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# A Conceptual Policy Framework for Leveraging Digitalization to Support Diversification in Sub- Saharan Africa

Mame Astou Diouf, Leonardo Pio Perez, Félix Fernando  
Simione, Arina Viseth, Jiaxiong Yao

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**A Conceptual Policy Framework for Leveraging Digitalization to Support Diversification in Sub-Saharan Africa****Prepared by Mame Astou Diouf, Leonardo Pio Perez, Félix Fernando Simione, Arina Viseth, and Jiaxiong Yao<sup>1</sup>**

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**ABSTRACT:** The need for Sub-Saharan African (SSA) countries to diversify their economies is more urgent than ever. However, despite its established economic benefits, several challenges have precluded diversification in SSA. Against this backdrop, interesting initiatives to further adopt digital technologies, particularly during the COVID-19 pandemic, suggest that digitalization is a promising avenue to overcome barriers to diversification. Fast-paced advances in the diffusion of digital technologies and knowledge have the potential to transform SSA economies through several channels. By connecting people and facilitating the rapid diffusion of information, digitalization also promises to reshape the industrial structure of activities in new and unprecedented ways. Therefore, digitalization has the potential to promote diversification and growth in SSA by acting both as an enabler and driver of economic activities, helping support resilience. Yet, while the empirical literature on SSA suggests that digitalization can provide new opportunities for growth, employment, productivity, and inclusion, the impact on diversification has not been studied. This paper aims to fill this important gap in the literature. It also aims to strengthen IMF engagement with SSA policy makers by providing a conceptual policy framework, encompassing both horizontal and sectoral policies, on how to leverage digitalization to support diversification and boost resilience in a post-COVID world.

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Authors' E-mail Addresses:	<a href="mailto:MDiouf@imf.org">MDiouf@imf.org</a> , <a href="mailto:LPioPerez@imf.org">LPioPerez@imf.org</a> , <a href="mailto:FSimione@imf.org">FSimione@imf.org</a> , <a href="mailto:AViseth@imf.org">AViseth@imf.org</a> , <a href="mailto:JYao@imf.org">JYao@imf.org</a> .

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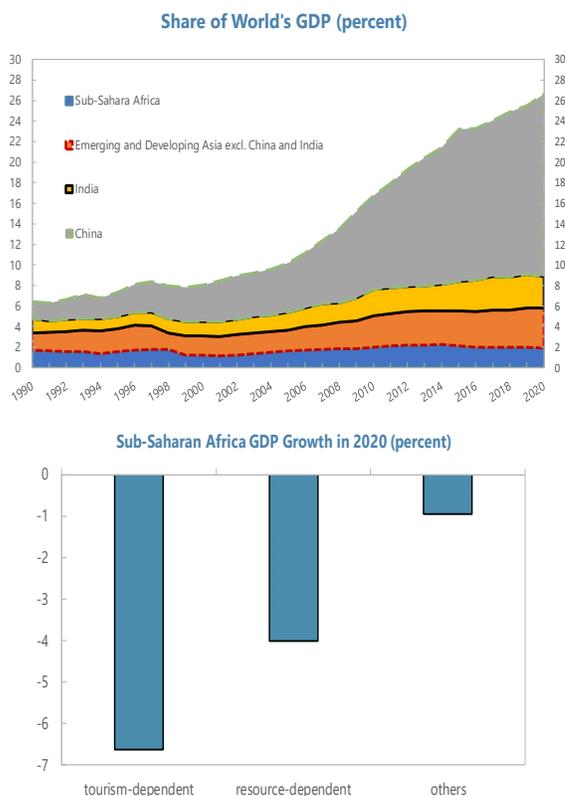
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# 1. Introduction

**Economic diversification is the process of an economy moving towards a diverse production and trade structure.** Often seen as a strategy to foster growth and encourage development, it is intricately linked to a reallocation of resources and economic activity across sectors, an emergence of new markets, and an increase in productivity. Both the introduction of new sectors and the increased value-added from activities in existing sectors can contribute to an economy's aggregate employment and output. Also, the diversification of exports generally entails a move from the export of one or a few primary commodities to that of a wider set of manufactured goods and services to a wider market (Usman and Landry, 2021). More diversified economies typically exhibit higher levels of GDP while less diversified ones are often associated with higher vulnerability to shocks (Papageorgiou and Spatafora, 2012; IMF, 2014, 2017, 2022). The past three decades witnessed the profound transformation of many Asian economies while Sub-Saharan African (SSA) countries fell behind.

**The need for SSA countries to diversify their economies is now more urgent than ever.** Diversification has remained elusive for most SSA countries, despite having similar starting positions to their Asian peers (Figure 1). The successful experiences of Asian economies offer a promising prospect for SSA countries to further diversify and reap the associated benefits. Diversification takes on a new relevance in the context of the supply chain disruptions caused by the COVID-19 pandemic as it is not only important in supporting

