the most in-demand occupations did not exist a decade ago. It is estimated that 65 percent of children currently entering primary school will ultimately end up working in new job types that do not yet exist (WEF 2016). As such, there is a pressing need to transform Africa's education system and equip students with the right skills for tomorrow's labor market.

One of the ways Africa's education system can be transformed is through innovation and technology, which are often linked. Examples include using solar power tablets to teach math to primary school children in Sudan, and collecting school administrative information in Peru using mobile phones to improve decision making (CEI and UNICEF 2016). In other cases, innovation may be as straightforward as a community-oriented initiative training mothers to assist with pre-primary school education in Ghana, or

FIGURE 3.1: Educational Attainment (population ages 15 and over)



Source: Adapted from Barro and Lee 2013.
Note: Education levels refer to attended and not necessarily completed.

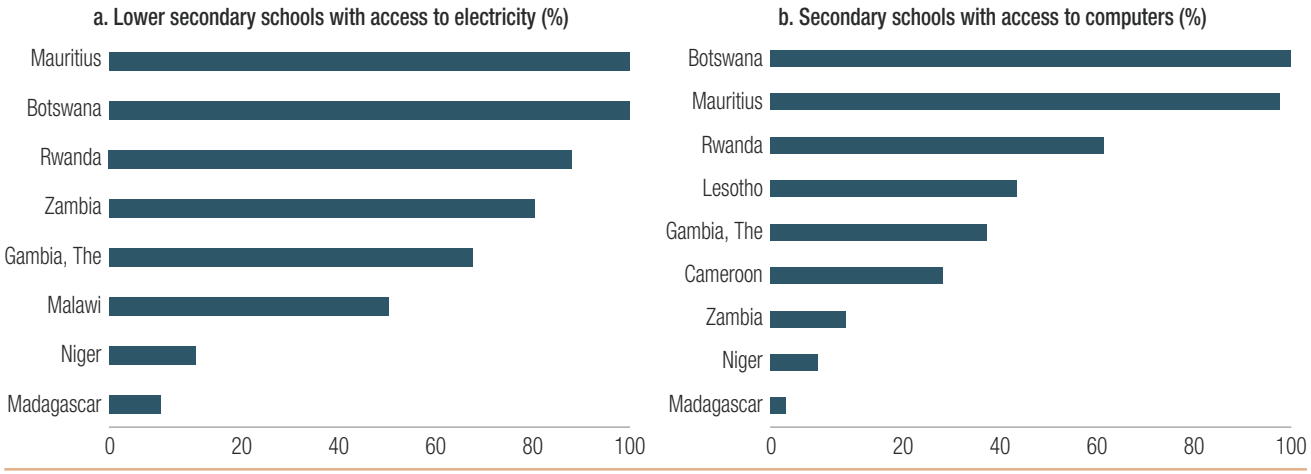
a comprehensive approach to improving literacy and learning in Brazil through teacher training, parental engagement, and the use of assessment data.

Technology has the potential to alter education by extending the learning space beyond classrooms and schools to help hundreds of millions of children stuck in dismal classes (*The Economist* 2017). The Internet is a cross-cutting enabler for education, providing unparalleled access to information and facilitating connections to educational resources, virtual labs, ideas, and people (Internet Society 2017). The Internet opens a way of exponentially expanding the physical limits of the school, giving students and teachers access to online learning resources from around the world. Students can use technologies to access courses not offered at their school; rural students can complete their studies without leaving their communities; and adults can benefit from a more flexible study schedule. The potential uses of information and communications technology (ICT) in education are not limited to the classroom (Trucano 2016). Digital technologies have the potential to improve the monitoring of various dimensions of a national education system, which is a valuable instrument for implementing a systems approach to education reform.

Education, technology, and innovation are co-dependent. Although technology and innovation may facilitate a leap in education growth, education makes it possible for innovation and technological development to take place. Innovation and technology by themselves are not a panacea and cannot fix poor policy and other contextual issues. But innovations can trigger a new approach and, if successful, create significant change through scaling up. Technology can supplement a lack of resources through remote online learning, but it requires knowledgeable teachers to know how to leverage and maximize its benefits. Success will depend on technology used at the service of teaching and not the other way around. Educational technologies should complement existing and emerging pedagogical approaches (WEF 2015).

There are a growing number of innovations and digital interventions in education. However, many are recent and often pilots. The challenge for Africa will be to know which are worth adopting and which can be used at scale (CEI and UNICEF 2016). And the region faces the major challenge of providing adequate infrastructure for digital technologies. Electricity availability, which is an essential prerequisite for computers and Internet access, varies widely across

FIGURE 3.2: Schools with Electricity and Computers, 2012–15



Source: Adapted from United Nations Sustainable Development Goals Indicators.

African schools (figure 3.2, panel a). There is also wide variation in the availability of digital technologies (figure 3.2, panel b). For example, almost all secondary schools in Botswana and Mauritius have access to computers, compared with less than a fifth of the secondary schools in Zambia, Madagascar, and Niger.

II. Leapfrogging School Enrollment, Educational Technology, and Outcomes

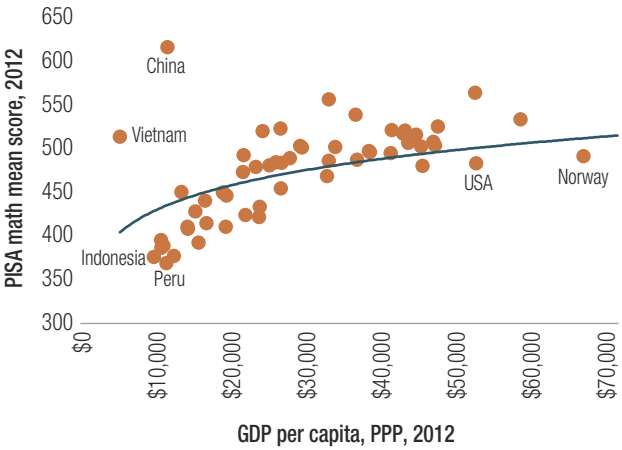
When most African countries gained independence in the 1960s or later, they did not reinvent the wheel; they adopted and adapted systems from the former colonial powers. This is an instance of leapfrogging that delivered early, much-needed skills for African states. Although most of the countries have not reached universal education, they have achieved remarkable gains, considering that at independence all sectors required major buildup. However, recent reports from Africa, as well as other developing regions, show an alarming level of poor learning. Delivering quality learning to all is constrained by resource limitations that make it difficult to expand education systems while maintaining quality. Student-teacher ratios have grown; school monitoring has deteriorated; and professional teacher development has stalled.

This section describes experiences on which Africa can draw to address these challenges. The experiences include examples of how learning outcomes improved rapidly in Vietnam, and how all teachers in Bhutan now receive ICT training. Another example is China's experiences with educational exploration, innovation, reform, and development (box 3.1). Africa provides several examples, such as a regional approach to the development of online learning in higher education, rapid increases in school enrollment in São Tomé and Príncipe, and quick provision of electricity and Internet access to primary schools to enable an innovative interactive math tool in Kenya.

Vietnam

Vietnam's progress in education over the past 20 years has been remarkable. Despite having the lowest gross domestic product (GDP) per capita among the countries that participated in the Program for International Student Assessment (PISA),[3] Vietnam scored higher than the Organisation for Economic Co-operation and Development (OECD) average and outperformed many developed economies (figure 3.3). Vietnam's PISA score was more than 100 points greater than the average of other developing countries taking the test

FIGURE 3.3: PISA 2012 Results Compared with GDP per Capita



Source: Adapted from data from the Organisation for Economic Co-operation and Development and World Bank.
Note: GDP = gross domestic product; PISA = Program for International Student Assessment; PPP = purchasing power parity.

(Parandekar and Sedmik 2016). Experts were particularly surprised that, despite being from a developing country with low GDP per capita, Vietnamese students obtained such high results.

The government has long recognized education as a national priority, and invested early in schools and teacher quality. It developed and enforced minimum quality standards for schools and professionalized its teaching force, setting standards around content knowledge, skills, and behavior. Vietnam was also an early adopter of standardized assessments of literacy and numeracy. Other factors underpinned the substantial progress in Vietnam's education system, including significant public and private investment in education, as well as strong political and parental commitment. Education financing grew from 7 percent of the national budget in 1986, to 20 percent in 2008. The country also has an outward-looking approach in learning and adapting best practices from developed countries, such as the Republic of Korea and Singapore. A central lesson of this success story is the will to reform, measure outcomes, and change what does not work.

Bhutan

In Bhutan, an innovative project was launched with the goal of assisting Bhutanese teacher education institutions in providing trainee teachers with skills in ICT and how to use it in the classroom. The country has two teacher education institutions and, before 2000, neither offered ICT training. The Singapore International Foundation, a nonprofit foundation, initiated a project in 2000 to assist Bhutan's Ministry of Health and Education with integrating ICT into its education system. The project aimed to close the gap between low ICT skills among pupils and the growing adoption of ICT technology in the workplace. The project ran in two phases during 2001–07, contributing to a tremendous increase in ICT skills among teachers (Wong 2008). Teachers went from knowing nothing about computers, to being able to design web pages. The project contributed to a radical switch in pedagogy, from the conventional teacher-centered approach to more collaborative models. The project also benefited from being designed in two phases, so the lessons from the first could be incorporated into the second. Today all trainee teachers in the country are taught ICT skills, with the focus shifting to using digital technologies for teaching and learning (Ministry of Education 2015).

Africa

The African Virtual University (AVU) has been at the forefront of using online learning in the region. AVU was initially launched in 1997 as a World Bank project to increase access to higher education and training using digital technology. Headquartered in Nairobi, Kenya, with a regional office in Dakar, Senegal, AVU is today an intergovernmental organization of 19 African countries. Its network connects 27 institutions across Anglophone, Francophone, and Lusophone African countries offering degree, diploma, and certificate programs delivered through online, face-to-face, and blended modes. One of AVU's flagship projects is the development of open educational resources (OER),

Box 3.1: Key Transformations in the Chinese Education System

China has long recognized that it must rapidly deliver the skills that are crucial for its economic development. For almost four decades, China's education system has experienced stages of exploration, innovation, reform, and development. The Chinese experience in the transformation of its education system can be summarized in five major thrusts.

Changing the Education Model to Accommodate Economic Development and National Conditions

In the early days of economic reform, major industries were underdeveloped, and all types of professional talent were in high demand. Instead of sticking to the traditional education model, the central government invested in the development of skills in key areas to accommodate the course of economic development. To ensure the long-term sustainability of the education system, there were strict evaluations of graduates and scientific research personnel from higher education colleges and scientific research institutions. Bachelor, master, and doctoral degrees were set up and the posts of professor, associate professor, and senior lecturer were established in colleges. Professional and technical titles, such as national research fellow and senior engineer, were established in scientific research institutions. Efforts were made to encourage intellectuals to improve their professional knowledge and promote the development of scientific talent, to improve the academic level of all disciplines and promote the development of education and scientific research.

Learning from Other Countries to Orient Higher Education to Global Demand

China's education system has been committed to a combination of traditional and imported methods. Experts from developed countries, such as the United Kingdom, France, Germany, the United States, and Japan, and the experiences of other countries in higher education were introduced to accelerate the reform of the tertiary sector in China. Aiming at building first-class universities and scientific research institutes, China's education system has developed high-quality talent and encouraged innovation and the conversion of scientific and technological knowledge to economic productivity.

Coordinating Market Demand and Supply, and Restructuring and Innovating the Education Industry

The education sector focuses on a combination of voluntary reform on the supply side and incentive and compensation mechanisms. Education training is adjusted to meet market demand. Synergy among academic freedom, university autonomy, and departmental supervision and administration is advocated. There is a balance between the development of all-round and specialized talent. Scholars are encouraged to develop original theories and textbooks. Large, medium, and small colleges and research institutions are committed to updating teaching ideas, adjusting teaching theories, and improving missions to adapt to social and economic development.

Channeling More Fiscal and Social Resources into Education and Increasing Investment in Rural Areas

In the course of developing the education sector, the central and local governments have increased their support for and investment in poverty-stricken areas and regions lagging in education. The concurrent development of urban and rural education and combination of macro and micro policies helps achieve balance in education development between regions, and promotes the overall development of the education sector. According to the National Bureau of Statistics, since the introduction of economic reforms, the growth of China's investment in education has remained higher than its gross domestic product

(*continued on next page*)

Box 3.1: Key Transformations in the Chinese Education System (*continued*)

(GDP) growth. In 2012, the proportion of education expenditure in GDP exceeded 4 percent for the first time.

Promoting Investment in Education as a Prerequisite for Economic Development

Evidence from China shows that education development is the prerequisite for rapid economic development and not vice versa. Education and economic development are interdependent, which means that economic development provides a material guarantee for education and education provides intellectual support for economic development. China's experience indicates that investments in education and economic transformation should be made simultaneously.

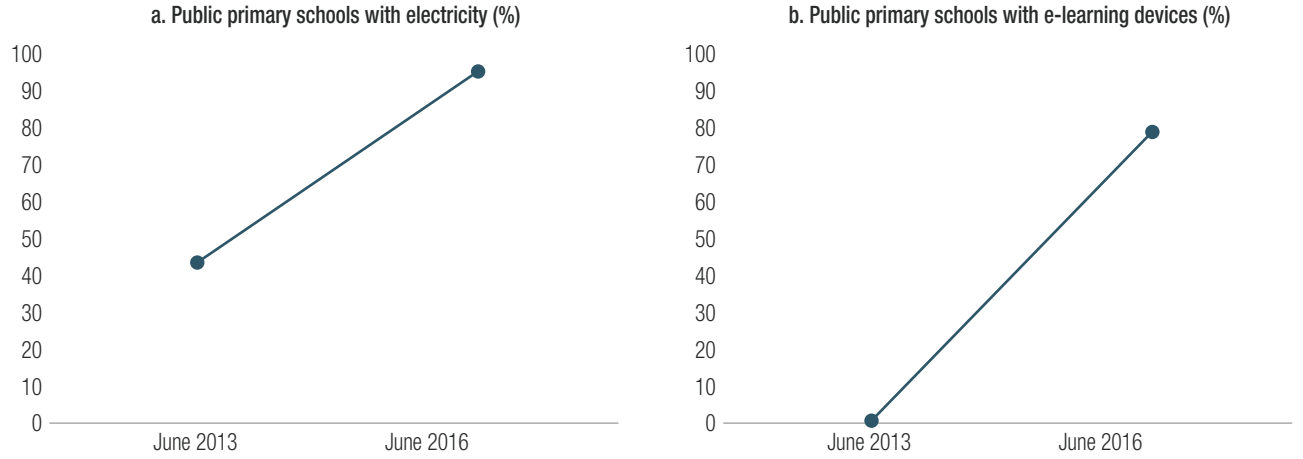
started in 2011 (Diallo, Thuo, and Wright 2013). AVU is the largest creator of online higher education content in Africa, with more than 200 OER courses that are used not only on the continent, but also overseas. AVU participates in the OpenCourseWare Consortium, which is a group of more than 200 leading higher education institutions from around the world collaborating to create shared open educational content. More than 63,000 African students have benefited from AVU since its inception.[4] Distance education offers an attractive supplement for boosting Africa's higher education training, given the inability of universities in the region to increase physical infrastructure rapidly.

Kenya provides an example of how quickly electricity and Internet access can be deployed even to remote rural schools to enable an innovative online learning product. For the past few years, the Kenyan government has devoted significant resources to enhancing ICT access and online learning in public primary and secondary schools. As a precursor to facilitating digital learning in public primary schools, the National Public Primary Schools' Electrification Project was launched in July 2013. Over the next three years, more than 12,000 mainly rural primary schools were connected to electricity using grid or off-grid solutions, raising the proportion of schools with electricity from 43 percent in 2013, to 95 percent by June 2016 (figure 3.4, panel a).[5]

Primary schools were also provided with Internet access through a range of initiatives and technologies, including fiber optic, mobile broadband, and satellite.[6] A separate program financed by the universal service fund of the Communications Authority of Kenya, is providing Internet access in all secondary schools.[7] The Kenya Education Network (KENET), which was previously responsible for connectivity of the country's higher education system, has seen its mandate expanded to coordinating the various public and private sector initiatives for providing Internet access in primary and secondary schools.[8] Around 70 percent of Kenyan secondary schools are within 20 kilometers of a higher education location, meaning that these high schools could leverage the Internet connectivity of these anchor institutions.

More than 90,000 teachers in Kenya have been trained in delivering digital learning. The Digital Learning Program (DLP) is the umbrella program under which all primary schools are being electrified and provided with Internet access and online learning devices. More than 18,000 primary schools have received e-learning devices since the DLP launch in May 2016 (figure 3.4, panel b).[9] For online learning content, one initiative is iMlango, launched in 2014 by the Ministry of Education, with support from the United Kingdom Department for International Development and several technology and courseware partners. iMlango is a learning platform that uses technology to help improve education outcomes.

FIGURE 3.4: Electrification and e-Learning Devices in Kenyan Primary Schools

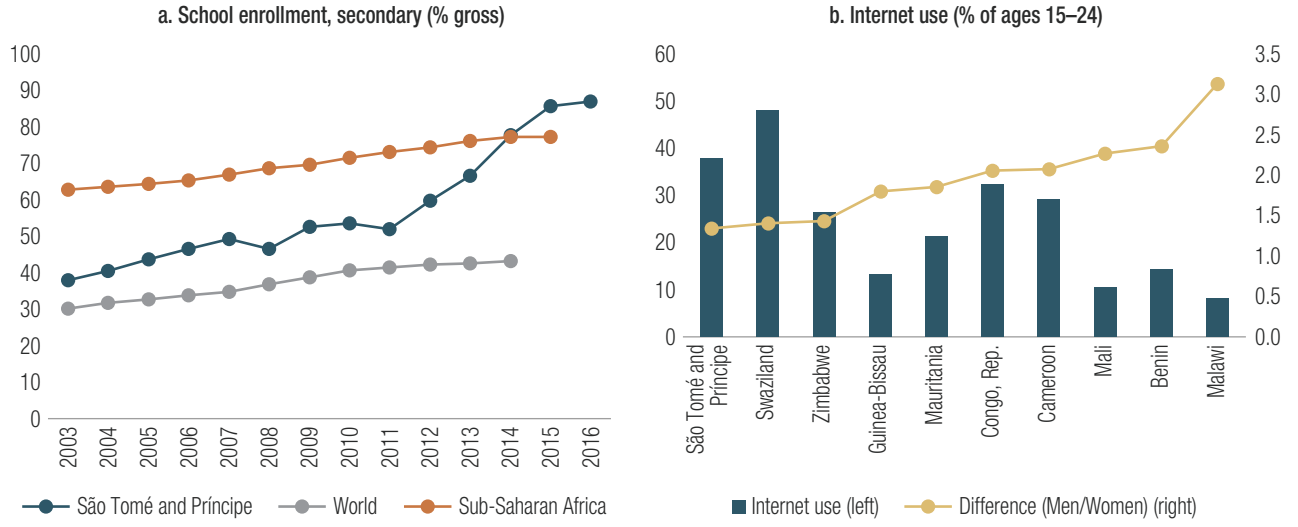


Source: Adapted from Ministry of Energy and Petroleum and Kenya ICT Authority.

