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POLICY BRIEF

LEAPFROGGING: LOOK BEFORE YOU LEAP

New technologies, such as digital mobile communications, drones for precision agriculture and decentralized renewable energy systems that provide electricity in rural areas far from the grid, open up opportunities for leapfrogging. As developing countries have limited capabilities, opportunities for leapfrogging in these countries are presented primarily through the adoption of technologies. Innovation policies can help developing countries foster and facilitate the deployment of frontier technologies and their adaptation to meet their needs, to promote sustainable development.[1]

Key points

- Countries engage in leapfrogging by bypassing the intermediate stages of technology in a development process.
- Rapid technological advances and cost reductions in ICT have enabled some developing countries to skip the development of landline infrastructure by moving directly to mobile telecommunications.
- To support leapfrogging, countries need strategic innovation policies, sound infrastructure and institutions, and appropriate technological standards.

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Frontier technologies and leapfrogging

Discussions of the developmental dimension of frontier technologies, particularly digital technologies, often highlight the possibility of "leapfrogging", the concept of "bypassing intermediate stages of technology through which countries have historically passed during the development process".[2] The traditional notion of "catch-up" refers to the narrowing of gaps in income and technological capabilities between a late-developing country and a front-runner country. Historically, this has entailed a sequential process of learning by latecomers in skills, process technology, design and product development. A major barrier is the need to learn product design and acquire the capability to create new products, as front-runner firms are generally unwilling to grant licences to catching-up firms.

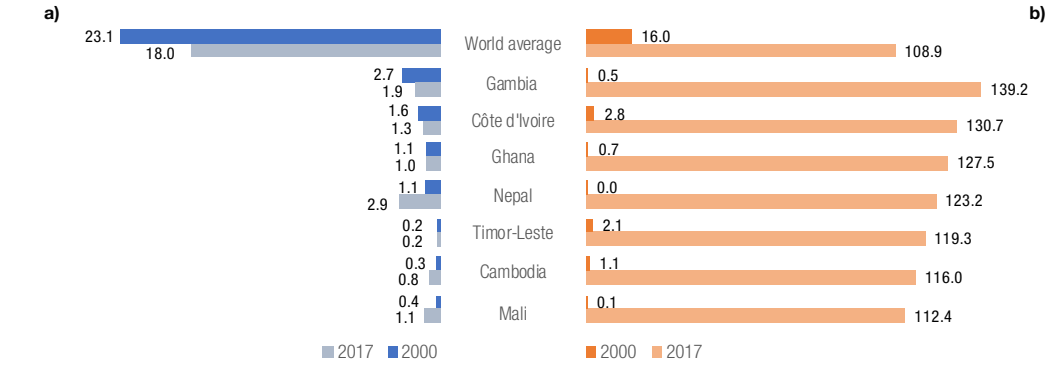
However, the nature of recent technological advances, notably in information and communications technology (ICT) and energy, means that catch-up no longer requires following the paths of frontrunners, as it can be achieved by leapfrogging.

Potential for leapfrogging

In large part, the experience of the ICT sector has brought increased attention to leapfrogging. Rapid technological advances and cost reductions in ICT in recent decades have enabled some developing countries, notably in Africa and Asia, to skip the development of landline infrastructure by moving directly to mobile telecommunications. For example, in the early 2000s, Cambodia, Côte d'Ivoire, Gambia, Ghana, Mali, Nepal and Timor-Leste had less than three fixed-telephone subscriptions per 100 inhabitants, well below the global average of 23.1. Mobile subscriptions were also marginal (figure 1). By 2017, however, these countries had bypassed the landline infrastructure and reached levels of mobile subscriptions per 100 inhabitants that were above the global average of 108.9: Gambia (139.2), Côte d'Ivoire (130.7), Ghana (127.5), Nepal (123.2), Timor-Leste (119.3), Cambodia (116) and Mali (112.4). Most developing countries have followed the same pattern. For example, in 2017, the mobile penetration rate in those countries was 98.7 subscriptions per 100 inhabitants, while that of fixed telephones was 8 per 100 inhabitants.[3]

[1] This policy brief is based on UNCTAD, 2018, *Technology and Innovation Report 2018: Harnessing Frontier Technologies for Sustainable Development* (United Nations publication, Sales No. E.18.II.D.3, New York and Geneva).
[2] UNCTAD, 2018, p. 84.
[3] UNCTAD calculations, based on data from the International Telecommunication Union.