**Figure 1. Sub-Saharan Africa: Urgent Need for Diversification**



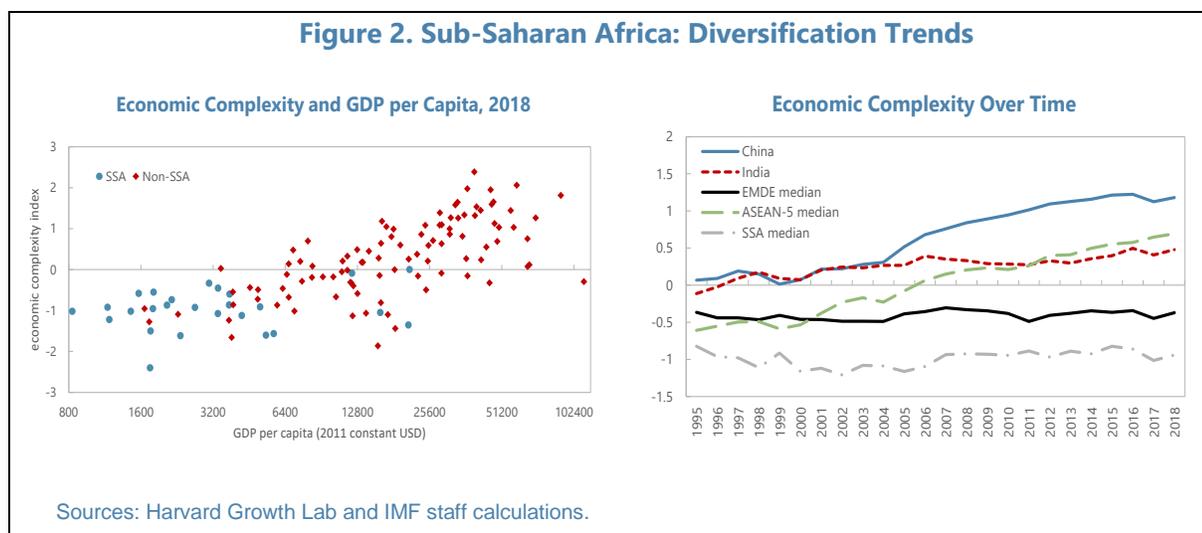
Source: IMF staff calculations.

growth, but also crucial to enhance resilience. A cross-country comparison shows that less diversified SSA countries, such as those reliant on natural resources, experienced more output loss during the pandemic than countries with multiple sources of income (Figure 1).

**Despite its established economic benefits, several challenges have precluded diversification in SSA.**

Economic complexity—a concept that measures the diversity of a country’s productive capabilities and is closely linked to diversification<sup>1</sup>—is cross-sectionally highly correlated with GDP per capita (Hidalgo and Hausmann, 2009). However, very few SSA countries have managed to increase the complexity of their products over time (Figure 2). While this partly reflects the general difficulty for EMDEs to expand productive capabilities (Hidalgo et al., 2007; Hausmann and Hidalgo, 2011), SSA countries face some unique challenges. Limited physical and human capital, low access to finance, and lack of competition in key sectors are major obstacles to diversification in SSA (IMF, 2017). Those challenges interact with the high dependence of natural resources creating a vicious cycle that limits growth opportunities.<sup>2</sup>

**Figure 2. Sub-Saharan Africa: Diversification Trends**



**Several initiatives to further adopt digital technologies, particularly during the COVID-19 pandemic, suggest that digitalization is a promising avenue to overcome barriers to diversification.** Digital tools have the potential to promote economic growth and mitigate the effect of a crisis, as evidenced by their critical role in the responses to the pandemic.<sup>3</sup> Digitalization also provides diversified sources of income and creates new job opportunities, which are critical to create jobs to help SSA countries reap the benefits of their young demography (Evangelista et al., 2014). In the wake of heightened uncertainty and structural breaks triggered by the pandemic, new ways of production and trade have emerged. Digitalization has

<sup>1</sup> Economic complexity measures the diversity of capabilities—non-tradable inputs that are combined to produce products—present in a country and their interactions (Hidalgo and Hausmann, 2009).

<sup>2</sup> Resource dependence has long hampered SSA’s diversification through the so-called Dutch disease (Corden and Neary, 1982). As of 2022, 22 out of 45 SSA countries are resource dependent, whereby more than 50 percent of those countries’ export earnings depend on primary products or fuel.

<sup>3</sup> Country-level empirical studies using broadband internet penetration and related variables as proxy for digitalization have corroborated the positive effect of digitalization on economic growth (Qiang et al., 2009; Czernich et al., 2011; and Zaballos and López-Rivas, 2012). A comparison of digitalization in SSA with OECD economies suggests that digitalization positively contributes to economic growth, independently from a country’s development level (Myovella et al., 2020). Also, digital financial inclusion is found to have had a positive impact on economic growth (Khera et al., 2021).

become even more important to buttress SSA countries' recovery through better connectivity and higher productivity. With likely long-lasting scarring impacts of the COVID-19 pandemic on poverty, education, and health, digitalization will also continue to be an essential element to support inclusiveness, provide targeted help to vulnerable groups, and build back better towards a more diversified economy (Copestake et al., 2022; Abidi et al., 2022).