It features an online mathematics courseware and data collection system that adapts to the learning level of individual students, while at the same time monitoring student progress. Within two years, iMlango was introduced in 205 primary schools in four counties, enrolling around 150,000 pupils. One distinctive aspect of the project is real-time monitoring of attendance and individual progress in math (Shome 2016). The project has benefited teachers by providing e-learning tools to support the curriculum, generating new ideas, and encouraging sharing among the teaching community. The project uses a train-the-trainer model, whereby the first batch of teachers learning how to use the application trains others in their respective schools. The project has affected local communities by providing Internet access during off-school hours. There is anecdotal evidence of parents reporting that their children have shown increased enthusiasm to attend school (Ndiku and Mwai 2015). However, despite the real-time data collection, there has been scarce dissemination of the impact of the platform on math performance. One reason is the relative novelty of the intervention. Another reason is that although ICT can complement teaching, there are underlying contextual conditions in Africa, such as highly variable and often volatile learning environments, affecting the impact of the introduction of digital technologies in education (Mubeen 2016).

São Tomé and Príncipe provides an example of rapidly leapfrogging secondary education enrollment above world levels. The government developed a plan, outlining strategies for the education sector with the objective of the government providing 12 years of free education to all children. The country had already achieved universal primary enrollment, with a significant number of children going to secondary. This was manifested through an increase of almost 50 percentage points in gross secondary education enrollment between 2003 and 2016 (figure 3.5, panel a). This increase was stimulated by the government's prioritization of the education sector, establishing the preconditions through an increase in resources: the proportion of public expenditure for education increased from 2.7 percent of GDP in 2002, to 8.8 percent by 2010 (World Bank 2013). There has been ongoing computerization of secondary schools through corporate social responsibility programs and investments from proceeds of a telecommunication license award. Today, almost all secondary schools have broadband Internet access. São Tomé and Príncipe has the second highest Internet penetration among youth compared with other African countries where similar data are available. São Tomé and Príncipe has the best gender parity in youth Internet use (figure 3.5, panel b).

FIGURE 3.5: Leapfrogging with Equality in São Tomé and Príncipe



Source: Adapted from World Bank and UNICEF.
Note: Panel b refers to multiple indicator cluster surveys conducted in 2014 and 2015.

III. Establishing the Preconditions for Leapfrogging Education Outcomes and Skills

Although education in Africa faces challenges, the examples of leapfrogging present potential for the continent to improve outcomes and skills quickly. To enable rapid educational transformation, the region needs to create the necessary preconditions.

Forming Partnerships

All the leapfrogging examples feature partnerships. The partnerships include intergovernmental agreements, such as AVU, as well as bilateral cooperation, whether formalized as projects or for one country to learn from other nations' successful experiences in education. This precondition points to the need for African governments and education ministries to collaborate more closely with each other[10] and with other countries outside the region to share scarce resources, learn innovative educational practices, and apply them on a large scale. Another promising area is partnerships with the private sector, for the introduction of technology or collaboration on industry skills training (box 3.2). The private sector could play a key role by investing in education and infrastructure, facilitating digital learning throughout the continent. This will entail reducing regulatory barriers that constrain private sector investment in the sector. Although this challenge must start with governments' efforts to reform, there is much for the private sector to gain by investing in support of the public sector in delivering skills.

Deciding Which Innovations and Technology Interventions to Scale

Not all education innovations are effectively impactful, transferable, and scalable. There is no shortage of educational technology examples around the world, or in the Africa region. The key question is whether they are addressing the right problems and most important challenges. A critical approach is required when reviewing global best practices and innovations in education as relevant to the African context. For optimal leveraging of innovations, it is critical that what

works be identified, tested, and potentially scaled. An impactful and scalable education innovation should be assessed by four characteristics: (a) novelty and variation; (b) impact on equity, learning outcomes, and education systems; (c) demand by users and stakeholders; and (d) potential to match the scale of the problem (CEI and UNICEF 2016).

Seizing the Window of Opportunity

Introducing change in African education systems is sensitively balanced between donor support, policy buy-in, infrastructure development, and sociopolitical stability. The speed at which innovations can be scaled up depends on seizing this window of opportunity at the right moment without significant trade-offs. Local input and collaboration are key for making innovation work, particularly in the diverse and challenging sociopolitical contexts of African countries. Strategic partnerships and strong institutional commitment and capacity can catalyze buy-in for innovation (CEI and UNICEF 2016).

Deploying Digital Infrastructure

The application of ICT in education necessitates digital equipment and Internet access (and regular and reliable electricity). There are many gaps in the region in the provision of electricity, computers, and the Internet, as well as significant differences in availability across different levels of education (primary, secondary, and tertiary). To benefit from e-learning, schools require broadband connectivity (CISCO 2015). Although governments need to invest resources in digital infrastructure for schools, there are various options for tapping additional funding. This includes drawing on the resources of the private sector for school connectivity projects and, as the case of São Tomé and Príncipe illustrates, leveraging the corporate social responsibility programs of telecommunications operators. Another example is Uganda's Rural Communications Development Fund (RCDF), which was established in 2003 and funded by a 2 percent levy on telecom operator revenue. At RCDF's inception, no government secondary school had a computer laboratory; by 2015, 1,067 government secondary schools had a computer lab, or 92 percent of the total.[11] The cost of the Internet can be made more affordable for schools by subsidizing service charges, a practice adopted in many countries (CISCO 2015). African countries can also tap the expertise of national education and research networks, which were initially created for higher education, to assist with primary and secondary school connectivity (Foley 2016).

Matching Skills to Jobs

Labor markets are rapidly evolving and many new skills are in demand. In Africa, there is a considerable imbalance between the demand for and supply of people holding medium-level and vocational qualifications (WEF 2014). To improve matchmaking between jobs and skills, the public and private sectors must work closely together. Labor ministries need to seek the input of industry to forecast labor and occupation requirements; ministries of education need to draw up sector plans to ensure proper skills are developed to meet this demand. Sources of innovation should be emphasized by encouraging entrepreneurship through the creation of digital hubs and close collaboration between higher education and startups.

Teaching the Teachers

Good students require good teachers. More effort is needed to train teachers and ensure that they are appropriately allocated throughout the education system. The success in the use of ICT in education is contingent on teachers' abilities and skills in integrating these technologies into the teaching process (UNESCO 2008). Therefore, if teachers are not provided with ICT skills, it is unlikely that digital interventions will be effective. The case of Bhutan shows that all prospective teachers

Box 3.2: Leveraging the Private Sector in Sub-Saharan Africa for TVET Skills Development

Public-private partnerships in the region are underway to introduce job-related technical and vocational education and training (TVET) designed to meet the short-term needs of employers. One example is the Ghana Industrial Skills Development Center (GISDC), which was launched in 2005 to provide training in mechanical, electrical, and process engineering. The seeds for this initiative were sown when TexStyles Ghana found that other factories shared its problem of being unable to find and retain employees who could service their machines. As a result, factories often had to fly in troubleshooters from abroad. To overcome the problem, the Governments of Ghana and the Netherlands joined forces with the Association of Ghana Industries to set up GISDC. Located on the premises of Tema Technical Institute (a government facility) but run independently, GISDC is now operational, with a governance arrangement that includes industry representatives on its decision-making board and several firms among its partners. The public-private partnership has helped to address the gap in skills provision; this is essential for the private sector to flourish (GTZ 2009).

South Africa's Middelburg Higher Technical School has established successful partnerships with companies that invest in the school, provide training after school hours, and consider learners favorably for employment (Center for Development and Enterprise 2012). For example, Toyota Motor Company provides equipment for training motor vehicle mechanics, has developed a modular training course, and appoints teachers to provide training outside school hours. Learners pay an additional fee for the training, and teachers are paid from these funds. The learners do the first modules in the series and once they complete their schooling, can apply for employment at Toyota, where they can complete the remaining modules as employees. Another example is the Samancor mining company, which operates an after-hours program at the school providing training in welding, fitting and turning, and skills needed by electricians. The company pays Middelburg Higher Technical School teachers to provide the training.

In Uganda, a Skills Development Facility project will promote employer-led, short-term training to address prevailing skills imbalances in the formal and informal sectors, starting with agriculture, construction, and manufacturing, before spreading to other sectors (World Bank 2015). The scheme is to be implemented through a grant facility mechanism to be co-financed by the private sector, through a matching grant. Firms that take on students for internships, especially in vocational studies, will receive a 100 percent grant.

In Nigeria, the government has started to process the certification and accreditation of private providers that meet certain criteria (including a governance structure that includes industry representation) to qualify as Vocational Enterprise Institutions (targeting those with nine years of schooling) or Innovation Enterprise Institutions (targeting those with 12 years of education).[a] These institutions provide practical training in target areas, such as telecommunications, computer hardware engineering, refrigeration and air conditioning, welding and fabrication, petroleum geosciences, building technology, film and TV production, paralegal studies, fashion design, hospitality, and tourism.

Many of the initiatives incorporate lessons from new models of training, including coherence with the country's economic development strategy. Another commonality is that training institutions, at least to start, are outside the traditional education and training system and thus more able to react quickly, flexibly, and innovatively to industry needs. Another critical aspect is arrangements that encourage close involvement by industry in defining training curricula, providing equipment and trainers, and exposing students and faculty to industry-driven projects (for example, internships, work placements, and so forth).

[a] See "Vocational Enterprise Institutions (VEIs) and Innovation Enterprise Institutions (IEIs)" at: https://www.nbte.gov.ng/iei&vei.html.

can receive digital training by including ICT skills as part of the curricula in teacher training colleges.

Developing a Policy

For innovative ideas and digital technologies to be scaled up and successful requires a robust education sector policy, strategy, and plan. A clear government vision of the education sector would identify how it fits in with national goals, the initiatives for the sector to achieve those goals, and the expected outcomes. This vision provides clarity on how innovation and digital technologies fit into education goals and outcomes. And having a vision enhances the chances of scaling up successful pilots, while minimizing initiatives that are driven by donors or the private sector that stop when funding runs out.

Adequate capacity and resources are essential, since adopting innovation and ICT in education brings new requirements and costs. Ideally, there should also be an ICT for education strategy that outlines why and how technologies benefit the education system; it should include initiatives, timetables, and costs. Strategies should be developed along a multi-stakeholder approach, including among ministries, to reduce education technology silos. The strategies should also include the input of teachers, parents, students, donors, and the private sector. Monitoring and evaluation are critical to track the implementation of digital technologies, to reduce inequities as well as assess what works in improving outcomes.

Investing in Lifelong Skills

A culture of ongoing skills development needs to be instilled across the continent. This is essential with constantly evolving economies and demand for new skills. Online learning platforms ease the task of continuous skill development and improvement. The platforms require access to digital technologies and development of relevant local content. At the same time, over half of Africa's adults never attended school or have only a primary school education. Effort is needed to reach this group so they are not left further behind. The efforts should include formal and informal training initiatives, including teaching basic computer skills. A recent initiative could have widespread ramifications for the continent: Rwanda plans to use 5,000 young "digital ambassadors" to train five million adults in computer literacy (Wong 2017).

IV. Future Research

One of the most significant obstacles in gauging the scope and impact of education in Sub-Saharan Africa is the lack of systemic data collection. There is no education system–related data collection process in some countries in the region (UIS 2015). There are many studies of technology adoption in Africa, but most describe the technologies deployed rather than the impacts, and many have been small pilots that have not been scaled up. Data on ICT inputs alone are insufficient for understanding their effects on student outcomes. Additional data on usage are essential, especially data on how, when, and how much teachers and pupils use digital technologies. There is also a lack of impact evaluation to provide insight into how ongoing technological adoption and innovation have affected education outcomes. Furthermore, there are few feasibility studies to compare the cost-effectiveness of ongoing projects.

Sub-Saharan Africa's skills balancing act requires countries to face a trade-off between skills that maximize productivity growth (for example, technical skills for catalytic sectors) and skills aimed at fostering inclusion (for example, basic skills to improve livelihoods). Moreover, Sub-Saharan African countries must find the right balance between investing in the skills for today's needs and those for future requirements. There is a need for more research to inform on the right mix of investments at different stages of development.

Endnotes

1 http://www.un.org/millenniumgoals/education.shtml.

2 http://www.un.org/sustainabledevelopment/education/.

3 Launched in 2000, PISA is the OECD's benchmarking tool to assess the achievement and application of key knowledge and skills of students at age 15 years. The assessment is conducted every three years and tests proficiency in mathematics, reading, science, and problem solving.

4 See "Facts and Figures" at: http://www.avu.org/avuweb/en/avu-at-a-glance/facts-and-figures/.

5 See "Primary Schools Electrification Project" at: http://www.energy.go.ke/index.php/projects/242-primary-schools-electrification-project.html.

6 See Avanti, "Project iMlango" at: http://www.avantiplc.com/wp-content/uploads/2016/12/EDU-CS-Project-iMlango.pdf.

7 See: "Authority to Connect All Public Secondary Schools to High Speed Internet" at: http://ca.go.ke/index.php/what-we-do/94-news/417-authority-to-connect-all-public-secondary-schools-to-high-speed-internet.

8 See "The KENET Schools Connectivity Initiative (SCI)" at: http://schools.kenet.or.ke.

9 See "Milestones Achieved" at: http://icta.go.ke/digischool/milestones/.

10 An example is the African Ministerial Forum on ICT Integration in Education and Training. See African Development Bank (2016).

11 See "10 Years of RCDF" at: http://ucc.co.ug/files/downloads/10%20YEARS%20OF%20RCDF.pdf.

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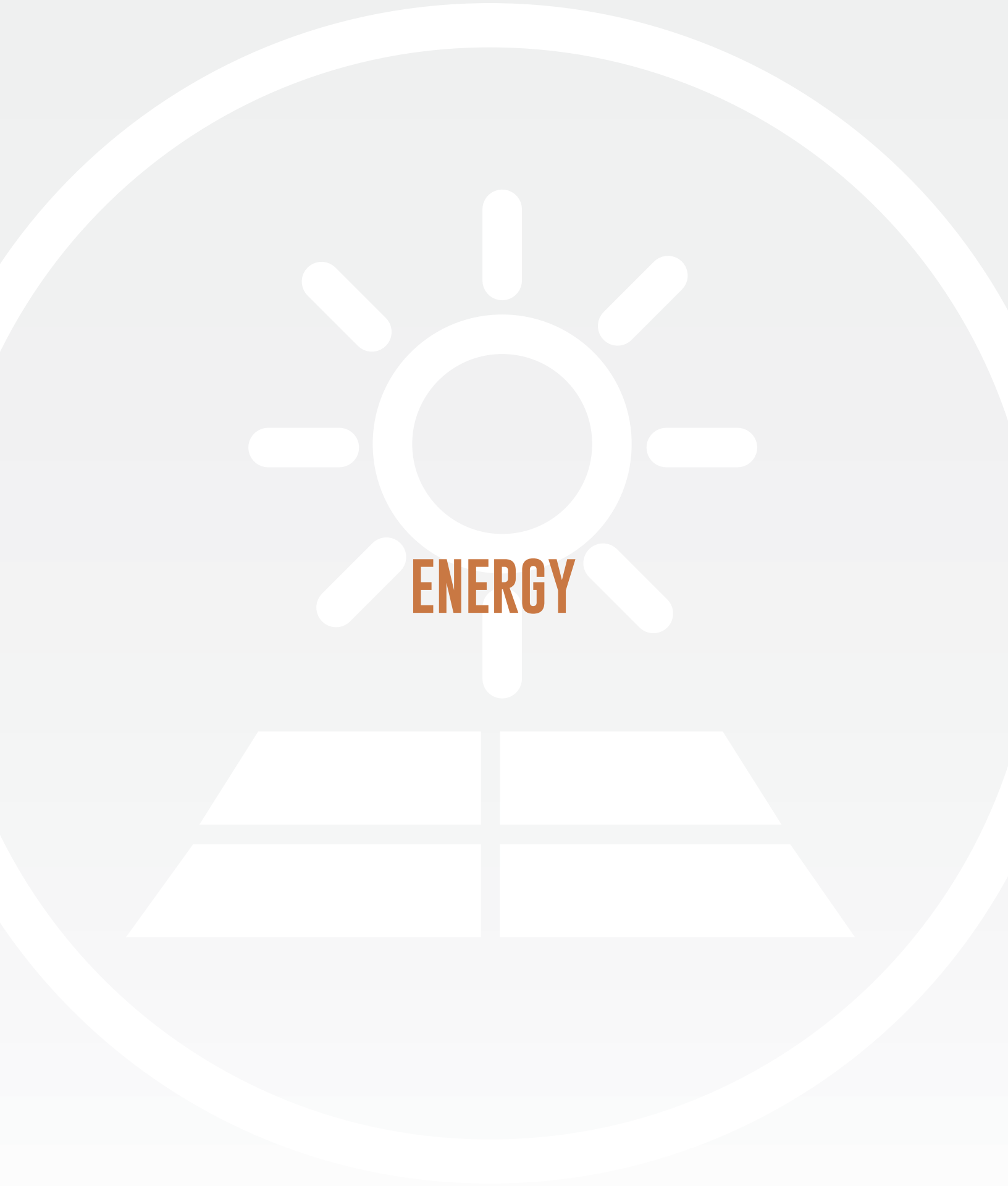