Figure 1 **Countries that leapfrogged to mobile technology: A comparison of (a) fixed-telephone and (b) mobile subscriptions per 100 inhabitants, 2000 and 2017**



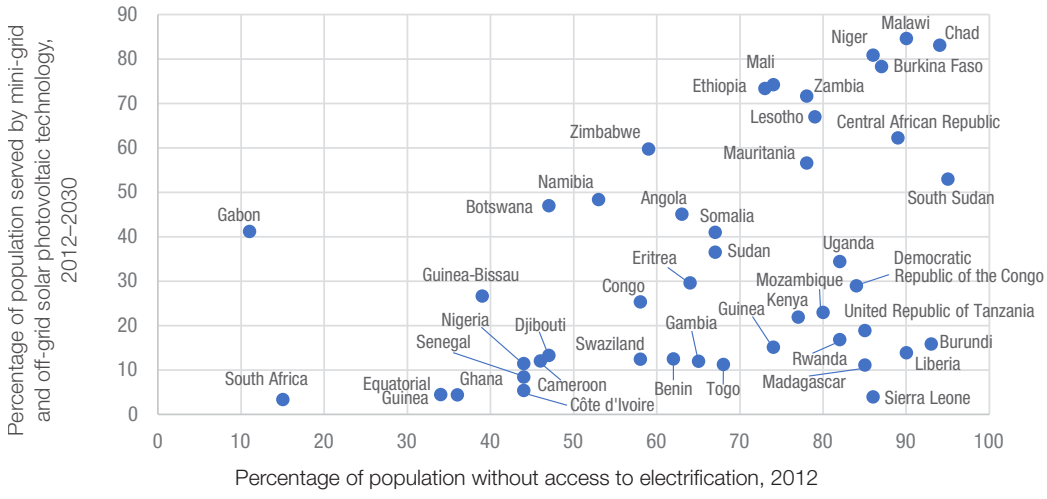
Source: UNCTAD calculations based on data from the International Telecommunication Union.
Note: Earliest data for Timor-Leste is for 2003; latest data for Gambia and Mali is for 2016.

The rapid adoption of mobile technology has not only contributed to increased productivity and new markets, it has also enabled innovative financial technology services. Examples are the M-Pesa mobile banking system and Grass Roots Bima insurance company in Kenya, and the Flutterwave technology company for large financial institutions in Nigeria. And they all bear major implications for financial inclusion. For instance, in 2017, countries in sub-Saharan Africa had the highest percentage of adults with a mobile money account, with a regional average of 21 per cent, compared with 4 per cent worldwide. According to the Global Financial Inclusion Database, the following countries are leaders in mobile financial inclusion, with over a quarter of the adults in the first four income deciles using a mobile account service: Kenya (59 per cent), Uganda (40 per cent), Zimbabwe (40 per cent), Gabon (37 per cent), Ghana (32 per cent), the United Republic of Tanzania (30 per cent), Namibia (29 per cent), Côte d'Ivoire (27 per cent) and Senegal (27 per cent).

An example of the potential for leapfrogging in frontier technologies is the development of decentralized renewable energy systems. Prices in renewables have fallen sharply in recent years as investments have increased. Since 2009, the cost of wind turbines has dropped by nearly 33 per cent, and that of solar photovoltaic modules, by 80 per cent, making both technologies increasingly competitive with fossil fuel generation. Solar energy is now the cheapest generation technology in many parts of the world. Cost reductions represent an opportunity for electrification in rural areas, especially in developing countries, through off-grid and mini-grid solutions.

An analysis using geospatial data shows that to bring electricity to all households in sub-Saharan Africa by 2030, the most cost-effective mix of conventional and renewable energy technologies for several countries would be off-grid and mini-grid solutions using solar technology. These solutions could serve a large share of the population with a lower

Figure 2 **Potential for leapfrogging in decentralized solar photovoltaic technology (Percentage)**



Source: UNCTAD calculations based on data from the United Nations open-source spatial electrification tool.
Note: Electrification scenario considers 22 kWh of electricity consumption per household per year, grid electricity cost of $ 0.1 per kWh and cost of diesel of $ 0.7 per litre.

cost in the following countries: Malawi (84 per cent of the population), Chad (83 per cent), the Niger (80 per cent), Burkina Faso (78 per cent), Mali (74 per cent), Ethiopia (73 per cent), Zambia (72 per cent), Lesotho (67 per cent), the Central African Republic (62 per cent), Zimbabwe (60 per cent), Mauritania (57 per cent) and South Sudan (53 per cent) (figure 2). In many cases, a wide electrification gap – the percentage of the population without access to electricity – is associated with a large potential for leapfrogging. These countries are represented on the right-hand side of figure 2. Exceptions are due to factors such as a higher density of population close to existing or already planned national grids, which reduce the need for off-grid and mini-grid solutions.

Frontier technologies as an alternative to traditional paradigms

Many leapfrogging opportunities are in technologies that offer an alternative solution for costly investment in infrastructure related to traditional technological paradigms. For example, mobile and renewable energy technologies eliminate the need for large investments in infrastructure such as landlines, extensions of the national energy grid and the establishment of financial branches in remote areas with a low population density.