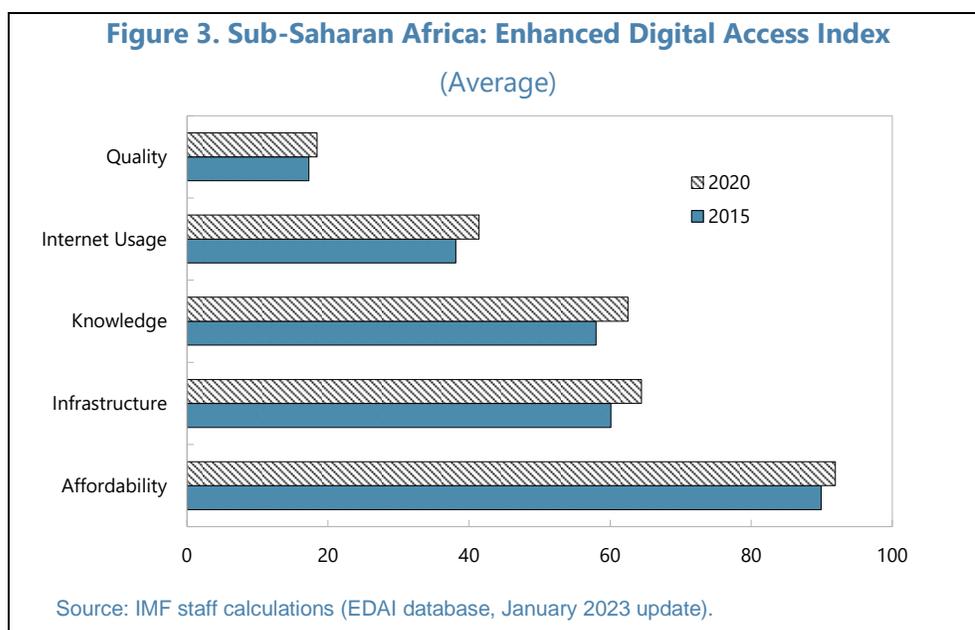
**Diversification takes on a new meaning in the digitalized world, but its direct link with digitalization is yet to be analyzed in depth.** Traditional manufacturing and export-led growth models may be less viable as digitalization changes the way in which economic activity is organized. In SSA countries, new development agenda must harness digital strategies to increase productivity in non-resource sectors and help catch up technologically with the rest of the world by implementing practices that have been proven successful elsewhere. This process can be expedited by leapfrogging traditional infrastructure gaps through the direct adoption of more advanced and innovative solutions (World Bank, 2016). However, new skills and infrastructure will be required to meet the new requirements of diversification. There is a need to adopt frontier technologies to be competitive, create niche markets to attract investment, and use digitalization as a policy tool to support economic growth and promote inclusiveness. By focusing on leveraging digital technologies and benefiting from their spillovers, the proposed policies, both vertical or horizontal, should avoid undermining multilateralism, and instead promote greater multilateral integration. There is no empirical study yet on the direct impact of digitalization on diversification, as digitalization is a relatively new phenomenon and data on successful diversification experiences remains limited. Nonetheless, the emerging evidence suggests a positive link between digitalization and diversification.

**This paper aims to both fill the gap in the literature and strengthen IMF engagement with SSA policy makers by providing a conceptual policy framework on how to leverage digitalization as a tool to support economic diversification and boost resilience in a post-COVID world.** It is meant to provide a high-level mapping of the digitalization-diversification nexus, with specific country examples to illustrate the importance of certain digital policies or initiatives. It identifies two channels of transmission by characterizing the role of digitalization as enabler of diversification, by alleviating obstacles such as limited human capital and low access to finance, and as driver of diversification, by introducing new sectors and modernizing existing ones. It also shows that those channels can reinforce each other. The paper discusses broad policy options encompassing both horizontal and vertical policies related to four areas: (i) human capital; (ii) the business environment and regulatory framework; (iii) redistributive capacity; (iv) infrastructure building and international cooperation; and (v) cybersecurity, privacy protection, and risk management. The paper also discusses institutional requirements as well as the role of key stakeholders. Notably, the paper argues that while SSA countries typically have a growth or development strategy encompassing policies to promote diversification, to be fully efficient, these policies should be integrated within a broad framework that embeds a digitalization strategy and ensures that all policies are mutually reinforcing. However, ultimately, operational guidance on the issue and implications on policy advice should be tailored to country specifics.

**The remainder of the paper is organized as follows.** Section II discusses the state of play of digitalization in SSA and provides examples of how SSA countries have leveraged digital solutions to boost the resilience of vulnerable groups. Section III analyzes how digitalization can be an effective tool to support diversification and structural transformation, including in the context of rapid technological change prompted or accelerated by the COVID-19 pandemic. Section IV discusses the role of horizontal and more targeted vertical policies to support the digitalization-diversification nexus and provides illustrative country examples. Section V concludes by discussing the role of key stakeholders.

## 2. Digitalization in Sub-Saharan Africa: State of Play

**While the degree of digitalization in SSA still lags behind the rest of the world, the digital divide was narrowing before the pandemic.** The IMF's *Enhanced Digital Access Index (EDAI)* shows a significant gap in *digital connectivity*—the ability to access and use technologies to connect to the internet and share digital information—in SSA. There are disparities across and within countries in the region, with higher income and coastal countries being more digitally connected, while rural areas tend to be less connected. There is also a gender disparity, with women tending to be less connected. The EDAI shows broad improvements from 2015 to 2020 in quality, internet usage, knowledge, IT infrastructure, and affordability (Figure 3).<sup>4</sup> Moreover, internet penetration in the region has increased tenfold since the early 2000s, compared with a threefold increase in the rest of the world. However, internet penetration and quality lag behind as the average mobile download speed in SSA is more than three times slower than in the rest of the world.