ENERGY

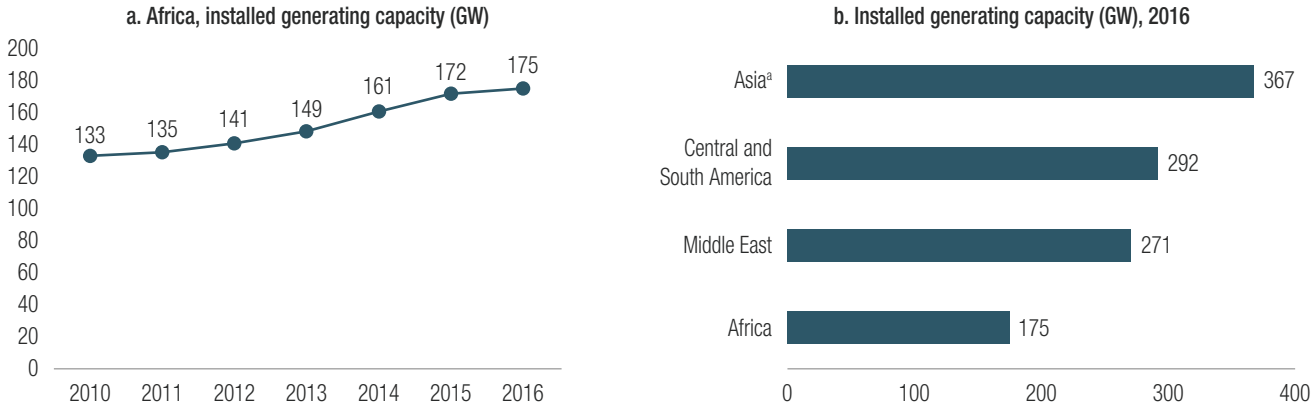
4 ENERGY

I. ABUNDANT RESOURCES BUT INSUFFICIENT CAPACITY

Energy capacity and use in Africa are the lowest in the world. Although the continent's power generation capacity grew 32 percent between 2010 and 2016 (figure 4.1, panel a), at 175 gigawatts it is the lowest among all developing regions (figure 4.1, panel b) (EIA 2016). Africa accounts for 16 percent of the world's population, but has only 2.8 percent of the world's power generation capacity. Some 25 Sub-Saharan African countries face an energy crisis.[1]

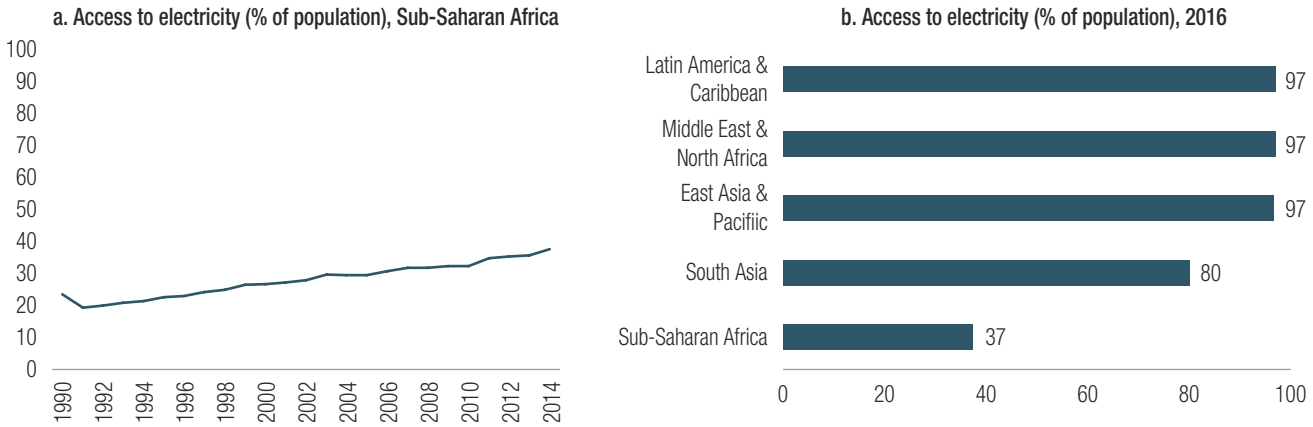
Household connections to the power grid are scarce in Sub-Saharan Africa. Although the share with access is slowly rising, only 37 percent of the population in Sub-Saharan Africa had access to electricity in 2014 (figure 4.2, panel a), which is far less than in any other developing region (figure 4.2, panel b). As a result, more than 600 million people in Sub-Saharan Africa—almost two-thirds of the population—live without electricity. Most of them are in rural areas where there is no grid-electricity, and expansion is financially and logistically impractical (Eberhard et al. 2011). Without radically increased energy production, it will be difficult for Sub-Saharan Africa to achieve the Sustainable Development Goals for energy, including "ensure universal access to affordable, reliable, and modern energy services" by 2030.[2]

FIGURE 4.1: Installed Generating Capacity



Source: Adapted from EIA 2016.
Note: GW = gigawatts.
[a] *Excluding India and China.*

FIGURE 4.2: Access to Electricity



Source: World Bank.

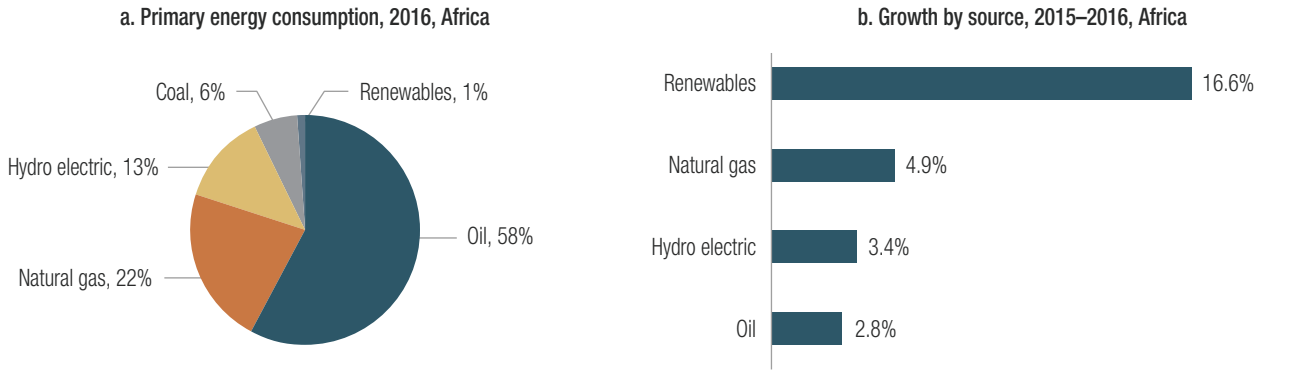
The lack of grid and off-grid electricity results in increased use of kerosene, candles, wood, and coal for cooking and lighting in Africa. Use of these materials has serious health, safety, environmental, and socioeconomic consequences, and disproportionally impacts women and children (Mills 2016). More than 3.5 million Africans die yearly due to pollutants or fires from liquid fuels for lighting and cooking (Akon Lighting Africa 2015).

The weakness of the African energy sector constrains economic growth and development (Castellano et al. 2015).[3] Electricity is a critical concern for businesses in Sub-Saharan Africa; after access to finance, electricity is listed as the second biggest problem for enterprises in the region.[4] Although Sub-Saharan Africa is improving in some areas of its business environment, it is performing poorly in electricity. It takes an average of 130 days to get a new electricity connection, and African consumers and businesses have the highest duration of outages in the world (World Bank 2015). Relative electricity prices are by far the highest among all regions, equivalent to almost 4,000 percent of gross domestic product (GDP) per capita.

Although Sub-Saharan Africa faces an energy crisis, it has abundant low-carbon and low-cost energy resources (Eberhard et al. 2011). The biggest potential energy source is water. Over 90 percent of Africa's economically viable hydropower potential, equivalent to about one-tenth of the world's total, is unexploited (Eberhard et al. 2011). Hydroelectric accounted for 13 percent of primary energy consumption in the region in 2016 (BP 2017). The largest sources of energy consumption in the region are oil and gas (figure 4.3, panel a). Although most Sub-Saharan African countries have thermal power stations, only a few use local oil and gas resources. Instead, most countries rely on imports, with a few exceptions (such as Nigeria and Angola).

Sub-Saharan Africa accounts for less than 5 percent of global oil reserves (BP 2017). Gas reserves in the region, mainly in Nigeria, make up less than 4 percent of the world's total, and gas production is an even smaller proportion (BP 2017). The only nuclear power station in the region is in South Africa, accounting for just 3 percent of South Africa's primary energy consumption (BP 2017). Geothermal has some potential in a few places, such as the Rift Valley in Kenya. The continent has abundant renewable energy resources, especially solar and wind. Due to declining equipment costs, greater efficiency, and innovative business models, solar in particular is rapidly expanding as an attractive solution for providing off-grid power in rural areas throughout

FIGURE 4.3: Primary Energy Consumption, Africa



Source: Adapted from BP 2017.
Note: The graphs exclude Algeria, the Arab Republic of Egypt, and South Africa.

the region (McKibben 2017). Solar and wind renewables are the fastest growing source of primary energy consumption on the continent (figure 4.3, panel b).

Africa needs huge investments to increase energy production. Compared with other sectors, power sector investment needs are high: they are 4.5 times larger than in the information and communications technology sector and approximately double the investment needs in the water, sanitation, and transport sectors (Eberhard et al. 2011). It is estimated that Sub-Saharan Africa needs to invest US$41 billion a year to meet the needs of its power sector, equivalent to over 6 percent of GDP (Gratwick et al. 2016). Although public utilities have traditionally been the largest source of power generation in the region, the investment required exceeds the funding capacity of the public utilities, making private investment critical for expanding energy supplies. Private sector investment in the sector is increasingly channeled through independent power projects (IPPs), which have spread throughout the continent and are present in 17 countries (Gratwick et al. 2016).

Given that Africa is the fastest growing region in GDP and population, there is increasing demand for energy to sustain such growth. Africa needs to follow a different trajectory to boost its energy sector. One challenge is the region's large rural population. Analysts used to believe that energy leapfrogging is a misconception and energy transitions in rural areas were incremental processes that depended on technical, organizational, and institutional factors and the capacity to absorb technologies (Murphy 2001). Additionally, the context of rural areas, such as low incomes and resistance to change, was seen as a barrier.

Four trends have emerged recently that are noticeably increasing the potential for leapfrogging in the energy sector. The trends are based on the confluence of technological change that is dramatically (a) reducing the cost of renewable energy, (b) improving the efficiency of appliances, (c) increasing the intelligence of power infrastructure through digital technologies, and (d) enabling decentralized service provision. Combining these factors with technology customization and innovative financing can radically effect socio-technical transitions to energy solutions (Relman et al. 2010). Applying spatial-economic analysis to the intense changes that energy technologies have experienced can help identify the least-cost rural grid, minigrid, and off-grid electrification options to end energy poverty in Sub-Saharan Africa (Szabó et al. 2013). This

will require complementary institutional, regulatory, and financial innovation.

II. Power Leaps

This section looks at leapfrogging experiences (that is, significant leaps in electricity production and access) through a regionwide initiative deploying off-grid electricity, an IPP in Ghana, and Rwanda's accelerated electrification initiatives. Leapfrogging was triggered by innovations in technology, project design, and regulation.

Regionwide Initiative

Lighting Africa is a World Bank/International Finance Corporation (IFC) initiative that was launched in Kenya in September 2007. The initiative aims at supporting the global lighting industry to catalyze a market for off-grid lighting products tailored to the needs of African consumers. The program's mission was to make affordable, environmentally sustainable, durable, and safe lighting available to the masses. The project design incorporated lessons from earlier IFC and donor grant-based solar lighting projects.

Lighting Africa is considered innovative on two levels. From a market development perspective, the project transformed the solar lamp market in Kenya by making modern, good quality, and affordable lighting products available to the very poor. It also demonstrated the commercial viability and sustainability of the approach to address the lighting needs of the base of the pyramid, in contrast to donor-subsidized lending for the purchase of solar lamps. To achieve viability and sustainability, Lighting Africa considered constraints along the entire supply chain (including market intelligence; business development support to manufacturers and distributors; development of international quality standards in product design, quality testing, and certification; and consumer education and financing). The pilot provided valuable lessons that were used to adapt the design and implementation of the initiative. By 2016, the project had been deployed in 11 Sub-Saharan African countries, affecting almost 21 million people (4 percent of those with access to electricity) (figure 4.4). The project aims to reach 250 million more people by 2030 (equivalent to 42 percent of those without access to electricity).

FIGURE 4.4: Lighting Africa's Impact as of December 2016

20,473,000[a]	**People in Africa who are currently meeting their basic electricity needs** through off-grid solar products meeting Lighting Global Quality Standards
13,285,000	**Quality-verified solar lighting products sold** through local distributorships in Africa since 2009
3,986,000	**Metric tons of GHGs avoids in Africa;** the CO_2-equivalent of taking 841,977 cars off the road for a year

Source: https://www.lightingafrica.org/about/our-impact/.
Note: CO_2 = carbon dioxide; GHG = greenhouse gas.
a Basic electricity needs are defined according to the Multi-Tier Framework as providing light for at least 1,000 lumen-hours / day and sufficient energy to keep a well-used mobile phone operational. This result is based on products sold in the last 3 years only. Some of these users also enjoy additional energy services such as multiple light points or the ability to power a TV or a fan. The impacts were reported using a calculation favored by many in the industry: number of products sold x 5 (average household size), which would give a result of 66,425,000 people with access to a quality verified solar light.

The project has also had important health, safety, and environmental benefits, such as reducing toxic fumes from kerosene lamps and paraffin, enabling children to study and do homework at night, and helping households and small businesses to save money by reducing kerosene purchases (Independent Evaluation Group 2016). The success of Lighting Africa has now spawned Lighting Global, to spread off-grid, solar-based electricity to other regions. Innovation has also been triggered by solar startups using mobile networks to manage generators and mobile money for consumers to make micro payments for use (Vodafone 2015). There were

over half a dozen of these new solar utilities raising venture capital of more than US$200 million in 2016, up from just US$19 million in 2013 (McKibben 2017).

IPPs in Ghana

In 2005, the Ghanaian government promulgated an amendment to the Act governing the country's main electricity utility, the Volta River Authority. The amendment, which was made in the context of the government's power sector reforms, largely restricted the Volta River Authority to the generation of electricity. This created the opening for attracting private sector investment into the energy sector through IPPs. Sunon Asogli Power Plant, located in Tema, around 20 kilometers from Ghana's capital, Accra, is one of the IPPs created by the reform.

Sunon Asogli Power Plant was the first power plant project in Africa to be directly invested and operated by a Chinese company. The project was jointly financed by the China Africa Development Fund (40 percent) and Shenzhen Energy Group (60 percent). In 2010, the 200-megawatt gas-fired generating units for phase I were put into commercial operation, with annual production of more than 1 billion kilowatt hours. The installed capacity of phase II, which started generating power in March 2017, is 360 megawatts. The construction of phase II was completed in less than a year, the fastest ever for a similar size project in Africa (*Energy China* 2016).

Four main factors influenced the investment in the Sunon Asogli Power Plant. First, with a stable political environment and rapid economic growth, Ghana was considered one of the most attractive African countries for foreign investment. Second, the government encouraged foreign investment, including 100 percent ownership in the power sector, to ameliorate a shortage of funding. Third, the project benefitted from cooperation with the China Development Bank, which financed the plant and the shareholders. The shareholders guarantee the loan, protecting the China Development Bank against market risks. Fourth, the business model made economic sense, with tariffs recovering the cost of operating the plant. Sunon Asogli plays an important role in meeting Ghana's power demand, with the potential to supply nearly a fifth of the country's power needs. The US$560 million project was the seventh largest private sector investment in the country.[5]

Initiatives in Rwanda

Although access to electricity remains low in Rwanda, at around half the Sub-Saharan Africa average in 2014, it nonetheless grew over 300 percent between 2005 and 2014, which is cited as an incredible achievement.[6] The impressive growth is tied to the adoption of a new Electricity Sector Wide Approach by the government in 2009. The Electricity Sector Wide Approach had several novel features, including joint coordination, a specific timebound target (16 percent access to electricity by 2013), a prospectus to attract investment, and strategies to reduce electricity costs through technical standards and geospatial analysis. The sector-wide approach was operationalized through the Electricity Access Rollout Program, coordinated by the national electricity utility, and supported by several development partners. The electrification rate target was reached a year early, rising to 20 percent by 2014. The second phase of the Electricity Access Rollout Program has an even more ambitious target, aiming for electrification of 70 percent by 2018, using a combination of grid and off-grid solutions. A key leapfrogging condition has been effective coordination among stakeholders in planning, financing, and implementation (Malik, Banerjee, and Baringanire 2014).

III. Preconditions for Powering Africa

With abundant energy resources, there is considerable potential for increased power generation in Africa.

More so than in other sectors, policy and regulatory challenges are the main impediments to leapfrogging in the region. Enabling leapfrogging in the African energy sector will require modernization of institutions, regulations, and finance.

Market reforms are crucial for creating an attractive environment for investment. This includes a sector *regulatory agency* for oversight and instilling a transparent framework to attract investment (Gratwick et al. 2016). The regulator needs to create an enabling *competition* environment to establish routes for investment in the sector. The lack of funding for the power sector in Africa is often because investment options are nonexistent rather than a shortage of capital. Market entry in the sector can be facilitated through the structural separation of generation, transmission, and distribution, which is lacking on the continent (Gratwick et al. 2016).

Another aspect of competition relates to the procurement of power projects. Competitive procurement increases transparency and lowers costs (Gratwick et al. 2016). Although tenders or auctions can be complex to design compared with unsolicited or directly negotiated contracts, the latter tend to have more drawbacks over time (for example, higher prices, contract disputes, and opaqueness). The challenges of competitive procurement can be overcome through outsourcing to transaction advisors until sufficient national capacity is developed. Most African nations now have electricity legislation that allows for the participation of the private sector. Regulators need to ensure that the playing field is level and guard against anti-competitive behavior of state-owned incumbents. They also need sufficient resources—human and financial—and independence. Skills are critical for effectively managing the complexities of the energy sector.

Energy sector *planning* is critical to ensure that investment sustains economic growth on the continent and factor in the consequences of climate change and the emerging potential of off-grid electricity. This requires expertise in forecasting demand and determining optimal supply options within the time constraint for identifying projects, obtaining funding, and deploying energy capacity. Ongoing updates are needed for planning software to ensure that it is relevant for changing demand and costs; the plans need to be revised on a regular basis to adjust to market conditions.[7] Planning should be neutral and, if it is entrusted to a utility, there should be oversight to ensure that the strategies represent the best outcome for the country. At the same time, plans should be flexible, with multiple options. The African nations that have attracted the most investment into their energy sectors have a range of policies and structures (Gratwick et al. 2016). Appropriate skills are needed for planning that cross a range of disciplines, such as engineering, law, meteorology, finance, economics, and data analytics.

Improving the financial sustainability of *public utilities* in Sub-Saharan Africa is critical. This is particularly important for the success of private sector investment through IPPs, since they rely on the "off-taker," typically a public utility, to get the power transmitted and distributed. Improvements are needed in areas such as governance, efficiency, and billing and collection (Gratwick et al. 2016). Better collection, transparency, and dissemination are needed for metrics measuring electric utility performance to diagnose weaknesses objectively (World Bank 2009).