Drones represent a leapfrogging opportunity for precision agriculture in developing countries to measure and respond more effectively to variability in crop and animal production. This technology offers an alternative to more costly agronomic information based on traditional remote-sensing technology. For example, the Third Eye project in Mozambique used low-cost drones to help small-scale farmers improve crop production by 41 per cent and reduce water use by 9 per cent. These results illustrate the systemic nature of the innovation process, which in this case includes the training of local drone operators, communication of relevant agronomic information to farmers and widespread availability of mobile phones. Drones could also revolutionize the delivery of supplies to remote areas. For example, in Rwanda, the Government has partnered with a robotics company, Zipline, to address maternal mortality by using drones to deliver blood to medical facilities, reducing the time to procure blood from 4 hours to 15 minutes.

The Internet of things also offers innovative and alternative solutions in health care, agriculture, energy and water management, for example. The Internet of things monitors and manages connected objects and machines, and is based on developments in Internet technology, smartphones and new sensing technology. In Bangladesh, the Internet of things is being used to assess groundwater chemistry and protect people in the Ganges Delta from drinking water that is contaminated with arsenic. This lessens the need for investments in the implementation and maintenance of traditional monitoring networks.

Small-scale satellites are used in communication networks and applications that draw on high-resolution imagery in monitoring land use and urban planning, for example. These satellites will soon be affordable for more developing countries, businesses and universities, diminishing the need for investment in more costly and traditional satellite technologies.

These examples highlight the potential for leapfrogging through the adoption of technologies developed elsewhere.

Leapfrogging and the development of new technologies

Another type of leapfrogging is through the development of new technologies. A few economies in the East Asian region, such as the Republic of Korea and Singapore, have experienced rapid growth by successfully leapfrogging in the development of a limited number of short-cycle technology sectors such as semiconductors and other electronics. Typically, they begin with the assembly of final goods using imported parts. Next, they move on to the development of low-technology components, and gradually to higher-technology components, before learning to modify the design of existing products and ultimately, to develop new products.

Yet for many developing countries, leapfrogging in the industrial sector is a challenge, particularly with the development of new technologies. Catch-up requires learning modern technologies and accumulating indigenous technological capabilities in innovation and technological know-how for production, as well as investing in physical assets. However, these innovation capabilities are often lacking, especially in the least developed countries. For example, in 2014, the average intensity of research and development in most developing countries was below 0.5 per cent, much lower than the world average (over 1.5 per cent). With regard to output in innovation, the technological gap is reflected in the differences in productive capacities. For example, countries with a high prevalence of extreme poverty mainly

export minerals and agricultural commodities; they represent only 0.4 per cent of global manufacturing production and 1 per cent of merchandise exports.[4]

Ultimately, long-term technological innovation depends on industrial development and a manufacturing base, and the hard and soft infrastructure for such development. For example, advances in ICTs have been credited for opening up opportunities to bypass manufacturing to leapfrog into the services economy – and some developing countries have moved in this direction, participating in global value chains through outsourcing in ICT services. However, relatively few have succeeded in developing substantial economic activities in this area, partly due to stringent infrastructure, quality and cost requirements. Moreover, benefits to the poorer segments of society are not automatic and are largely limited to second-order effects such as indirect job creation. Even in the successful cases of India and the Philippines, most direct and indirect job creation has occurred in a few major urban agglomerations (see the UNCTAD publication, *Information Economy Report 2010: ICTs, Enterprises and Poverty Alleviation*).

Successful as it has been, Africa's mobile revolution also demonstrates the limitations of leapfrogging. Despite the developmental role of ICTs, their economic impact in sub-Saharan Africa appears smaller than in other regions. This partly reflects the limitations of innovation policy in Africa to co-evolve with the development of ICT and to fully exploit the opportunities to build on the mobile revolution to foster innovation and development. Sustaining progress requires constant innovation and investment in the latest technologies to keep up with continuing swift technological change in the sector. Investing in broadband installations, building absorption capabilities and developing skills

level of technological development, its economic structure and the capabilities of its public institutions and the private sector. The capabilities of stakeholders – firms, research and education systems, government, civil society and consumers – the connections among them and the enabling environment for innovation that they create, characterize a national innovation system.

Therefore, leapfrogging should be supported by strategic innovation policies that strengthen the effectiveness of their innovation systems to promote and facilitate the deployment and adaptation of frontier technologies to their production needs and to build capacity for developing them further.

The potential to harness and sustain a development trajectory based on leapfrogging depends on the state of infrastructure and institutional capacity, which are lacking in many developing countries, particularly in the early stages of technological development. The selection of technological standards appropriate to local circumstances and the development of markets for complementary technologies are also important factors.

International forums, such as the Commission on Science and Technology for Development and the Multi-stakeholder Forum on Science, Technology and Innovation for the Sustainable Development Goals, offer knowledge-sharing platforms about policy choices on leapfrogging in frontier technologies. UNCTAD science, technology and innovation policy reviews, mandated by the Commission, contribute to the design and implementation of national strategic innovation policies. As of the end of 2018, 14 such reviews had been conducted. The latest reviews were carried out in Rwanda and the Islamic Republic of Iran (2017).

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