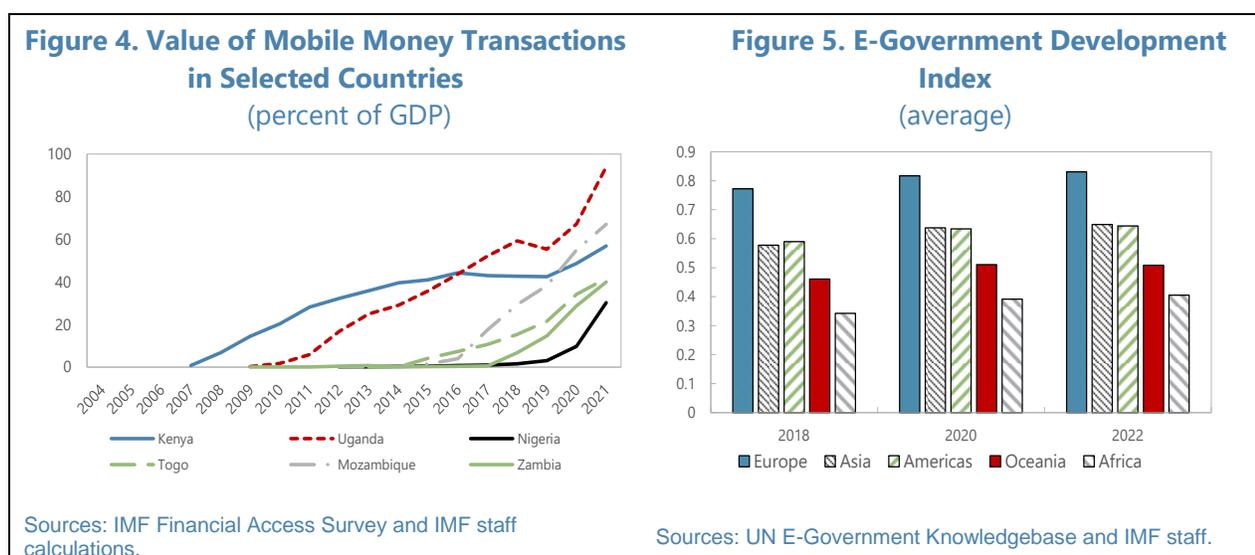


**The pandemic has accelerated digitalization even further in SSA, as countries embraced digital tools to cope with and cushion the lockdown.** In SSA, the ability to shift to partial telework has been more limited than in most other regions, but private businesses have still deployed digital responses to ensure business continuity and safeguard jobs amid the pandemic. For instance, local private innovators in Uganda upgraded an existing ride-hailing app to allow customers to make online orders of essential goods. Governments have also embraced digital platforms to continue providing public services during the pandemic, such as the ePassport agency in Côte d'Ivoire and the eCitizen portal in Kenya. In Togo, the NOVISSI social protection program has leveraged mobile money and electronic cash transfers to protect vulnerable informal sector workers. Digitalization has also supported the public health response, with many countries using contact tracing apps to track infection cases. Some central banks in the region have relaxed mobile money regulations to encourage greater use of digital payments rather than risking the spread of the

<sup>4</sup> The methodological details on the EDAI are presented in Annex II.

virus through bank notes. In Rwanda, robots were used during the pandemic to monitor patients to minimize infection risks for health workers. In Nigeria and Ghana, drones have been used to deliver blood and vaccines.

However, progress in SSA has been mixed regarding the degree of *digital depth*—the extent to which economic activity, transactions, and policies have become digital. One area where SSA is leading in digital depth is the financial sector. Some countries in the region are global leaders in mobile money transactions, which exceeded 50 percent of GDP in Kenya, Mozambique and Uganda in 2021, according to the IMF Financial Access Survey (Figure 4). The region has also been advancing digital innovation in Fintech, resulting in the buoyant development of new services and apps. Yet, developments in other areas remain timid. For instance, public sector digitalization, despite a modest improvement from 2018 to 2022, remains low compared to non-SSA regions (Figure 5), and so is the case for e-commerce transactions.