Tariff policy is critical not only for the viability of power utilities, but also for attracting new investment in the sector. The challenge is finding a model that balances affordability and access with investment needs. Logic suggests that tariffs should increase with rises in consumption; yet, in countries in Sub-Saharan Africa, tariffs stay the same or even decline, making it impossible for utilities to recover costs, let alone make future investments. According to a survey of top managers in the African energy sector, less than a third of the countries in the region had cost-oriented tariffs (PwC 2015). The structure of tariffs, including the ratio of fixed charges to consumption charges, also merits

scrutiny. It should be ensured that fixed charges do not discourage demand, while at the same time recovering some of the costs of building distribution networks to users. If subsidies are required, they need to be well designed. Energy subsidies account for a significant portion of government resources in the region, often benefit the richest, and create disincentives for maintenance and investment (Alleyne and Hussain 2013).

Capacity building is needed in *climate change finance*, which is critical for the implementation of clean energy solutions. Although billions of U.S. dollars have been raised globally for climate change, African countries have faced difficulties accessing the funds and applying them to local needs. One challenge is that although resources such as the Adaptation Fund and the Green Climate Fund can channel resources to national institutions, these institutions need to meet specific standards. Of the 45 official entities working with the Green Climate Fund, fewer than 10 are in Africa (African Development Bank 2017). The Green Climate Fund is offering capacity-building support through a readiness program, and development partners have similar initiatives. African countries can also learn from each other by sharing experiences with the processes that national agencies have undertaken to gain accreditation.

IV. Future Research

Clean energy goals and the recent rapid progress of off-grid electricity have changed the energy equation for Sub-Saharan Africa. The recognition of climate change impacts and commitments in the Paris Agreement will impose requirements on countries in the region in areas such as reducing carbon emissions and carbon trading. This would suggest even more of an impetus to exploit clean energy, such as the continent's vast hydroelectric potential. However, climate change already seems to be affecting weather patterns in the region, triggering droughts, with ramifications for waterpower. The rise of renewables, especially solar for off-grid electricity, has been somewhat unexpected and is changing the energy scenario for rural areas. Perhaps because these issues are relatively recent, there is scarce literature about their impacts and how they will affect national energy strategies going forward.

Digital technologies have many applications in energy, such as smart grids[8] and smart metering. Mobile networks have been critical in the surge of off-grid solar systems being deployed across Africa. Mobile networks provide machine-to-machine communications that allow solar power generators to be controlled remotely to check for malfunctions, install software updates, and cut off the system when consumers do not pay (Vodafone 2015). Mobile money has also been instrumental for the off-grid business model, by allowing remote rural users to make incremental payments for energy consumption (GSMA 2017). At the other end of the spectrum, some energy utilities are leasing the spare ("dark") fiber optic cable in their networks to telecommunications operators as an attractive side source of revenue.[9] There is scope for wider dissemination of these experiences.

Endnotes

1 See: "Fact Sheet: The World Bank and Energy in Africa," at: http://go.worldbank.org/8VI6E7MRU0.

2 http://www.un.org/sustainabledevelopment/energy/.

3 Although there is a link between energy and economic output, the direction is unclear. An analysis of data in Ghana finds that increases in per capita income resulted in higher energy consumption, a growth-led-electricity hypothesis (Adom 2011).

4 See "Enterprise Surveys" at: http://www.enterprisesurveys.org.

5 https://ppi.worldbank.org/snapshots/country/ghana.

6 World Bank. 2017. *Rwanda – Renewable Energy Fund Project*. http://documents.worldbank.org/curated/en/684571498183375303/Rwanda-Renewable-Energy-Fund-Project

7 Including climate change factors such as temperature increase, rainfall variability, and carbon dioxide emissions. See: CRIDF+, "Building Regional Climate Resilience through Electricity Trading and Related Infrastructure." http://www.sera.org.sz/images/RERA%20CRIDF%20Presentation%2025%20November%202015%20Swaziland.pdf.

8 https://www.intel.com/content/www/us/en/energy/iot-smart-grid-paper.html.

9 For example, Kenya Power earned K Sh 1 billion (US$11 million) between 2010 and 2014 from leasing fiber. By June 2014, it had installed more than 1,800 kilometers of fiber optic on high-voltage power lines to manage the national power grid. The extra capacity is leased to telecommunications service providers. See "Kenya Power Earns Shs. 1 Billion from Fibre Optic Business," Press Release, June 19, 2014. http://www.kplc.co.ke/content/item/246/kenya-power-earns-shs.1-billion-from-fibre-optic-business.

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FINANCE

5 FINANCE

I. A SECTOR IN NEED OF CHANGE

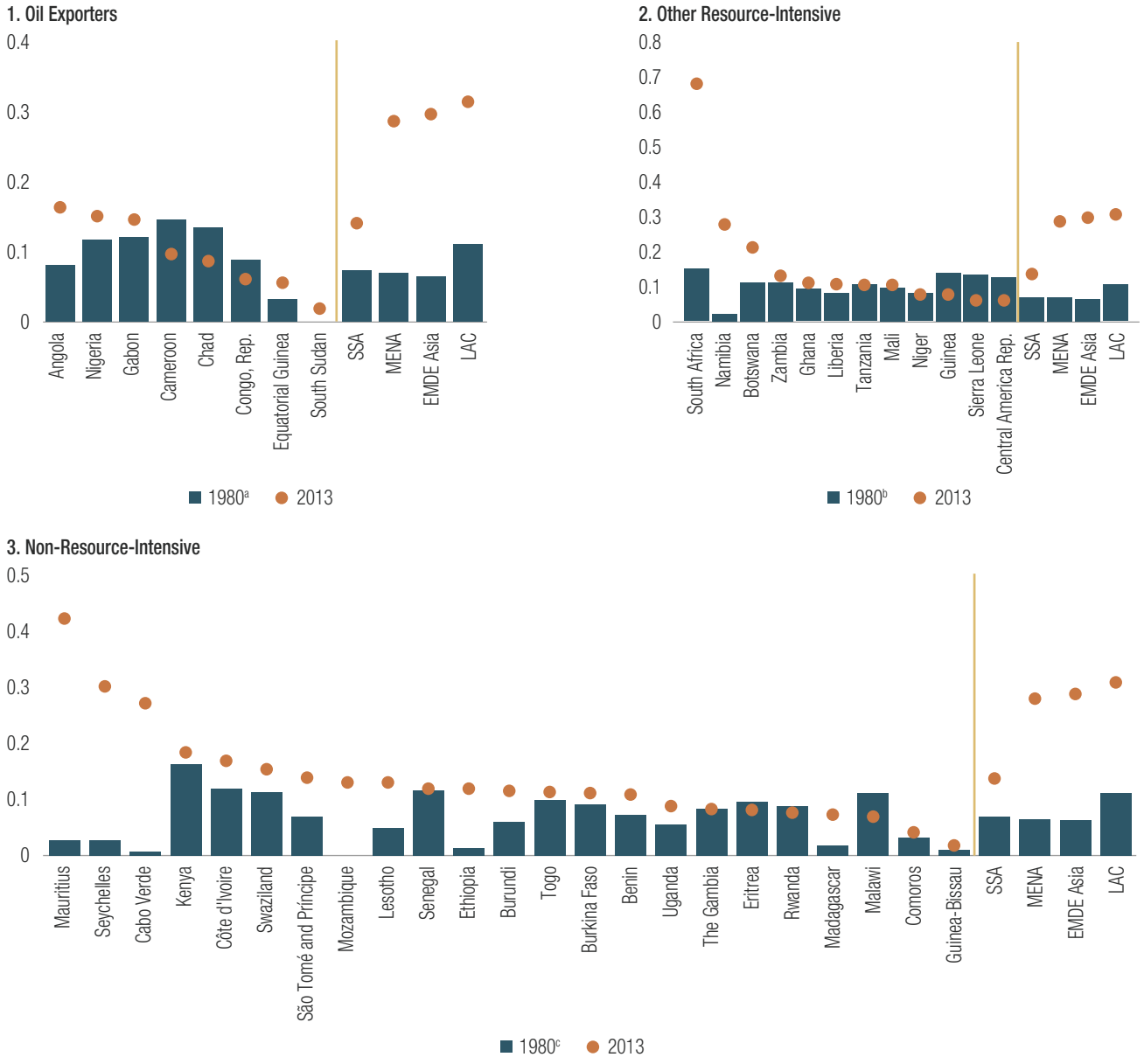
It is unanimously recognized that access to finance is key for inclusive economic growth. Foremost, a developed financial system reduces the cost of financial intermediation, hence enhancing the efficiency of transforming savings into investment. This increase in efficiency lowers interest rate margins, thereby raising the availability of credit to firms and households. Second, in reducing savings held in the form of unproductive liquid assets, financial intermediaries may positively influence savings behavior. Thus, a developed financial system increases households' savings rates by providing attractive risk-return combinations, which should induce households to save more and, in turn, stimulate investment and consequently higher economic growth. Third, a well-functioning financial system improves financial intermediation, leading to a better allocation of resources across investment projects, as it provides economic agents with a mechanism that allows for hedging, trading, and pooling risk, thereby raising the level of investment and economic growth. In Africa, there is very little formal savings mobilized and even less credit allocated to productive firms, and as a result economies are not diversifying or growing at a pace one sees in East Asia.

A vibrant financial system promotes economic efficiency, thus facilitating the growth process. This is particularly relevant for Africa, where financial deepening and broadening can contribute to poverty reduction and help the region move from low-income status toward middle-income and emerging market status (Beck et al. 2011).

Financial markets in Africa are considerably less developed than those elsewhere in the world, according to virtually all indicators of financial development. The development and financial inclusion gaps are wide in Africa (Allen et al. 2016). In Sub-Saharan Africa, only 34 percent of those ages 15 years and older have an account at a formal financial institution (Demirgüç-Kunt et al. 2014). In the nonbank finance area, for instance, based on the standard measures of trading activity and capitalization, most African stock markets are quite thin, with low levels of liquidity.

There is also a lack of access to credit for small and medium-size enterprises (SMEs) across the region. Some 40, 18, and 9 percent of small firms in Ghana, Kenya, and South Africa, respectively, cited access to finance as a barrier to the growth of SMEs (Hansen et al. 2012). Per the World Bank's Doing Business report, the distance to the frontier for "Getting Credit" shows that in 2017, Sub-Saharan Africa was 63 points from New Zealand (the frontier country), the second lowest performing region after the Middle East and North Africa.[1] Rwanda is a rare example of good performance in the region, ranking second for reasons such as having a private credit bureau, including credit scoring and flexibility in the types of debts and obligations that can be secured through a collateral agreement.

FIGURE 5.1: Sub-Saharan Africa: Financial Development Index, 1980–2013



Sources: Sahay and others 2015; IMF staff calculations.
Note: The index is from 0 (least developed) to 1 (most developed). EMDE = emerging market and developing economies; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SSA = Sub-Saharan Africa.
[a] For Angola, 2000; for Equatorial Guinea, 1990.
[b] For Guinea and Namibia, 1990.
[c] For Eritrea, 2000; for Mozambique and São Tomé and Príncipe, 1990.

Currency markets in many Sub-Saharan African countries remain risky and are devoid of liquid, long-term investment instruments. Regular institutional investment in local currency debt in these countries tends to be disadvantaged due to volatile exchange rates and the risk of currency depreciation, and inadequate market infrastructure, among others. Thus, international investors command greater returns to compensate for

taking these risks, which often makes local currency financing prohibitively expensive. Consequently, governments and private sector participants are constrained to borrow in foreign currencies from donors or through the capital markets, thereby exposing them to currency risk. This applies to entrepreneurs and households who take out microloans as well and may have to borrow in foreign currency.

Based on a comprehensive measure of financial development (Sahay et al. 2015), which considers financial institutions and markets, the financial system in Sub-Saharan Africa trails other regions, although there has been some modest acceleration over the past several years (figure 5.1). The index shows that some middle-income countries, like Mauritius, Namibia, Seychelles, and South Africa, have seen rapid financial development since the 1980s, yet less progress has been made within other groups in the region. In countries like the Central African Republic, Cameroon, Chad, and Sierra Leone, the current level of financial development is lower than it was in the 1980s, due partly to civil conflicts or change in the relative importance of state-owned enterprises. For some countries, for example, Kenya, the level of financial development may be understated, since the index does not fully capture the recent impact of mobile payment systems.

The African banking sector is characterized by high spreads, short tenure, and general risk aversion, and does not offer adequate products, with its lending activities being concentrated in certain sectors. This culminates in scenarios where banking systems tend to have high levels of liquidity, but provide little lending to SMEs (Pougue and Bernasconi 2013). SMEs in Sub-Saharan Africa are also often unable to provide adequate financial statements and quality collateral, limiting their access to finance from formal financial institutions (Sacerdoti 2005). The absence of credible credit bureaus in most countries and the concomitant effect on interest rates further hinders SMEs from gaining access to finance (Bass and Schrooten 2005). The lack of access to credit for SMEs in Sub-Saharan Africa is further reflected in the data on bank and domestic credit to the private sector (table 5.1). Based on data for 2015, Sub-Saharan Africa trails other developing regions in both indicators of financial development.

In a similar vein, equity financing is limited, as portrayed by the relatively low private equity penetration in Africa. For instance, in 2014, the ratio of private equity investments to gross domestic product (GDP) across Sub-Saharan Africa stood at a meager 0.12 percent, compared with 0.21 percent in South Africa, 0.81 percent in the United Kingdom, and 1.23 percent in the United States (KPMG and SAVCA 2015).

TABLE 5.1: Bank and Domestic Credit to the Private Sector

	Domestic credit to private sector (% of GDP)				Domestic credit to private sector by banks (% of GDP)			
Region	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**
East Asia & Pacific (excluding high income)	97.0	97.9	111.8	140.5	96.5	97.7	110.4	139.1
Europe & Central Asia	–	95.8	106.6	95.4	–	95.5	105.9	94.7
Latin America & Caribbean	25.5	26.0	40.1	49.3	24.8	24.2	36.9	45.7
Middle East & North Africa (excluding high income)	34.9	33.0	39.4	42.1	34.4	32.8	39.1	41.8
South Asia	27.3	38.3	47.0	47.3	27.3	38.3	47.0	47.3
Sub-Saharan Africa	57.0	61.1	54.7	45.7	32.9	33.3	32.0	28.9

Source: World Bank, World Development Indicators.
Note: GDP = gross domestic product.

A key characteristic of the financial system in the region is the crowding-out of private sector financing by the public sector. Financially constrained governments tend to offer high real interest rates on government bonds, which become more attractive to banks when compared with providing credit to SMEs. This crowding-out can be direct when the banking sector purchases a substantial share of bonds, or indirect when the government bond rates set the risk-free floor for private sector financing, which serves as a disincentive to borrowing. Therefore, banking is very expensive in Africa, reflected by high interest spreads and margins compared with other regions in the world (Beck et al. 2009). Moreover, extremely low returns on deposits have discouraged savings and limited the ability of the banking sector to perform its intermediary role. This has been a contributory factor in limiting the development of the financial system, which remains narrow and illiquid, with limited access to long-term financing and, consequently, a hindrance to local debt financing. The financial systems also lack innovative financial instruments, especially those geared toward SMEs, which constitute most businesses in the region and tend to be confined to informal sector financing because of inadequate financial services.

Several factors have served as impediments to the development and efficiency of the financial system in African countries. The institutions required for building an efficient financial system, including robust contractual and informational frameworks and incentive-compatible regulation and supervision, are weak (Beck, Fuchs, and Uy 2009). The inadequacy of the regulatory framework in these countries has produced a concentrated banking sector, very low intermediation rates, and inefficient collateral registry systems that further hinder access to credit for businesses and individuals.

The benefits of relatively broad and deep capital markets, complemented by an active derivatives market, can be captured by factors such as lower pricing, reduced cost of capital, mitigated risk exposures, and increased liquidity, among others. The development of the financial system in emerging markets is often characterized by disintermediation from the traditional financial intermediaries—mostly commercial banks—as well as by extended maturities of funding that can better match the expected lifespan of large projects and investments.

Financial innovation can provide opportunities for leapfrogging in financing and make capital more efficient, risk management more targeted, hedging better matched, and trading less costly. It should also contribute to the unbundling of risk, improved liquidity, broader access to capital, and optimal portfolio diversification. However, financial innovation is not without dangers, as it is often driven by risk and, in return, incentives at the level of the individual, structured financier or institution. The financial incentives of individuals, coupled with advancements in technology and financial engineering skills, can result in situations where new instruments outpace the existing market and regulatory infrastructure.

Nevertheless, there is an advantage for emerging markets more generally, and particularly for countries in Sub-Saharan Africa in pursuing financial innovation, to trigger the transformation for leapfrogging in the financial sector. Conventional financial services have room to be more inclusive and innovation can offer viable services to those at the bottom of the pyramid. Moreover, development of the formal financial services industry will expand access to finance, and innovation in the financial sector is critical in this regard.

II. Leapfrogging Finance

There has been a paradigm shift in the financial sector across the globe over the past decade, as the ecosystem was created for disruptive innovation in finance. This section documents country experiences in financial innovation, and its impact on financial inclusion and access to financing. Access to finance has been made

easy and affordable via the use of mobile phones, the best example of financial leapfrogging in Africa. Other examples of financial leapfrogging include the relatively rapid take-up of risk index insurance in some African countries, including innovative payment and collateral options, and lowering the time to develop local currency–denominated bonds.

M-Pesa, launched in 2007 by Safaricom in Kenya, ignited the mobile money revolution in Africa. The service allows customers to use a mobile phone to undertake deposit, withdrawal, and money transfer activities; pay bills; and purchase airtime. M-Pesa's initial innovation was to leapfrog the lack of financial services by exploiting existing telecommunications infrastructure and network subscriptions in Kenya, circumventing the expenses associated with storefronts and in-cash transactions. The service has expanded to include more advanced offerings, including ATM cash withdrawals, savings accounts, on-site retail payments, mobile ticketing for events, and corporate banking accounts. M-Pesa has spawned competing mobile money services. By 2016, 75 percent of the country's adult population had a mobile money account, with transactions amounting to the equivalent of 4.5 percent of annualized GDP a day (Ndung'u, Morales, and Ndirangu 2016)). M-Pesa was a disruptive innovation that transformed banking in other countries, leading to an explosion of mobile money services across Africa, enhancing financial inclusion. M-Pesa also enabled innovations in other sectors, such as energy. One challenge with expanding off-grid solar energy in Kenya was that low-income citizens could not afford the upfront full cost of the solar panel. M-Kopa Solar, a company that supplies solar panels to low-income rural households, allowed customers to acquire a solar panel kit by making daily micropayments (less than 50 cents) using M-Pesa after an initial down payment of about US$35. After around two years of payments, the customer owns the solar panel kit.