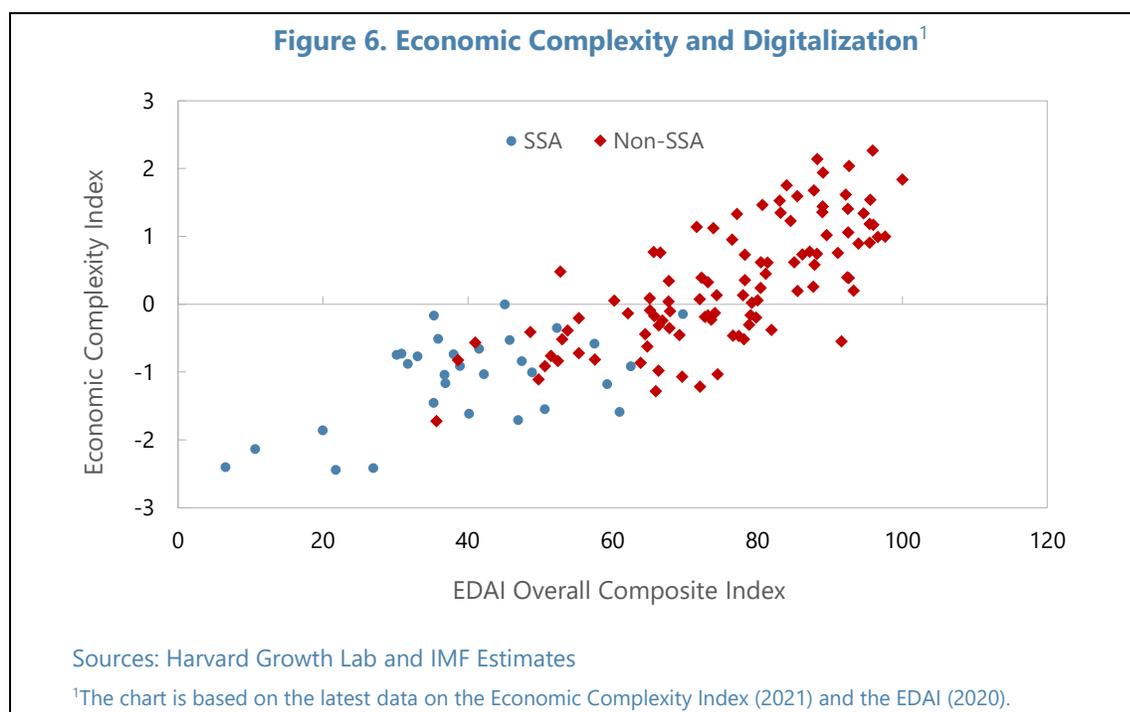


### 3. Digitalization as a Tool to Support Economic Diversification and Structural Transformation

#### 3.1 Channels of Transmission from Digitalization to Diversification and Growth

The empirical literature on SSA suggests that digitalization can provide new opportunities for growth, employment, productivity, and inclusion, but the impact on diversification has not been studied in depth. Expanding internet access in SSA by an extra 10 percent of the population could increase real per capita GDP growth by 1 to 4 percentage points (IMF, 2020; Simione and Li, 2021). Digitally connected firms tend to record higher annual sales, employ more workers, and create higher skilled and full-time jobs. Some literature finds that the digitalization-driven net job creation comes with little or no job displacement, and is driven by increased firm entry, productivity, and exports (Hjort and Poulsen, 2019). Further, the literature has also established the positive impact on productivity, showing that digitalization increases labor productivity, competitive advantage, and efficiency, hence enabling greater business

growth.<sup>5</sup> Digitalization, for example through penetration of mobile money, has also been found to strengthen financial inclusion in SSA through higher access to loans and savings, and larger and more frequent financial transactions (Jack et al., 2013; Okello et al., 2018; Ky et al., 2018). The direct impact of digitalization on diversification has not been well studied empirically in part because digitalization is a relatively new phenomenon and successful recent diversification experiences remain scant. Nevertheless, the positive correlation between digitalization (proxied by the EDAI) and diversification (proxied by the Economic Complexity Index) is striking both in SSA and non-SSA countries (Figure 6).<sup>6</sup>



**Fast-paced advances in the diffusion of digital technologies and knowledge have the potential to transform SSA economies through several channels.** First, by lowering entry costs and connecting firms to a wider, more global market, digitalization can dramatically boost local competition and efficiency. Second, by allowing for the automation of routine administrative tasks (e.g., business registration or tax payments) and for a better targeting of policy interventions, as well as for the rapid scaling of key services (e.g., education), digitalization can significantly boost revenues and improve public service delivery. Third, by allowing for increased transparency and reduced opportunities for rent seeking, digitalization can also be a critical part of the global fight against corruption (IMF, 2018; Ouedraogo and Sy, 2020).