At the same time, a responsive retail banking model with innovations aimed at the African context has proven successful in Kenya, as the example of Equity Bank demonstrates. Equity specializes in the provision of high-volume small loans at low interest rates. Micro-loans are available from as little as K Sh 500 (US$5.81) (*The Economist* 2012). Other innovations included waiving property ownership requirements for opening an account, flexible forms of collateral including personal belongings, and trucks with a satellite dish and a bank manager to go to places where there were no branches. Equity also provides free financial literacy programs. By 2011, Equity had provided US$750 million in loans to almost 300,000 SMEs.[2] Consequently, Equity's deposit accounts have increased to more than nine million, making it the second largest bank in the country (Central Bank of Kenya 2017).

In South Africa, the region's most sophistical banking sector has been at the forefront of various financial developments. The largest banks have an agreement under the Financial Sector Charter to provide a special bank account for poor households, called the Msanzi account. This initiative generated more than 3.3 million account holders in the first 18 months after its launch in 2004. Further, since 2007, foreign issuers can list rand-denominated bonds at the South African Bond Exchange, further opening toward foreign market participants. South Africa's securitization market has experienced growth and remained relatively healthy, aided by the heavy concentration of industry activity around the five major banking groups. South Africa has followed the global trend and witnessed unprecedented growth in its derivatives market, which includes exchange-traded derivatives and a well-developed over-the-counter market in derivatives. The South African Reserve Bank is beginning to review regulatory issues related to digital currencies such as Bitcoin.

Credit denominated in foreign currency carries risks for borrowing countries, especially concerning currency depreciation, which tends to increase debt burdens, as well as fluctuations in the value of currencies,

which could be unnerving for potential investors. The World Bank and International Finance Corporation (IFC) are addressing this by issuing local currency bonds, aiming at strengthening domestic capital markets by working with governments, regulators, capital market institutions, investors, and local financial institutions. The instruments include offshore bond sales in local currencies aimed at international as well as domestic investors, as well as domestic bond issues. The World Bank has issued about US$8.5 billion worth of bonds in 19 currencies since 2011, including in several African currencies, such as the Uganda schilling. Since 2002, IFC has issued bonds in 14 emerging market currencies around the world, including Rwanda. Given that a local currency bond issue takes several years to develop, IFC aims to reduce the time by standardizing the process. It notes that in Africa: "...there is a great desire to catch up. Some countries are impatient enough they want to leapfrog—they don't want to wait another 20 years to develop the market." (World Bank 2014)

Agricultural risk schemes have emerged to avoid situations where farmers resort to selling off valuable assets, like livestock and equipment, due to climatic events beyond their control. To address this challenge, index-based risk financing has been developed to hedge against specific climate-related events. Data on such events are tracked and payouts are triggered when deviations from historical averages reach preset levels. For instance, a significant drop in rainfall below the norm would be a trigger. The first government-level, index-based insurance was piloted in Ethiopia in 2006, spearheaded by the United Nations' World Food Program (WFP), with 26 weather stations monitoring rainfall throughout the country daily. The experience resulted in the Rural Resilience Initiative (R4), which was launched by WFP and Oxfam in 2011.[3] R4 currently reaches more than 43,000 farmers (about 200,000 people) in Ethiopia, Senegal, Malawi, Zambia, and Kenya. The initiative has introduced several innovations for rural insurance, including allowing poor farmers to pay for crop insurance with their own labor and using the insurance policy as collateral for better credit terms. R4 found that insured farmers in Ethiopia saved more than twice what those without any insurance saved, and invested more in inputs and assets. In Senegal, after two years of bad harvests, insured farmers were able to maintain food security compared with others exposed to the same risks. R4 aims to reach 500,000 farmers in the region by 2020.

The Women Entrepreneurship Development Project (WEDP) is an investment lending operation of the World Bank. WEDP's objective is to increase earnings and employment for women-owned enterprises in Ethiopia. It created the first women entrepreneur–focused line of credit in Ethiopia in 2013, disbursing about US$2 million in loans monthly. As of the end of 2015, more than 3,000 women entrepreneurs had taken loans, 64 percent of them being first-time borrowers, and more than 4,500 participated in business training. WEDP microfinance institutions improved their ability to appraise, which resulted in a decline in collateral requirements from an average of 200 percent of the value of the loan to 125 percent. Moreover, they are adopting and diffusing new techniques to improve their reach and service to women entrepreneurs. They are developing new loan products and recognizing new forms of collateral, such as vehicles, personal guarantees, and even business inventory. WEDP is introducing innovative credit technologies to lenders, such as psychometric tests, which can predict the ability of a borrower to repay a loan and reduce the need for collateral. This technology allows entrepreneurs who do not have collateral to take an interactive test on a tablet computer, which predicts the likelihood of repayment. A high score makes it possible to borrow without traditional collateral. Other banks are requesting the technology, and scaling-up could have a significant impact on access to credit in Ethiopia.

The Asian Bond Fund (ABF) is an example of a regional initiative designed to protect economies from damaging currency speculation while at the same time enhancing

bond market development. It is one of the first initiatives in the world where a regional organization contributed financial resources to setting up a bond fund. The 11 members of the Executives' Meeting of East Asia and Pacific Central Banks (EMEAP) launched the ABF in June 2003. The 11 central banks pooled US$1 billion to invest in dollar bonds issued by the EMEAP sovereign and quasi-sovereign borrowers in the EMEAP countries (Ma 2005). This was followed by ABF2, launched in 2005, which invested US$2 billion in local currency bonds. The bonds had the desired effect of drastically reducing currency speculation; they also helped develop the bond and local currency bond market in the region. Equally important was the catalytic role of ABF in collaboration and building trust among the region's central banks.

The ABF initiative is designed to facilitate greater financial integration in Asia, with the objective of promoting the diversity and efficiency of financial intermediation across countries. In 2008, a new Asian Bond Market Initiative roadmap was endorsed following the recognition that the existing activities had some shortcomings. The new roadmap focuses on promoting the issuance of local currency–denominated bonds, facilitating the demand for local currency–denominated bonds, improving regulatory frameworks, and developing the relevant infrastructure for bond markets. The Asian Development Bank has actively supported the development of local bond markets in Asia, through the provision of technical and research assistance to the Asian Bond Market Initiative, issuance of local currency–denominated bonds, issuance of the Asian Currency Note Program of US$10 billion, and support for online information dissemination.

During the years following the 2008 global financial crisis, two financial innovations were developed in China. These solutions comprise a development financing model supporting China's urbanization, and digital inclusive finance aimed at providing financial services to groups with limited financial options. The China Development Bank (CDB) has served as the facilitator of development financing. CDB has devised major development strategies for the economy through medium- and long-term credit, investment, and other financial services. In its development financing role, CDB has built a bridge between the government and the market, through the use of public credit to attract social funds for urbanization, economic transition, and stable development. Development financing has been a key instrument in China's urbanization strategy. For example, from 2004 to 2014, CDB issued loans amounting to 54 percent of fixed asset investment in China's public infrastructure, providing a capital guarantee for over half of the city construction projects.

Inclusive finance aims to provide services to groups with unfavorable economic circumstances and limited financial options. The ultimate objective is to facilitate economic growth of enterprises and families, eliminate poverty and inequality, and incorporate all persons needing financial services into the financial system. Alipay, a third-party mobile and online payment platform, is an example. Alipay was established in February 2004. In 2010, China's central bank issued licensing regulations for third-party payment providers and a separate set of guidelines for foreign-funded payment institutions. Alipay, which accounts for half of China's nonbank online payment market, was restructured as a domestic company to facilitate the regulatory approval for the license. In the fourth quarter of 2016, Alipay had over half the market share of China's US$5.5 trillion mobile payment market, by far the largest in the world. Alipay provides an escrow service, where consumers can verify their satisfaction with purchased merchandise before releasing money to the seller. Worldwide, more than 300 merchants use Alipay to sell directly to consumers in China.

Alipay has progressed with several recent innovations in digital finance. Quick Payment, launched in 2011, aimed to solve the problem of the low success rate and poor experience caused by complicated payment steps on online shopping platforms. Quick Payment

introduced a one-click solution, streamlining the process. Market response was favorable, and Quick Payment soon became a standard product for all payment institutions, including Tenpay and Chinabank payments, significantly improving the degree of inclusive digital finance in payments. Alipay also experimented with various technologies for offline small and micro businesses without Point-of-Sale machines. It implemented a Quick Response solution, where merchants can scan a customer's payment details using a smartphone, providing a convenient payment solution for many small and micro businesses in rural areas. Alipay is also providing payment platforms for other types of services, including in the medical field, where hundreds of institutions have access to Alipay. For example, Alipay is connected to insurance providers in the city of Shenzhen, where it established the first medical insurance mobile payment platform in the world.

III. Changes to Transform the Financial System in Africa

African countries will need to undertake several reforms to exploit the potential for leapfrogging. Empirical studies on the development of mobile banking in East Africa show that an enabling regulatory environment is essential for supporting growth in mobile money services and financial inclusion (Mlachila et al. 2016). Moreover, the leapfrogging experiences provide examples of policy measures that underpin innovation in and development of the financial system. The experiences of leapfrogging in finance also serve as the basis for options available to African countries to circumvent the challenges presented by underdeveloped financial markets through various instruments (box 5.1).

Regulatory bottlenecks can be tackled by establishing and enforcing laws and creating facilities that enable smoother credit flows. Investor confidence can be enhanced through the creation of credit bureaus that oversee repayment records. One of the major impediments to borrowing in Africa is the lack of collateral, not because of insufficient assets, but due to inefficient registration systems. Reliable credit registries, effective cadaster systems, and effective land title transfers are critical for the performance of financial intermediaries, particularly for assisting SMEs.

The banking system needs to be reorganized by opening the sector to competition, reviewing prudential ratios, and putting in place innovative savings and borrowing instruments adapted to local needs. A typical characteristic of the banking sector in African countries is the high concentration ratio; at an aggregate level, Beck and Cull (2013) estimate that the average market share of the five largest banks in the median African country was 81 percent in 2011. This oligopolistic structure has negative consequences, among which are high interest rate spreads, which crowd out credit to the private sector by making loans too costly. Mobilization of domestic resources is vital for investment and sustainable growth. Banks, as the primary channels of financial intermediation, have a key role to play in this regard. Thus, the banking sector needs to be reformed to increase competition and effective accommodation of the demand for credit from the public and private sectors, so that savings and resources can be channeled toward productive investment.

The gap between the informal and formal financial sectors needs to be bridged by formalizing microfinance institutions to help them scale up activities while developing financial products geared toward SMEs. The emergence of microfinance as a tool for financing the informal economy coincides with the growing understanding between nongovernmental organizations, development experts, and policy makers that a significant proportion of the population in developing countries has no access to financial services. Microfinance, which at first seemed to be a panacea, has demonstrated its limitations in scaling up operations. Thus, formal financial institutions need to adapt

Box 5.1: Financial Options for Leapfrogging

Several areas of finance present opportunities for African countries to leapfrog:

In *agriculture financing,* the opportunity relates to how effectivity such financing can be aligned to the agricultural production cycle. There are two options for this purpose. The first, *commodity collateralized finance,* uses commodities or, more broadly, inventories as collateral for lending. Commodities in this sense may already exist as stocks or inventories, but also could be pledges of future production. The use of digital technologies enhances the tracking of commodities, and the emergence of collateral management companies provides an additional level of comfort for financiers. This requires an enabling environment that promotes the use of commodities as collateral. The second option *links value chains to financial institutions.* As agriculture value chains in Africa become better organized, opportunities increase to introduce digital payments and collect information by anchor firms that could be used by financial providers of finance to facilitate efficient allocation of credit. This would require tripartite arrangements between farmers, anchor firms (for example, agribusinesses), and financial institutions.

Agricultural index insurance provides protection against climate shocks like drought, flooding, and irregular rainfall. Because of the need for on-site farm visits, the traditional agriculture insurance market largely fails to meet smallholder farmers' demand for affordable insurance. Satellite-based index insurance, when combined with mobile technology for registration and claims settlement purposes, has huge potential to meet the needs of these farmers. However, insurance companies need strong capacity building and training to develop sustainable index insurance products that are profitable and helpful for smallholder farmers. One example of support for capacity building is the Global Index Insurance Facility, which has delivered managerial and technical training for the insurance industry in Ghana and South Africa.

Financial inclusion can be enhanced via measures such as making government payments like conditional cash transfers through electronic channels; establishing or accelerating universal coverage of national ID systems, which facilitate not only opening bank accounts, but also making transactions using the accounts; and strengthening education programs to deliver financial and digital skills and literacy. One example is the World Bank's support for the Government of Kenya in the design of a platform to distribute government debt to retail investors through mobile phones. The instrument has been designed with minimum investment amounts that are accessible to lower-income groups.

Local currency financing in Africa has been constrained by the lack of incentives, policy coordination, and affordable solutions to enhance clearing and settlement connectivity and build effective secondary market architecture. A tailored solution can be developed by combining technology and knowledge based on lessons learned in other countries in (a) clearing and settlement technology used to integrate markets; (b) implementation of trading platforms; (c) design of market-making systems and alternative trading arrangements, such as call markets; (d) design of local currency indexes; and (e) participation of multilateral development banks as conveners in the development of investment products.

Infrastructure finance can be "leapfrogged" by developing unconventional financing solutions that do not need to wait for full-fledged capital markets. For example, the World Bank is supporting an approach in Kenya to mobilize long-term local institutional investors into infrastructure financing through alternative financing vehicles, such as debt funds and hybrid financing featuring long-term institutional investors and local bank co-financing. Another feature is a World Bank guarantee, which enhances projects to acceptable risk-return profiles. This financing solution provides the flexibility needed in markets

(*continued on next page*)

Box 5.1: Financial Options for Leapfrogging *(continued)*

that are not yet fully functional, as is the case across Sub-Saharan Africa, and leverages the benefits of a private-equity fund structure, but modified to accommodate features like those of fixed-income debt. Through an intensive training process, when the pipeline projects reach their financing phase, investors would be prepared and comfortable to invest in these infrastructure projects through a suitable investment vehicle to pool their funds. Credit risk guarantees are also useful for long-term financing, specifically when issuing local currency debt. Most importantly, through domestic debt issuance, countries can use and recycle their savings toward their investment needs rather than increase their external debt.

their products to local demand. Specifically, innovative financial tools that use technology such as mobile banking can also help in leapfrogging traditional financial services and reaching a larger population.

IV. Future Research

A potential method for promoting financial inclusion in sparsely populated areas is agent banking. A review of the Latin American experience suggests that agents have been effective in reaching the unbanked (AFI 2012). However, there have been no rigorous studies of the effects of agent banking, and certainly none for Africa.

Digital currencies such as Bitcoin could have a revolutionary impact in Africa as a solution to the unbanked population, high remittance fees, restrictions in cross-border payments, hyperinflation resulting in limited savings and investment opportunities, and problems with online payments. The International Monetary Fund is analyzing how distributed ledger technology (that is, digital currencies) could facilitate cross-border payments (He et al. 2017). Bitcoin is being used in Zimbabwe to leapfrog traditional banking (Antoni et al. 2015). Clearly, more research is needed in this area to explore the potential of digital currencies in Sub-Saharan Africa to stimulate financial sector leapfrogging.

Africa is characterized by the short-term nature of finance across the region, as illustrated not only in the balance sheet structures of banks, but also in the limited development of contractual savings institutions and financial markets. Although financial inclusion has dominated the recent policy debate and research agenda, the need for long-term finance for households, enterprises, and the government is enormous. Analysis is needed on the short-term nature of finance and potential remedies.

Research on financial inclusion has identified policy levers to improve access to and use of financial services by households and microenterprises. Moving forward, this line of research should go beyond microenterprises, in supply- and demand-side constraints. Although there is a large literature analyzing the financing constraints of firms of different sizes, there is less evidence on specific policies and interventions that have differential effects on firms of different sizes (Beck and Cull 2013).

Reform processes have been dominated by the global financial crisis and the fragility concerns of economies with developed, if not sophisticated, financial markets. Africa's fragility concerns are different and its reform capacity is lower. Some of the suggested or implemented reforms, such as centralizing over-the-counter trades, seem irrelevant for almost all African countries or might have substantially worse effects in the context

of shallow financial markets than in sophisticated markets increasingly dominated by high-frequency trading. An approach of best fit would be more appropriate than a best practice approach that blindly adopts international standards. The extent to which the prioritization of regulatory reforms according to risks and opportunity costs is relevant for financial deepening and inclusion is worth analyzing.

Another issue worth examining is globalization and cross-border bank regulation, given that the degree of financial integration of Africa compared with other emerging and developed countries has been increasing, as a region as well as intra-regionally. Identifying the cross-border links between countries is critical. The collection of data represents an important first step (Claessens and van Horen 2014). It is also critical to gain a better understanding of the channels through which cross-border banking can help deepen financial systems and foster better integration, and the channels through which cross-border banks can threaten financial stability.

The establishment of credit registries and the concomitant collection of an increasing amount of information on borrowers can generate data that could be a critical input into research, as is the case in other developing countries. These micro-level databases thus provide an important impetus for further research. They can enable assessments of various lending techniques, delivery channels, and organizational structures conducive to small-business lending. They can also be used to gauge the impact of specific interventions or policy reforms.

Endnotes

1 http://www.doingbusiness.org/data/exploretopics/getting-credit.

2 See "Equity Bank: Impact Case Study" at: http://www.igdleaders.org/reports/equity-bank-impact-case-study/.

3 See " R4 Rural Resilience Initiative" at: https://docs.wfp.org/api/documents/b9a3d33bd9974e5aaf01b11a3e3da410/download/?_ga=2.156293689.305589595.1504192173-1880160767.1504192173.

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GOVERNANCE

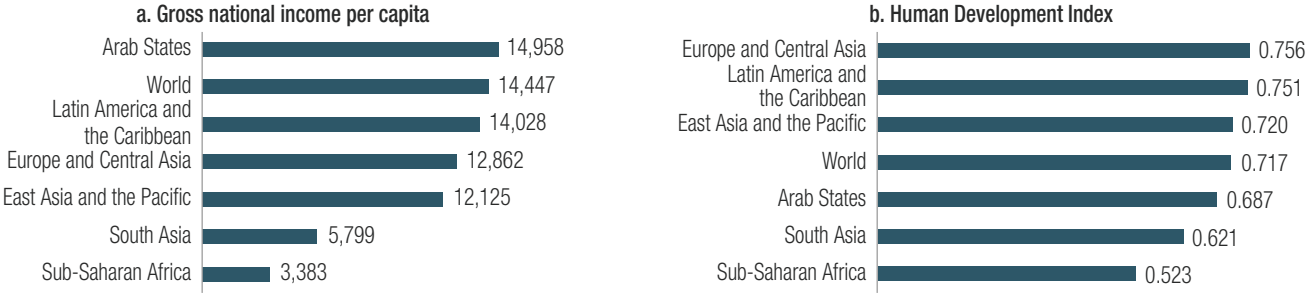
6 GOVERNANCE

I. DIGITAL TECHNOLOGIES: THE FOREMOST CHANGE

The World Bank defines governance "as the manner in which power is exercised in the management of a country's economic and social resources for development" (World Bank 1992). Good governance is critical for government and market efficiency, and this strongly influences economic development. The implementation and enforcement of laws, quality of institutions, and degree of transparency affect market-driven economic development. The Office of the United Nations High Commissioner for Human Rights (OHCHR) considers that there is no universal agreement about what constitutes good governance. OHCHR finds that, depending on the context, good governance includes "full respect of human rights, the rule of law, effective participation, multi-actor partnerships, political pluralism, transparent and accountable processes and institutions, an efficient and effective public sector, legitimacy, access to knowledge, information and education, political empowerment of people, equity, sustainability, and attitudes and values that foster responsibility, solidarity and tolerance."[1]

There is a consensus that good governance relates to the political institutional procedures and the results required to realize development goals, such as decent access to health, housing, food, education, justice, and security. The United Nations Development Programme believes that governance and human development are indivisible, and that good governance is a primary means of reducing poverty (UNDP 1997). The potential of good governance to improve economic and social development outcomes is of utmost relevance to Sub-Saharan Africa, which has the lowest per capita income and human development of any region in the world (figure 6.1).

FIGURE 6.1: Gross National Income per Capita and the Human Development Index, 2015



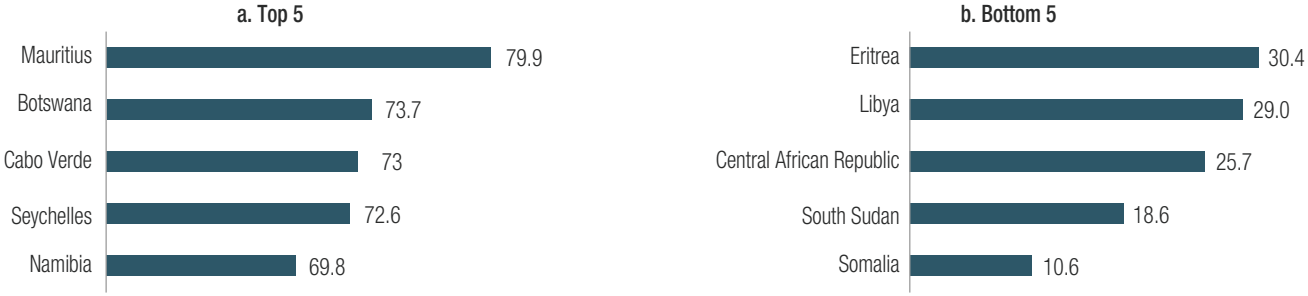
Source: Adapted from United Nations Development Programme data.
Note: In panel a, gross national income is based on 2011 purchasing power parity.

The Ibrahim Index of African Governance (IIAG) is a tool for measuring and monitoring governance in Africa. The IIAG defines governance as "... the provision of the political, social and economic public goods and services that every citizen has the right to expect from their state, and that a state has the responsibility to deliver to its citizens" (MIF 2016). The IIAG measures outputs and outcomes of government rule from four angles: safety and the rule of law, participation and human rights, sustainable economic opportunity, and human development. The latest results of the IIAG suggest that small populations positively affect governance, with the top five ranked countries in total having just five million inhabitants (figure 6.2, panel a) (Dahir 2016). At the other end, the worst-performing countries are all in a fragile situation (figure 6.2, panel b).[2]

Since 2000, the foremost change affecting governance has been advances in the use of information and communications technology (ICT). The Internet, mobile communications, and social networking have facilitated the transformation of public administration in some countries, and triggered a shift in the relationship between citizens and governments in others (UNDESA, UNDP, and UNESCO 2012). The potential of digital technologies for improving governance has been recognized for some time. In 2001, the African Development Bank described reasons for applying digital technologies to government processes: "... to improve the quality of service, increase the effectiveness of governments, and reduce costs" (Adesida 2001, 9). ICT is viewed as affecting democratization and democratic governance, macroeconomic and public sector management, and agriculture and environmental management. Potential impacts include "enlarging the democratic space, enhancing dialogue, facilitating inclusiveness, and by providing governments the tools to better perform their administrative and management functions" (Adesida 2001, 18). The digital divide between Africa and the rest of the world is noted as a major barrier to the application of digital technologies for governance.

Heeks (2002) points out that African governments have been using information technology for over four decades, and that progress in the use of ICT for governance is evolutionary rather than revolutionary. Nevertheless, the emergence of computer networking in the 1990s is a key innovation transforming the processing and communication of government data. Three impacts from the use of e-government include improving the internal workings of the public sector and reducing costs; improving communications with the public as voters/stakeholders or users of public services; and improving relationships between public agencies and other institutions, such as other public agencies, the private sector, and civil society institutions. Stakeholders need to understand the large gaps between project design and the reality of the African public sector. These "design-reality gaps" underlie failure. They arise due to the origin of e-government concepts and designs in developed countries, which have considerably different contexts compared with

FIGURE 6.2: Ibrahim Index of African Governance, Top and Bottom Five Countries, 2015



Source: Adapted from MIF 2016.

those in African countries. Some best practices may help to improve project success, but only if they are appropriate for African contexts.

The rise of digital technologies, especially social network applications, provides tools for citizens to push for improved accountability and greater transparency. Turianskyi and Gruzd (2016) find that increasing rates of cell phone use and Internet penetration in Africa facilitate access to information and reporting of issues. An example was the role of social media in North Africa for coordinating demonstrations during the "Arab Spring." Mobile features, such as cameras and GPS, can be powerful tools for citizen involvement. Cell phone cameras were used to record election results posted outside counting stations in Zimbabwe. Kenya's Ushahidi, an open-source software system using Google Maps, used geo-tagging to report incidents of voting irregularities during the 2008–09 election. Digital technologies have a global aspect in lobbying for better governance by aiding advocacy groups to organize across national boundaries (World Bank 2017).

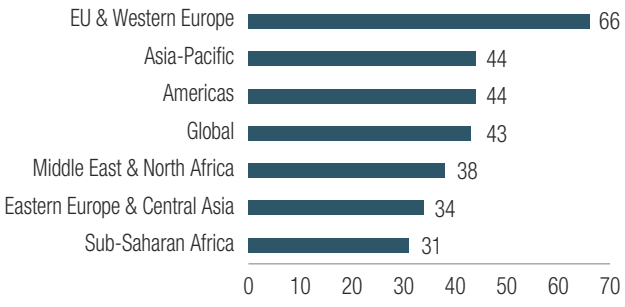
The digital divide across and within countries can result in those better provisioned with ICT having greater influence on and use of e-government (World Bank 2017). Designing public services for a wide audience and variety of ICT can mitigate this. In Kenya, the government partnered with mobile operators to support an application that works on older model cell phones to communicate with citizens living in remote areas without access to the latest technologies (Turianskyi and Gruzd 2016).

Depending on the legal and constitutional framework, governance may be decentralized. Some African countries are decentralizing, with greater power for provinces and municipalities. This moves governance from purely a federal matter to greater local involvement, with implications for the levels and types of digital technology applications. There are implications for leadership roles in the use of digital technologies for government. E-governance has the potential to enable local governments in Africa to engage citizens in greater participation in areas such as service delivery, taxes, financial management, land management, education, local economic development, citizen registration, and political inclusion (Waema and Adera 2011).

Corruption is a major, and some argue the greatest, obstacle to social and economic development.[3] Digital technologies can lead to more transparency, reducing corruption among public officials. One study finds a connection between corruption and e-government, with a statistically significant link between the United Nations E-Government Development Index (EGDI) and Transparency International's Corruption Perception Index, suggesting that as the use of e-government increases, corruption decreases (Mistry and Jalal 2012). The impact of e-government on reducing corruption is higher in developing countries than in developed ones. This finding is especially significant for Sub-Saharan Africa, which ranks lowest in the perception of corruption (figure 6.3).

Digital technologies can improve registration processes for citizens in areas such as births and passports. An important area is the national identification (ID) card. The lack of official identification prevents citizens in many developing countries from exercising their rights and isolates them socially and economically. For example, they may not have access to voting, legal action, receipt of government benefits, banking,

FIGURE 6.3: Corruption Perceptions Index, 2016



Source: Transparency International.

and borrowing (Dahan 2015). Digital IDs, combined with the broad spread of mobile devices in developing nations, offer a transformative solution to the problem. Digital IDs are a simple means for capturing official identification that can reach far more people; digital IDs also create innovative and efficient ways for governments and businesses to serve citizens.

Despite the promise of ICT for governance, it is not a panacea. Moving government online can exacerbate inequalities in government services between those with and without access to ICT. Further, the mere adoption of digital technologies will be insufficient to improve governance, unless it is accompanied by "analog" complements (World Bank 2016). Governments play an important role by enhancing the regulations for competition in different markets, retraining workers for the requirements of the new economy, and ensuring that institutions are accountable.

II. Experiences Implementing Innovation and Technology to Make Government More Effective

African countries are implementing innovation and technology to make government more effective in several ways. These include standardizing government data architectures and databases to make back-office work flows more productive, connecting government offices to enhance information sharing and reduce costs, and providing information online or through mobile phones with various stages of interactivity. Ninety-two percent of the countries in Sub-Saharan Africa have established at least a central portal providing some information about the government and, in some cases, links to procedures and forms as well as some interactive services.[4] Examples of notable practices in innovation and leapfrogging in the application of digital technologies to government include top-ranked Mauritius, which has one of the oldest histories of applying computerization to the public sector, as well as the continent's best digital infrastructure. Other examples include Tanzania's creation of a dedicated agency for electronic government, and Rwanda's success in connecting government agencies and deploying online public e-services. Kenya and Burkina Faso are notable for innovative deployment and use of open data; Côte d'Ivoire has had the greatest improvement in governance indexes.

According to the EGDI,[5] Mauritius ranks at the top in Africa by some margin. Its Online Service Component score is 23 percent above the second highest–ranking country in the region, Tanzania. The reasons for the high rank of Mauritius include the country's long experience with computerization of government, dating back to the 1990s. Further, Mauritius has the best developed ICT infrastructure in Africa, ranking first in the continent in the International Telecommunication Union's ICT development index.[6] There are more than 60 major multi-user systems implemented and operational in the public administration, and Mauritius has assisted several other African countries with implementing systems.[7] Although back-end processes have long been computerized, a recent impetus has been more focus on services for citizens. Some 800 households across the country were surveyed to solicit their views as background for the development of the citizen-centric *e-Government Strategy 2013–2017* (Republic of Mauritius 2013). The strategy has already had an impact. By July 2017, almost 70 e-services were available online, with 10 mobile applications also under development (Republic of Mauritius 2017).

Tanzania's Electronic Government Agency is an innovative example of a dedicated entity charged with handling government computerization for the country. Established in 2012, the Electronic Government Agency assists government departments with several activities, including designing websites so they have a consistent look and feel, managing the government's domain name (.gov.tz), and helping agencies develop mobile applications.[8] This is the first phase of Tanzania's e-government path, involving connectivity of government institutions, re-engineering and computerizing back-office processes, and sensitizing

and training government officials. The next phase that is elaborated in the country's e-government strategy has the vision of "becoming an effective Government in delivering innovative public services enabled by ICT" (United Republic of Tanzania 2013). The strategy calls for delivering efficient and responsive services to citizens, beginning with launching several flagship applications.

Rwanda has made notable use of its own resources, assistance from the development community, and public-private partnerships (PPPs) to link government offices, computerize back-office processes, and deploy electronic public services for citizens and businesses. The World Bank eRwanda project (2006–10) provided a US$10 million grant aimed at the deployment of local area networks in government offices, development of government applications and services, and training for staff (World Bank 2011). The government used proceeds from the sale of its incumbent telecommunications operator to construct a national fiber optic network that enabled connections of government offices. The backbone is operated as a PPP and is available for telecommunications operators to use at cost-based prices. Today, most ministries are connected to the Internet via fiber optic broadband.

In 2013, the government entered a 25-year PPP with Rwanda Online Platform Limited (ROPL) for the provision of online government services. Although moving services online has reduced costs for the government, user fees have remained the same so that ROPL can earn income. Services are provided over the Irembo (Kinyarwanda for gate) platform, which is accessible via web and mobile.[9] More than 30 services are available, ranging from birth certificates to driving tests, with plans to expand to more than 100 services. Some 90,000 transactions are processed per month.[10] ROPL has partnered with banks and mobile money providers to enable payments to be made online. More than 200 service centers are spread throughout the nation for citizens to learn how to use the system or have an intermediary carry out the transaction for them. There are anecdotal stories of how the system has reduced waiting times and the number of offices that need to be visited for government services (RwandaOnline 2014).

Open data provide unstructured government data available online to the public, to enhance accountability and transparency. The 2010 Kenyan Constitutional revision included a new section calling for citizens' right to government information. This was one of the factors leading to the establishment in 2011 of the Kenya Open Data Initiative, the first in Sub-Saharan Africa.[11] Former Kenyan President Mwai Kibaki launched the portal, reflecting high-level commitment. The Kenya Open Data Initiative helped citizens acquire information about job vacancies, tenders, and government procedures. As of June 2016, 850 data sets had been uploaded. The portal received approximately 1.1 million unique visits in 2013, while more than 5,500 data sets were downloaded and embedded into various websites and blogs (Centre for Public Impact 2016). The initial implementation received some criticism that it did not contain enough relevant government information and was too unstructured and thus difficult for citizens to interpret (Brown 2013). These issues were remedied through several improvements, including the Data Bootcamp program. The program provides training to journalists and civil society organizations interested in using open government data; Code for Kenya assigns them computer experts and data analysts. Several tools have been developed, such as Open Budget, replacing unstructured budget data with an intuitive, interactive tool. Data Lens is a new, visual way to explore and experience data that makes it easy for citizens and others to get answers to their questions in a visual, intuitive way, without getting lost in data (Kaplan 2015).

Burkina Faso provides an encouraging and innovative illustration of the use of open data to disseminate the results of the 2015 presidential election, moving from unstructured, static data to real-time, formatted data (Scott 2016). A consensus emerged that rapid dissemination of the election results would

increase transparency and encourage confidence in the results. There was close collaboration between the Commission Électorale Nationale Indépendante (CENI), Burkina Faso's electoral commission, and government, civil society, and international partners. CENI worked to secure political support for rapid processing and publication of the election results that would be unprecedented in Burkina Faso, and almost unheard of in Sub-Saharan Africa: just one day. The Burkina Open Data Initiative was launched by Burkina Faso's national agency for ICT—Agence Nationale de Promotion des TIC—in June 2014, along with an open data platform featuring around 50 open data sets. Burkina Faso was the first Francophone country in Africa to take such a step. The Burkina Open Data Initiative's Open Elections project sought to provide CENI with a tool to help relay election results to the public in a transparent and credible manner. This tool—a web application that publishes results in real-time—enabled citizens to access results instantly as they were validated by CENI on election day.

Côte d'Ivoire is a case where governance is leapfrogging, supported by statistical measurement. Over the past decade, it was the most improved African country in the IIAG, with its score rising 13 points between 2006 and 2015, and its ranking rising from 42nd to 21st. Part of the change was due to the end of the civil wars, with the second concluding in 2011. This led to a rise in safety and the rule of law, with the ensuing political stability driving a rise in foreign direct investment. Good governance and anti-corruption efforts are cited as reasons behind improved business procedures (IMF 2017). As a result, business registrations rose 28 percent between 2015 and 2016. The High Authority for Good Governance was established in 2013 as part of the government's national anti-corruption plan. It is an independent administrative authority responsible for devising the national anti-corruption strategy and preventing and combating corruption and related offenses. The High Authority for Good Governance is part of the Network for Integrity, whose members include similar institutions from 13 other countries.[12]

III. Prerequisites for Contextual Leapfrogging

Most African governments have made at least some progress in applying digital technologies within the public administration. This ranges from simply putting up a few websites, to interactive processes for the delivery of services. Most use ICT at least for some back-end processes; a few have extensive fiber optic backbones connecting government offices nationwide.

Leapfrogging in the sense of catching up with developed countries in the short run is unlikely, given the resources and state of connectivity required. A contextual type of leapfrogging is necessary, where the appropriate application of digital technology is made available within the African environment. E-governance interventions also need to be cognizant of the region's absorption capability, with grandiose projects having a poor record compared with an evolutionary approach. Leapfrogging requires certain prerequisites to enable success. Heeks (2002) identifies six types of soft and hard infrastructure requirements for successful application of digital technology to governance in Africa: data architecture, laws, institutions, human capacity, technology, and leadership. At the time, most of these were viewed pessimistically as significant barriers to digital technology applications for governance in the region. Since then, there have been significant improvements in most of these areas and other factors have emerged. Essential prerequisites for leapfrogging are updated and described in the following paragraphs.

The main factor for leapfrogging in the application of digital technologies to governance is *high-level government support*. Political will and leadership are prerequisites for successful e-government (PCIP 2002). Without strong government commitment, there will be inevitable bureaucratic resistance and lack of coordination among ministries. One of the prime examples of a high-level champion is Rwanda, where President Paul Kagame has been a keen advocate of ICT, serving as co-chair of the Broadband

Commission for Sustainable Development and winner of the International Telecommunication Union's 2014 World Telecommunication and Information Society Award (ITU 2014).

A common attribute of successful instances of e-government in Africa is a *strategy*. This was found to be the case for example in Mauritius and Tanzania. A strategy provides a concrete reference to goals and often a schedule for implementation. Strategies also ensure that there is a whole of government approach to the use of digital technologies, rather than individual silos in ministries. This can be further strengthened through the establishment of an *agency* responsible for e-government to coordinate with information officers in all ministries.

In the absence of a strategy, and often where there is bureaucratic resistance to e-government, a *quick win* approach can be considered. Quick wins are often innovative and characteristic of leapfrogging in an area. They are especially relevant where there is not much digital expertise in government, or it varies across ministries. Quick wins help countries to gain experience that can then be used to develop larger projects. They provide proof of concept that could then attract deeper political buy-in and are often perceived as nonthreatening.

Bangladesh is a prime example of the use of quick wins for governance: "Quick-Wins, led by e-Governance/ ICT Focal Points, provided a safe space and stealthstroming [sic] opportunities within the bureaucracy to experiment with new and innovative ideas, which was hitherto unheard of and in many cases, discouraged... In a matter of eight years (2006–2014), hundreds of e-services have mushroomed throughout Bangladesh. This has been made possible through a[n] SPS exercise, built on the parameters of time, costs and visit (TCV), which were carried out under the Quick-Wins auspices." (Chowdhury and Zaman 2014)

Quick wins have been used in Malawi for the creation of integrated budget management systems to overcome antipathy toward e-government after the failure of earlier large projects (Deloitte 2012). There is often a thin line between bottom-up activities that can be scaled up as opposed to one-off interventions that fade when funding runs out. Therefore, a good understanding is needed of how quick wins fit into a long-term strategy for sustainable e-governance.