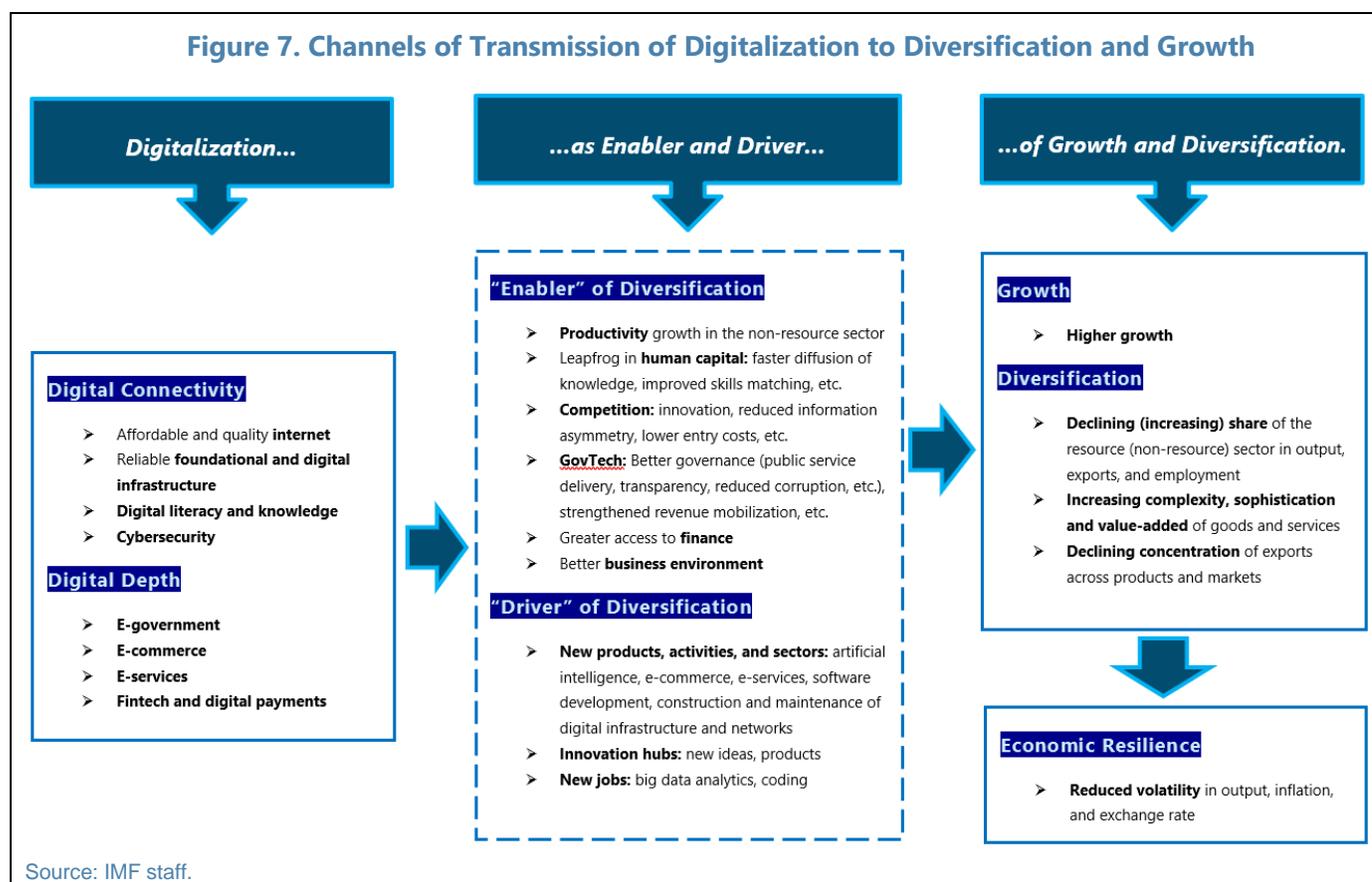
**Moreover, by connecting people and facilitating the rapid diffusion of information, digitalization promises to reshape the industrial structure of a broad range of activities in new and unprecedented**

<sup>5</sup> Studies using the arrival of submarine cables in SSA as a natural experiment, both at the firm level and at the country level, find a significant impact of internet penetration on employment (Hjort and Poulsen, 2019), and on macroeconomic performance and labor productivity (Simione and Li, 2021). Other related studies with similar findings include (Dieppe, 2020; Franklin et al. 2009; Paunov and Rollo, 2016; and Akerman et al. 2015).

<sup>6</sup> Figure 6 depicts correlation, not causality which can go both ways. Estimating a causal relationship is beyond the scope of this paper.

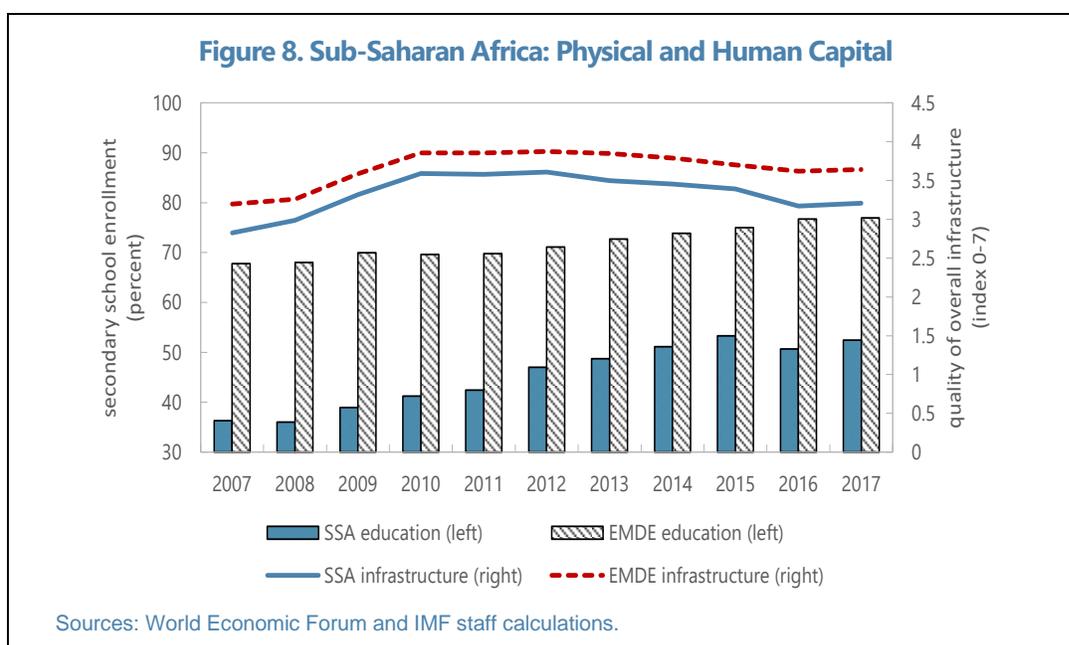
**ways.** For example, the leveraging of new data sources has allowed the provision of financial services to firms, households and individuals that have traditionally been excluded, allowing them to participate and contribute to the local economy. More broadly, industries that are ahead in digitalization tend to be in the service sector, or sectors that deliver products that are less physical and more immaterial. Digitalization, therefore, may boost the role of services as a key driver of an economy's growth and development model.