Governments also need to have a *citizen-centric* approach, especially when devising e-services. This is particularly relevant in Africa, where most citizens do not have access to the Internet. As one study on e-government in East Africa notes: "The lack of citizen involvement in designing and developing ICT tools and initiatives for governance hinders a comprehensive capturing of the pressing needs of citizens...From these findings, we recommend that citizen consultations should be conducted to serve as needs assessments when designing ICT for governance initiatives; low cost and non-Internet based ICT tools should be favoured because of technical accessibility and affordability; extensive awareness and information campaigns should be conducted to let citizens know about the existence of and how to use the tools." (iHub Research 2014) It is understood that e-services should be in the local language and, in addition to being online, also targeted to mobile phones. The use of public centers to teach citizens how to use e-services or provide intermediary services is another approach.

Limited resources often deter governments from adopting digital technologies, due to the high cost involved in connecting agencies and developing e-services. This can be ameliorated through a progressive implementation over time, as well as the assistance of development agencies and the use of PPPs.

Sensitization and training are also needed for successful implementation of e-government initiatives. There is often limited expertise and a lack of incentives among government officials to use ICTs. Therefore, e-government projects should have a substantial training component to enhance the potential for success.

Several *infrastructure* areas need to be addressed. Although Africa lags in wired broadband deployment, there is widespread mobile phone availability. Therefore, e-services need to be deployed that target cell phones. Government services may require payment to make them truly interactive. Collaboration with mobile money providers is essential. This also requires the adoption of laws that recognize the legality of electronic transactions. Some wired broadband networks and supporting infrastructure, such as data centers, are critical for connecting government offices and delivering cloud services. These can be encouraged through PPPs and infrastructure sharing. Government data need to be standardized through common architectures to reduce duplication and facilitate sharing.

IV. Future Research

Much of the literature on the application of digital technologies in Africa is not only outdated, but also quite pessimistic. It was drafted in the early 2000s when the level of ICTs was much lower and there were few visible success stories. As described in this chapter, an irreversible path toward e-government has been taken in many African countries, although the depth and impact vary. Several success stories pose a contrast to the earlier literature. There is a need for more timely research on e-government developments in the region, especially in the context of widespread mobile phone adoption.

E-government indexes paint a depressing picture, with many African countries ranking near the bottom. One reason is the inclusion of related but nonetheless extraneous factors, such as the availability of specific types of ICT infrastructure and educational levels of the population. For example, the United Nations e-government index includes fixed telephone and fixed broadband subscriptions, which are largely irrelevant in the African context. As the examples in this chapter illustrate, although the widespread availability of these technologies is absent in Africa, e-government is nonetheless progressing, and much of it in innovative ways that are applicable to the African environment. More research is needed on the application of technologies for enhancing governance in Africa. In the same vein, the measurement of online services might be made more transparent and objective. The Economic Commission for Africa (2012) has proposed a set of objective indicators within the international framework of the Partnership for Measuring ICT for Development, yet little progress has been made.

Little research has focused on measurable outcomes from e-government, so there is scarce evidence of the impacts. Most studies refer to anecdotal stories of people saving time and money by not having to wait in long queues and not having to travel to government offices. Or studies discuss quantities, such as the number of open data sets, rather than the effects of open data on governance. A variety of areas could be better measured to make a case for e-government. For example, the connection of government buildings through a fiber optic network in Senegal saved CFAF 10 billion (US$17 million) between 2014 and 2016, due to the state having its own internal communications network (ADIE 2017).

Better measurement of savings in cost and money might generate more momentum for deploying e-services. It would also be useful to have information on the proportion of the population using public e-services (ictDATA 2012). Similarly, increases in transparency and reductions in corruption that can be linked to governance initiatives in the region need to be better understood. These efforts can help to build up the evidence base of the necessary conditions for applying digital technology and innovation to leapfrog governance in Africa.

Endnotes

1 See OHCHR, "Good Governance and Human Rights," at: http://www.ohchr.org/EN/Issues/Development/GoodGovernance/Pages/GoodGovernanceIndex.aspx.
2 See "Harmonized List of Fragile Situations," at: http://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations.
3 International Chamber of Commerce et al. (2008).
4 https://publicadministration.un.org/egovkb/en-us/Resources/Country-URLs.
5 EGDI assesses national websites and how e-government policies and strategies are applied in general and in specific sectors for the delivery of essential services. The results are tabulated and combined with a set of indicators embodying a country's capacity to participate in the information society, without which e-government development efforts are of limited immediate use. See United Nations (2016).
6 See "ICT Development Index 2016," at: http://www.itu.int/net4/ITU-D/idi/2016/#idi2016byregion-tab.
7 Examples include the PAYE system, Treasury System, Electoral System, Digital Court Recording System, Computerized Audit System, Public and Disciplined Forces Service Commissions Systems, Automatic Fingerprint Identification System, Police GPS System, Crime Record Office System, Customs Tradenet System, Registrar-General and Registry of Companies Systems, Social Security Contributory Benefits and Pension Systems, Integrated Hospital and Patient System at Nehru Hospital, Unallocated Stores System, and the Passport and Immigration System. See "Public Sector Computerisation," at: http://prb.pmo.govmu.org/English/Pages/Public-Sector-Computerisation.aspx.
8 See "e-Government Agency Services," at: http://www.ega.go.tz/uploads/publications/cc58501e625c38f08f4649fb984a032c.pdf.
9 https://irembo.gov.rw.
10 See "IREMBO," at: http://rwandaonline.rw/in-the-works.php#sthash.1L9AqIoY.dpuf.
11 http://www.opendata.go.ke.
12 See "Network for Integrity," at: http://www.networkforintegrity.org/the-network/.

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ICT

Information and Communications Technologies 7

I. The Mobile Revolution

Information and communications technology (ICT) is revolutionizing the world. Not only is ICT an important sector on its own, it affects every other sector of the economy. As ICT evolves in speed, from narrowband to broadband, and in scope, from connecting just humans to machines, it is having an even greater effect.

The rapid decline in the cost of digital technologies, particularly the Internet, has dramatically reduced transaction costs, benefiting economic development in three ways (World Bank 2016). First, the Internet helps overcome information asymmetry by better linking sellers and buyers. Second, lower transaction costs enabled by the Internet raise productivity in businesses. Third, the Internet triggers innovation associated with the so-called "new economy," which is characterized by new business models, customization of services, and industry disruption. Yet, the dividends from the benefits of digital technologies lag. One reason is the digital divide in Internet access across and within countries. Adoption alone is insufficient to benefit from ICT. Countries also need to work on "analog complements": strengthening competition, adapting workers' skills, and ensuring that institutions are accountable.

Broadband Internet is a general purpose technology cutting across all sectors to deliver efficiency and productivity gains. Firm-level studies find that web use by local businesses is linked to labor productivity and growth. It benefits all types of firms regardless of size or trade orientation, and has a larger impact on small and medium-size enterprises than large firms (Clarke, Qiang, and Xu 2015). However, the capacity of firms to absorb new technologies varies, limiting their impact (Schmidt 2010).

Important trade-related aspects of ICT are relevant in a globalized economy. There is a reciprocal relationship between trade and ICT (TMG 2007). An enabling trade environment facilitates the development of ICT, while ICT fosters and enables goods and services trade. Three dimensions characterize ICT-related trade: trade in ICTs (for example, international communications), trade in ICT-enabled services (for example, business processes outsourcing), and ICT as a general facilitator of other types of trade (for example, farmers using text messaging to check market prices). Barriers that impede the development of ICT-related trade, such as insufficient investment, can be addressed through trade commitments.

ICTs and particularly mobile networks have grown rapidly in Africa. The speed of mobile evolution, policy reforms, and ways to finance investment is distinct among infrastructure sectors in the region (Williams, Mayer, and Minges 2011). The availability and quality of services have increased and prices have decreased. Sector reform has driven this radical change. Markets have been opened and regulatory agencies created. This has resulted in competition spurring investment. The region has skipped fixed telephone lines and

jumped into the digital age (Pew 2015). Cell phones are used for more than basic voice communications in Africa; sending text messages and taking pictures are popular activities. In some countries, mobile banking is common. Mobile networks are generating innovation and boosting incomes, with farmers using cell phones to check market prices and traders accepting payments in mobile money (*The Economist* 2016). However, there remains a large digital divide in Sub-Saharan Africa, due in part to large rural populations and high costs.

The international development agenda stresses the importance of ICT infrastructure for achieving the Sustainable Development Goals (SDGs). The ninth SDG calls on countries to build "...resilient infrastructure, promote sustainable industrialization and foster innovation" (United Nations 2015). The relevance of infrastructure investments for development links to their cross-cutting nature. Despite the importance of ICT for goal 9, only one tracking indicator was established: "significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in the least developed countries by 2020" (SDG Target 9c). Although the target refers specifically to the least developed countries, it is highly relevant for Africa, since 33 of the 47 least developed countries are in Africa.

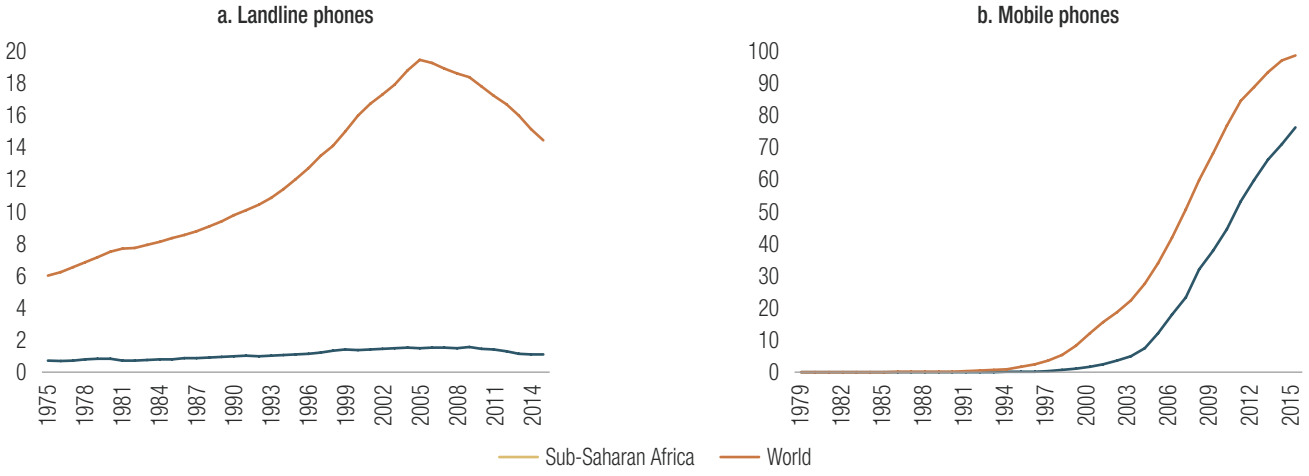
Although Sub-Saharan Africa has made impressive progress in expanding digital infrastructure over the past few years, there is still further to go to expand broadband infrastructure, lower costs, and leverage benefits more fully. Much of this infrastructure has been constructed by the private sector under varying degrees of competition (Minges 2016). Despite the steady gains, the region continues to lag all others in access to ICT. This is partly due to the link between per capita income and access to telecommunications. However, in many cases, the market is not functioning as well as it could. The problems are sometimes linked to exogenous factors, such as poor governance, lack of electricity, high cost of doing business, and low level of digital skills. Other factors are internal to the sector, such as imperfect competition, lack of open access to fiber optic backbone networks, and constrained spectrum allocation. Government strategies to narrow the digital gap through universal service funds have been largely ineffective throughout the region. Solutions to these challenges require a top-level, multisector approach. They can be alleviated through a more competitive market environment, including embedding open access principles in sector regulations, supporting training for regulators, providing more efficient and speedier spectrum allocation, improving universal service programs, and implementing initiatives for promoting mass digital literacy.

II. Rapid Progress through Substitution and New Approaches

Africa has several relevant leapfrogging experiences in the ICT sector. The region has experienced rapid growth of mobile networks and, more recently, the deployment of a growing number of submarine cables. Some Sub-Saharan African countries stand out for mobile connectivity on par with developed nations in the application of mobile communications in other sectors, and in innovative approaches to mobile broadband network deployment. Leapfrogging has often been stimulated as a substitute for inadequate alternatives (for example, a lack of fixed telephone lines or limited formal banking services); in other cases, leapfrogging has been driven by public-private partnerships.

Mobile communications are the one type of ICT where Africa has been closing the gap with the rest of the world. Although fixed telephone networks have been around since the early 1900s, access was always limited in Sub-Saharan Africa, at less than 2 percent of the population (figure 7.1, panel a). Once the first mobile networks launched in Sub-Saharan Africa in 1989, they grew rapidly. The gap between Sub-Saharan Africa and the rest of the world dropped from 99 percent in 1989 to 23 percent by 2015 (figure 7.1,

FIGURE 7.1: Telephones per 100 People

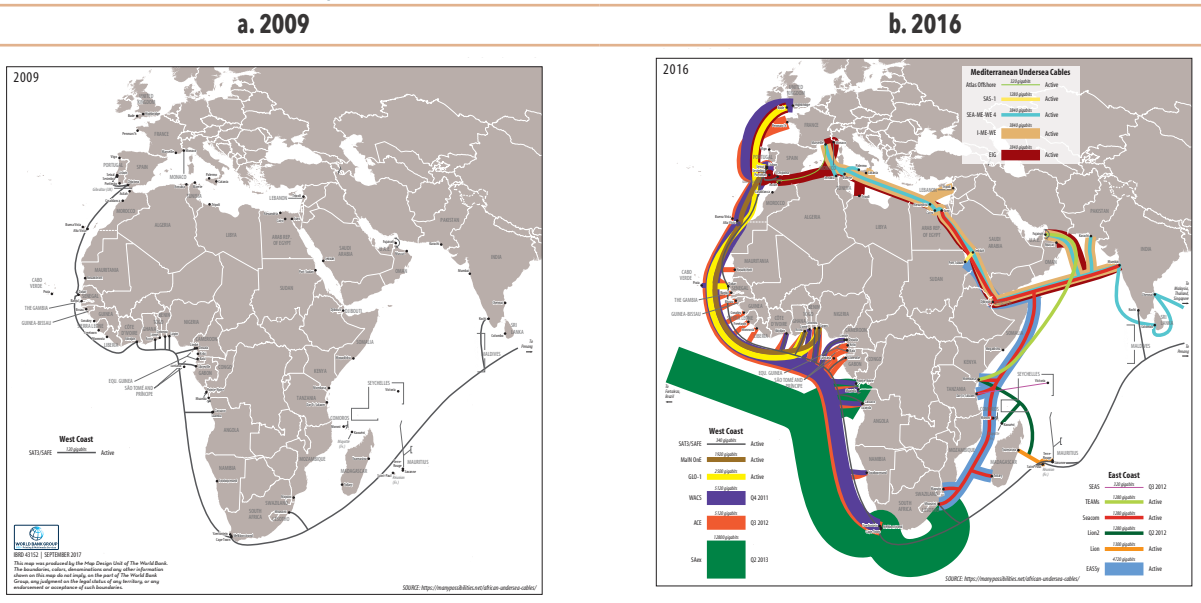


Source: Adapted from World Bank data.

panel b). The reason for the popularity of mobile in Africa is largely contextual: ineffective monopoly land-line operators that did not pose a strong competitive threat to new mobile operators, the lower investment costs of greenfield wireless networks, huge pent-up demand due to the lack of landlines, and the prepaid model that fit the region's economic circumstances.

The rapid growth of submarine cables in Sub-Saharan Africa is another area where there has been astounding leapfrogging. Before 2009, there was only one monopoly-controlled cable on Africa's west coast and only a handful of countries were connected (map 7.1, panel a). The deployment of cables on Africa's east coast in 2009 led to a surge of undersea fiber optic networks.

MAP 7.1: Undersea Fiber Optic Cables in Africa, 2009 and 2016



Source: Adapted from https://manypossibilities.net/african-undersea-cables/.

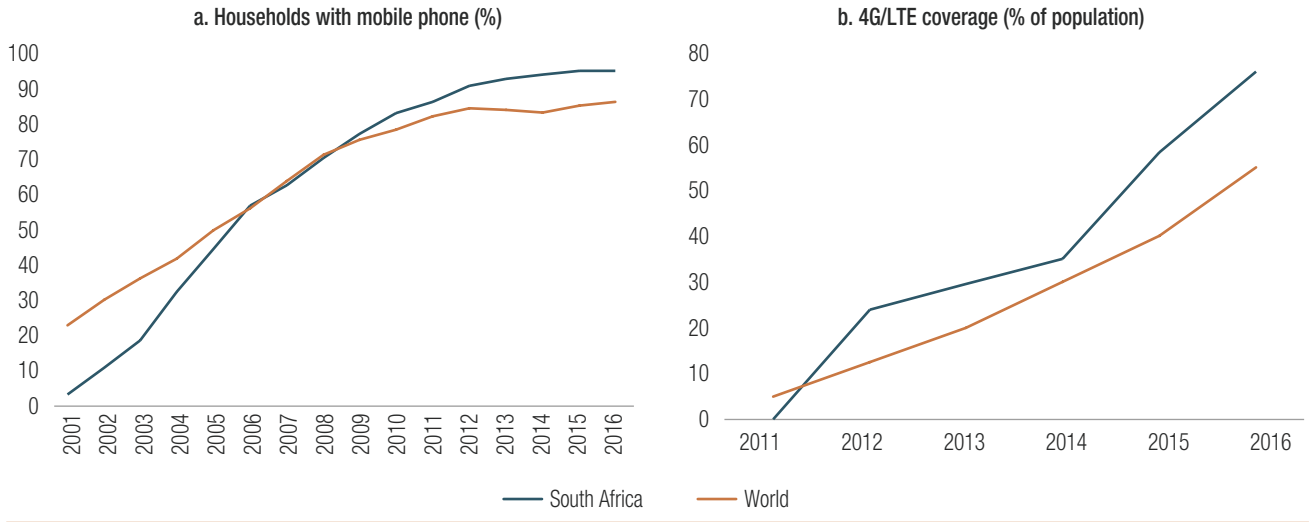
By 2016, all sea-facing African countries except Eritrea and Guinea-Bissau were connected to submarine cables; seven countries were connected to three or more cables (map 7.1, panel b). The growth has been stimulated by a combination of rising demand for Internet capacity, open access to submarine cables, pan-African telecommunications operators, and assistance from development agencies.