**Therefore, digitalization has the potential to promote diversification and growth in SSA by acting both as an enabler and driver of economic activities, thereby helping support resilience.** The effects of digitalization on growth have been somewhat documented (for example, Matthes and Kunkel, 2020), although the channels of transmission remain largely underexplored from an empirical standpoint. Digitalization can enable diversification by promoting higher productivity growth, faster diffusion of knowledge and ideas, stronger competition, more efficient access to finance, and better governance and business environment. It can also drive diversification by promoting the creation of new products and sectors (e.g., e-commerce, e-services, artificial intelligence) and stimulating job creation. The dual roles of enabler and driver are mutually reinforcing and have the potential of addressing SSA countries' diversification challenges in a complementary way. Some of these dynamics are discussed below and illustrated in Figure 7.



### 3.2 Digitalization: An Enabler of Economic Growth by Overcoming the Challenges for Diversification in SSA Countries

**Digitalization can help SSA countries overcome the challenges of diversification and break the resource trap by increasing productivity in non-resource sectors.** Lack of adequate physical and human capital is an enduring constraint for SSA's diversification. In general, SSA countries have larger physical and human capital deficits than other EMDEs (Figure 8), which has been limiting their ability to expand productive capabilities. However, digital solutions based on remote connectivity and online services have proven to be effective in alleviating bottlenecks in physical infrastructure and reach remote locations. Further leveraging on digitalization offers potential for SSA to enable diversification through strengthened human capital, greater access to finance, and stronger competition and business environment. These four “enablers”, illustrated in Figure 7, are discussed in detail in the next paragraphs.<sup>7</sup>



**Digitalization strengthens human capital by making workers more productive, increasing labor supply and narrowing the gender gap through increased access to education, skill building, and knowledge diffusion.**

- **SSA's limited knowledge diffusion and human capital development can be addressed by digitalization as shown by several country examples.** By circumventing constraints in transportation infrastructure, digitalization can promote people-to-people interactions, which have the potential to generate new ideas. By lowering the costs of information sharing, broadening the fora of information transmission, and promoting connectivity, digitalization allows countries to build human capital more quickly while improving its quality. Indeed, since it allows for the rapid and

<sup>7</sup> Figure 7 does not exhaustively list the “enablers” and “drivers” of diversification.

flexible scaling up of service delivery, investment in digital learning is often less costly than building classrooms and universities, while creating the potential to reach a much larger audience. Digital learning also diversifies the sources of learning outlets (special learning applications and platforms, more popular platforms such as YouTube and social media, etc.). For example, Cote d'Ivoire, Kenya, and Sierra Leone have already been enhancing education by leveraging digital technology for education services and upgrading of teachers and recruitment process. Angola, Burkina Faso, Cameroon, Madagascar, Malawi, and Sierra Leone have also introduced educational television and radio programs and Cote d'Ivoire, Ghana, Kenya, Liberia, and Uganda launched virtual campus apps and website to provide free study materials. While some countries focus on building basic skills and financial literacy (Kenya, Rwanda), other countries are focused on building more advanced technical skills (coding academy at Niger's tech center and more options for tertiary training in software development and entrepreneurship in Kenya). Regarding healthcare, telemedicine can promote a healthier workforce by bridging the gap on specialized care to remote regions and enable the management of chronic diseases (UNDP-led project SanDi, in Mali).

- **Equally important, digitalization has the potential to support greater inclusion.** It helps reduce gender gaps and integrate informal workers, which would provide the foundation for long-term sustainable growth. COVID-related school closures provided a prime example for how digital technology allows for continued educational opportunities when lockdown measures prevented in-person learning. However, SSA countries lag the rest of the world regarding digital access and face a wide gender gap. With the pandemic pushing more households into extreme poverty, young girls are more likely than boys to be forced to drop out of school. Without education, either in an in-person or remote environment, these girls suffer a permanent loss of human capital, sacrificing productivity growth and perpetuating the cycle of poverty among women.

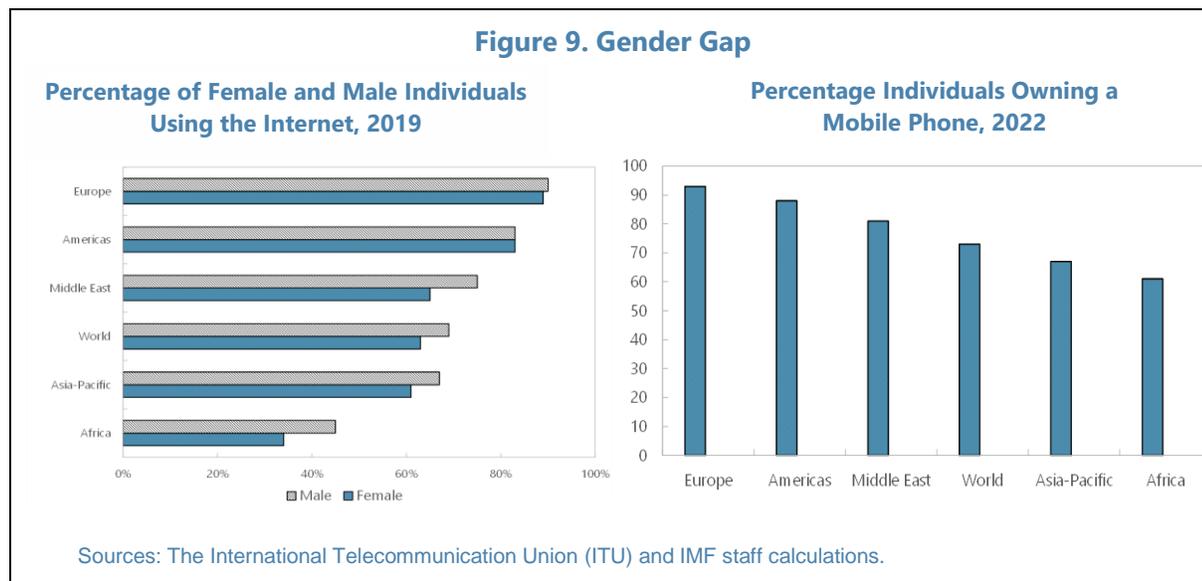
#### **Digitalization supports greater financial inclusion and financial depth.**