South Africa is notable as one of the first Sub-Saharan African countries to introduce competition in its mobile sector. Today, cell phones are as common in South Africa as they are in the United States, with 89 percent of adults having a cell phone (Pew 2015). Although South Africa had an analogue mobile network in the 1980s, it was essentially restricted to the well-off, due to high costs and low coverage. The launch of second-generation mobile and the introduction of competition between the two private companies, MTN and Vodacom, in 1994 transformed the industry. South Africa and Guinea were the only two Sub-Saharan African countries with competition at the time. By the 2001 Census, almost a third of the households in South Africa had a cell phone; by the 2011 Census, almost nine in 10 households had a cell phone. By 2016, cell phones were almost ubiquitous, with 96 percent of the households having one (compared with less than 10 percent with a landline), a figure higher than that in the United States (figure 7.2, panel a).

Today, there is widespread mobile broadband coverage, with a 3G signal reaching 99 percent of the population and 4G/LTE covering over 75 percent of South Africa's inhabitants. These are the highest levels in Sub-Saharan Africa and significantly above the world average (figure 7.2, panel b). Additional competition through the market entry of Cell C in 2001 and the incumbent fixed line operator Telkom in 2010 has sustained growth. MTN and Vodacom have also been instrumental in introducing cell phones to other Sub-Saharan African countries, with subsidiaries in 19 markets in the region (Mbarika and Mbarika 2006).

Kenya provides several examples of ICT policy and technical innovations. Although the East African nation faces the sea, it long relied on expensive satellite connectivity, because of the lack of access to submarine cables. The government felt this was a major obstacle to the country's becoming an ICT hub (Msimang 2011). The government created a public-private partnership to build an open-access undersea

FIGURE 7.2: Mobile Leapfrogging in South Africa



Sources: Adapted from Statistics South Africa; Centers for Disease Control; Vodacom and Ericsson.

fiber optic cable to the United Arab Emirates. The East African Marine System undersea cable was launched in 2009. The country is now connected to three submarine cables and this will double by the end of 2018. Kenya has emerged as the leading bandwidth hub in East Africa, providing international Internet capacity for landlocked countries, including Ethiopia, Rwanda, Uganda, and soon South Sudan.

Kenya is also a trendsetter in the application of mobile to the financial sector. In 2007, mobile operator Safaricom launched M-Pesa, the first mobile money service in Africa. The lack of or costs of formal banking quickly stimulated take-up, as did a relaxed regulatory framework to allow the service to develop. Kenya has one of the highest rates of mobile money penetration in the world, strengthening financial inclusion in the country. The share of the population ages 15 years and older with an account rose from 42 percent in 2011 to 75 percent in 2014.[1] A success factor is the light-handed regulatory approach banking officials took in allowing mobile money.[2] Mobile money has spawned add-on applications, such as links to savings and insurance and payments for e-commerce. One example combines cell phones, mobile money, and off-grid electricity. M-Kopa Solar[3] produces solar panels to cater to the huge demand for electricity in rural areas.[4] A challenge is that most rural dwellers cannot afford the outright purchase of a panel. M-Kopa Solar provides a solution by charging a small daily amount, with payments made using mobile money. Once the panel is paid for, it belongs to the purchaser. To ensure compliance, the panel circuitry is remotely controlled over the mobile network.

Although Rwanda is a landlocked, least developed country, this has not stood in the way of government aspirations for the ICT sector (UN-OHRLLS 2017). An innovative government-led initiative is the world's first wholesale-retail model for a fourth-generation mobile network. The KT Rwanda Network, a joint venture of Korea Telecom and the government, was established in 2013, among other things, to deploy 4G technology. The KT Rwanda Network builds the network and acts as a wholesaler, selling capacity to existing mobile operators and Internet service providers.[5] The 4G network was launched in 2014, with the target of covering 95 percent of the population by 2018. One reason for this model is that the government wanted to accelerate the rollout of superfast mobile technology. The existing mobile operators were hesitant to deploy 4G until they had recovered the investment in their 3G networks. Rwanda is the first country in the world to adopt a single wholesale network for 4G (GSMA 2015).

The experiences of China illustrate how the adoption of digital technologies has triggered economic and social changes (box 7.1).

III. Enhancing Conditions for Digital Leapfrogging

ICT is an important sector on its own and in cross cutting with impacts across other sectors. Leapfrogging within the sector is dependent on a proper regulatory environment to stimulate competition, investment, and innovation. Its impact on other sectors is dependent on regulations as well as knowledge of how to apply ICT to areas such as finance, agriculture, health, and so forth. Other necessary preconditions include a clear sector strategy, human capacity development, and innovation support. Once these preconditions are in place, there are several potential technological options for leapfrogging, such as the Internet of things, drones, new spectrum sources (such as analog broadcasting and white space), and jumping straight to 4G and 5G networks.

African countries need the right *enabling framework*, including the creation of a sector regulator, introduction of competition, and private sector investment. The World Trade Organization outlines six basic principles for an appropriate regulatory environment to foster a vibrant telecommunications sector (WTO

Box 7.1: Leapfrogging of China's Digital Economy

The past two decades have witnessed the rapid development of China's Internet-based industry. Internet enterprises have made great achievements in technical expertise, business models, and changes brought to the economy and society, and even assumed a leading position in the world in some ways. The main experiences include the following:

1. A complete e-commerce platform and network has been established. The development of credit, payment, and other new finance infrastructure has been boosted to provide inclusive financial services for individuals and small and micro businesses. Financial technology enterprises have been supported to construct a global payment network, making online and mobile payment more convenient. China's third-party payment agencies have become the largest mobile payment companies in the world. Taobao, Dangdang, Jingdong Mall, and other shopping websites have broken the constraints of time and space; provided convenient, low-cost channels for linking buyers and sellers; and promoted the development of small enterprises.

2. Various platforms have been established to enhance access to local content and facilitate learning. The ratio of Internet users using instant messaging has reached 91 percent. Tencent, Sina, Netease, Sohu, and Baidu have become important platforms for people to communicate and obtain information through the Internet. These platforms have spawned a self-media era, making the Internet a source for user-generated content and an important channel for transmission.

3. In areas such as customer-oriented businesses, cloud computing, big data, and recognition technology, China's Internet enterprises have reached and, in some cases, even exceed the world's top level. The development and utilization of up-to-date technologies by financial enterprises have been promoted for increasing efficiency, optimizing user experience, and maintaining market competitiveness. For example, during the annual online "11 Day Global Festival" on November 11, 2016, some 120,000 payment transactions were processed per second during peak times (Azila 2016).

4. The new economy represented by the Internet has developed rapidly, brought about huge social and economic benefits, and provided new energy for China's economic development. The e-commerce company Alibaba is an example. In fiscal year 2016, total sales on the Alibaba platform exceeded Y 3 trillion (around US$4.5 billion), which was more than the total sales of Walmart, historically the world's largest retailer (Jing 2016). The 18-year development of Alibaba has surpassed the 54-year development of Walmart.

5. With the transformation of urban development and the evolution of smart cities, advanced e-government services have accelerated. Network information technology has created a new pattern of economic and social development where the relations between people and services, people and cities, people and society, people and resources, and people and the future are transformed. In 2015, Alipay launched the "City Service" smartphone app, which allows users to carry out a range of tasks related to urban living, including paying for traffic tickets and utility bills, scheduling medical appointments, and accessing information about traffic and public transportation. Another example is "Sesame Credit," where users of the Alipay digital payment service generate real-time credit scores; those with high scores accrue rewards, such

(*continued on next page*)

BOX 7.1: LEAPFROGGING OF CHINA'S DIGITAL ECONOMY (*continued*)

as avoiding car rental deposits or getting quick airport security checks. Ant Forest, an app from Ant Financial, is a game that tracks users' behavior to help them reduce their carbon footprint. Some 200 million of Ant Financial's 450 million users signed up for the app in nine months, equivalent to one-fifth of China's adult population. The lifestyle changes the app induced are estimated to have avoided 150,000 tons of carbon emissions (Green Digital Finance Alliance 2017).

1996). Although it was published over 20 years ago, the paper remains applicable today.

- The principles include *competitive safeguards* for anti-competitive behavior, such as cross-subsidization and control over key bottleneck facilities (such as towers and fiber optic backbones). Some governments have promoted the separation of wholesale and retail services, open access to key facilities, and infrastructure sharing to encourage a more competitive market environment.
- A second principle is *interconnection*, which refers to the physical connection of different operator networks. The lack of interconnection rules for transparent, cost-based wholesale pricing has often resulted in the use of multiple SIM cards, since it is cheaper to call on the same network (on-net) than to make calls across networks (off-net). Several African regulators have established cost-based wholesale prices for mobile voice and text.
- The principles recognize the right of countries to adopt *universal service* mechanisms administered in a transparent, nondiscriminatory, and neutral manner. This is particularly relevant for Sub-Saharan Africa, where there is a wide gulf between ICT facilities and access in urban and rural areas. Many countries in the region have struggled with the design of effective universal service programs. Often the type of universal service initiative has not had widespread impact, resulting in an ongoing digital divide between urban and rural zones. Although many African countries collect funding for universal service through a levy on operators, they have not always been effective in dispersing the money. One study finds that most universal service funds in the region have had "deficiencies in fund structure, management and operation 'requiring' significant reform and restructuring in order to be transformed into functional and effective investment support vehicles for unserved and underserved areas" (GSMA 2014). Contributions to universal service funds combined with other sector-specific taxes are burdensome in some countries, diverting money from investment and raising prices for consumers (GSMA 2017b).
- Clear rules about *licensing* requirements for market entry are another principle. This includes distinguishing between types of licenses when they are needed, and publicly available information about licensing criteria (that is, the time required to reach a decision, terms and conditions, and so forth). A challenge is to price licenses correctly to attract strong players, while at the same time not charging so much as to discourage market entry.
- The establishment of an *independent sector regulator* is a key principle. The regulatory agency should be separate from suppliers of telecommunications services. The decisions of and procedures used by regulators must be impartial with respect to all market participants. Although most African countries have established an ICT sector

regulatory agency, in practice some struggle for political independence, due to the continuing government ownership in incumbent operators.

- Finally, efficient mechanisms are needed for the assignment of *scarce resources*. This is especially important in the African context, where most access is through wireless networks that require frequency spectrum. Transparent procedures are needed for the allocation of scarce resources, such as frequencies, numbers, and rights of way.

An ICT sector *strategy* is vital for providing guidance and accountability and describing how digital technologies fit in with overall national development plans. The most effective ICT strategies are those with realistic targets and corresponding budgets and mechanisms for monitoring and evaluation. Ongoing, multiyear plans offer some predictability about the government's direction for the sector, providing reassurance for the private sector.

The *quality of competition* matters. The strength of telecommunications operators, their involvement in other countries, and scale make a difference. Governments should award major telecommunications licenses based on a variety of criteria, including the operator's experience, particularly in other African countries; proven technical expertise; financial depth; and willingness to engage in a significant way with the social and economic goals of the country.

Digital *skills* across various domains are essential for Sub-Saharan Africa to be successful in exploiting ICT opportunities. Governments need the right skills to create policies and regulate the sector. Technical skills are needed across sectors to develop ICT applications and services. Digital literacy is essential for citizens to make productive use of the Internet. The transition to broadband and Internet is often constrained because it requires a higher level of skills than using a mobile phone.

The need to stimulate *innovation* is critical for triggering new uses for ICTs that benefit the economy and society. Most innovation frameworks are based on top-down theories. These models see innovation output reflected by patents, trademarks, and scientific journal citations, and driven by national innovation strategies that emphasize large-scale research and development (R&D). The difference between top-down R&D–based innovation and the generation of bottom-up ideas is especially relevant in emerging economies, where *"innovation in developing countries is more incremental than radical and takes place in an informal setting more often than it does in formal R&D laboratories"* (Cornell University, INSEAD, and WIPO 2015). Innovation in developing countries is often "under the radar" of traditional indicators, such as patents and R&D (Zanello, Fu, and Essegbey 2013). Almost 80 percent of the firms surveyed in Ghana reported introducing some form of innovation between 2011 and 2013 (Fu et al. 2014). Their largest external constraints to innovation were markets dominated by large enterprises and institutional inflexibility in regulations and standards. Governments need to encourage ICT–based, disruptive innovation that challenges traditional industries (Cornell University, INSEAD, and WIPO 2015). In Africa, thousands of digital entrepreneurial innovators have clustered in tech communities across the continent that need to be encouraged and stimulated (Firestone and Kelly 2016).

IV. Future Research

There is a consensus that ICT infrastructure investment in the region requires a predictable regulatory environment combined with competition. Although most African countries have created a competitive market with regulatory institutions, rates of penetration vary. Perhaps it is not just the creation of a regulator that is important, but how it regulates, and not just competing operators, but also the intensity of competition. A more granular analysis is needed that examines why some countries do better than others.

Sub-Saharan African governments are adopting ambitious ICT sector plans, and some are creating software parks (UN-OHRLLS 2017). The premise is that emerging digital economies will generate thousands of jobs. However, there is a lack of precision about the link between the digital economy in developing countries and employment. More information is needed about labor market supply and demand and the types of digital jobs that will be created and how.

There is a growing body of literature on the impact of narrowband mobile applications across various sectors, such as voice calls for agricultural market prices (World Bank 2017), text messaging for health information (USAID 2014), and alerts and mobile money to strengthen financial inclusion and reduce costs (GSMA 2017a). Third- and fourth-generation mobile broadband networks promise great potential for more impactful applications. However, there is scarce information about the effects of these technologies in the region and examples of noteworthy scalable applications across sectors such as health and education.

Similarly, emerging fifth-generation networks and the Internet of things connecting devices and machines can have a significant impact in Africa. In Ghana, sensors are used to track vaccines in the supply chain, to verify that they have remained at the proper temperature (Scherf 2016). A study predicts that around 40 percent of the value-added from the Internet of things will be generated in developing countries by 2025 (McKinsey & Company 2015). However, despite the immense development potential, there are few practical examples of the Internet of things in Africa.

ENDNOTES

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2 https://www.alt-m.org/2016/06/28/finance-for-all-kenyas-m-pesa/.
3 http://solar.m-kopa.com/about/.
4 According to a 2015 survey, only 16 percent of rural households had electricity (NMCP, KNBS, and ICF International 2016).
5 For more on the technical details behind the 4G network, see Nokia (2014).

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Concluding Remarks

This book describes similarities behind successful leapfrogging experiences in various sectors. It also uncovers challenges that need to be overcome to spur transformational changes on the continent. The following key messages emerge.

Leapfrogging is enhanced through the proper balance between top-down and bottom-up approaches.

Africa needs both push and pull to transform. Top-down initiatives are essential for creating an enabling environment for large-scale investment, building major infrastructure that triggers spillover effects, and boosting knowledge to use and adapt technology. Bottom-up innovation is essential for successfully adapting technology to local needs and challenges. Generally, the relationship has been lopsided, with more emphasis on top-down adoption strategies. Better balance can be achieved through greater effort to boost adaptation by investing in education and research and development (R&D) and enhancing the enabling environment for innovation-driven entrepreneurship.

Africa is not an exception, is not new to leapfrogging, and is generating its own innovations.

Despite the significant challenges the region faces, this book presents evidence of leapfrogging experiences in Africa. They demonstrate that with the right governance, attractive business climate, and proactive policies, leapfrogging can and does occur across all sectors. Significantly, various innovations, such as mobile money and pay-as-you-go off-grid solar, were spawned in Africa, and are spreading to other developing regions. This makes Africa very attractive as a test-bed for technological innovation and adaption.

Not all leapfrogging attempts are successful.

African countries, as well as private investors, must be willing to take risks and learn from failures, which are a normal part of the innovation ecosystem. Risks can be mitigated in various ways, including the support of development partners. A testing stage is essential for refining and adapting technology to the variety of local conditions on the continent.

Failure allows technology to be refined and improved. M-PESA began as effort to use mobile phones for microfinance loans and only later evolved to mobile money. Similarly, Lighting Africa continually adapted the program based on the results of early field trials in Ghana and Kenya, and found that on-the-ground engagement needed dedicated local specialist resources in addition to global expertise.

Constraints that African economies face are investment opportunities.

Challenges are what motivates entrepreneurs to find solutions. African governments need to create the

right conditions to encourage innovators to overcome constraints, and for the private sector to provide support and the necessary resources. The benefits for the private sector can be significant. In just a decade, M-PESA has become Safaricom's largest driver of revenue growth, contributing to over a quarter of its fiscal year 2017 revenue, with the mobile money service generating K Sh 55 billion (US$103 million).[1]

Having the right regulatory environment is crucial for enabling leapfrogging.

A flexible regulatory environment enables innovation by allowing new business models to be tested—regulation can then scale with the innovation. This was the case with M-PESA, where other than requiring users to register, the Central Bank of Kenya imposed few restrictions during the mobile money service's early deployment. Flexibility is also required to create investment channels, such as delinking generation, transmission, and distribution and opening energy markets to private participation.

Innovation must scale to trigger leapfrogging.

Technological innovation must be accessible in cost, the skills required to use it, availability, and meeting a widespread need. Mobile money scaled rapidly because it filled the gap in formal banking, was simple to use, worked on inexpensive basic cell phones, and answered the need for a cheap and safe way for urban Kenyans to transfer money to family in rural areas.

Public investment should prioritize skill acquisition.

Education, especially foundational skills acquisition as well as science, technology, engineering, and mathematics, is fundamental for using, adapting, and triggering technological innovation that enables leapfrogging. Of all the sectors, education has unique attributes that make it least conducive to attract private investment on the scale needed. Governments should prioritize public spending for the education sector, given the potentially high returns it can generate as a lever for transformational leapfrogging.

R&D is key for adapting technology to local contexts.

R&D is an important determinant of absorptive capacity and technological progress. It enables technology to be adapted to local environments for rapid adoption. Part of Africa's lack of leapfrogging can be explained by low R&D expenditure: the lowest of any developing region and almost four times less than the world average. This report has identified several promising areas meriting research. R&D is particularly essential for two sectors that have not experienced significant leapfrogging, agriculture and education. Characterized by unique agroecology and small shareholdings, Africa's agriculture sector has remained largely unaffected by the Green Revolution. R&D is needed to investigate how to increase productivity and sustainability, given these distinctive characteristics. R&D in itself is a good investment that should be prioritized. A study from India finds that investment in research, education, and roads was the most effective for agricultural growth and reducing poverty.[2]

In education, outcomes remain constrained, meriting research into causes and solutions. Several educational technologies are being piloted across the continent. However, few have found scale despite the promise of some, such as online learning, which could help alleviate shortages of teachers. R&D is needed to explore the adaptive potential of these technologies, including impact evaluations, to determine if and how they can be scaled for Africa.

Endnotes

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