- **Digitalization can help improve access to finance in SSA, an important constraint for investment and innovation, mainly for small and medium enterprises (SMEs).** Digital financial services have helped firms address liquidity issues during the pandemic crisis. They are expected to continue playing an important role during recovery.<sup>8</sup> For example, Fintech firms leverage digital payment data to assess lending risk more easily using big data analysis, which allows them to offer tailored financial solutions including using lending and capital raising platforms. Between 2020 and 2021, the number of tech startups in Africa tripled to around 5,200 companies, of which nearly half are Fintech (McKinsey & Company, 2022). The growth of Fintech in SSA has the potential to close gaps in the delivery of financial services and improve access to finance for SMEs.
- **Digital financial technology has an important role in promoting inclusive growth and diversification.** It has improved access to financial services in SSA and can be further leveraged to reduce the gender gaps in access to finance. The Global Findex Database shows positive trends in increasing access to mobile money for both men and women from 2014 to 2017, with SSA

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<sup>8</sup> *The Global Covid-19 FinTech Market Rapid Assessment Study*. Cambridge Centre for Alternative Finance, World Bank Group and World Economic Forum with the support of UKaid (2020).

countries leading the way (Figure 9). However, the gap between the percentage of women and men with mobile money accounts increased over the three-year period.



**Digitalization stimulates competition and encourages innovation, improves the quality of public services and the business environment, and increases sustainability and resilience.**

- Market power concentration is a major impediment to SSA’s diversification.** Such monopolies, especially state-owned, typically stifle export competition and hinder productivity growth. More than 70 percent of the countries in the region fall below the global median in terms of domestic and foreign competition indicators (IMF, 2020). Digitalization supports more firm entries and reduces the cost of doing business. The ICT sector can be utilized to reduce the time it takes to launch a business and decrease the cost of starting one, allowing the number of businesses to increase (Tchamyu, 2017). For example, Eswatini, Nigeria, and Zimbabwe were able to simplify the process of starting a business by introducing online platforms among other measures. Also, fast internet significantly increases the productivity of existing manufacturing firms (Ethiopia) and net firm entry (Hjort and Poulsen, 2019), especially in sectors that benefit from ICT such as finance (South Africa). In addition, ICT facilitates initiatives to reach individuals and businesses at very low cost and collect and manage large sets of information, improving prospects to expand businesses and profit margins.
- Digitalization improves the quality of public services and trust in government officials, which are important dimensions of a business-friendly environment.** Govtech can improve a country’s attractiveness through cost and time reductions, efficiency gains, greater transparency, and the accessibility of government information.<sup>9</sup> E-government services have been found to stimulate the inflow of foreign direct investment (Al-Sadiq, 2021), increase trust in tax officials

<sup>9</sup> Amaglobeli et al (2023) propose four elements of an effective national digital strategy: (i) digitalizing the government and by extension providing digital government services to citizens; (ii) recognizing the role of the private sector and fostering an environment that promotes responsible innovation; (iii) managing digital risks ensuring trust to end-users; and (iv) focusing on hard-to-reach citizens to study digital divide as a multi-dimensional issue.

(Ouedraogo and Sy, 2020), and reduce corruption (IMF, 2018). Côte d'Ivoire and Kenya are examples of countries that have made payment of taxes easier by rolling out electronic filing and payment systems. Advances were also observed in the process of dealing with construction permits by investing in georeferencing (Cabo Verde), having the requirements available online (Kenya), and providing an online portal for the submission of applications (Togo).

- **Digitalization also promotes sustainable growth by increasing economic resilience, which is essential to increase new business survival.** During the pandemic, greater connectivity allowed businesses to continue operations. For example, online orders picked up in Kenya and Nigeria while, in Senegal, e-commerce platforms were set up to provide easy access to the websites of SMEs that sell essential goods. Telework arrangements have allowed to provide continuous public services. In Kenya, the e-citizen portal provides continuous services for civil and vehicle registration. In Rwanda, the judiciary has used videoconferencing for court proceedings. Digital platforms have allowed the deployment of targeted social protections programs (Benin, Côte d'Ivoire, The Gambia, Lesotho, Madagascar, Namibia, Togo, Uganda, Zambia, and Zimbabwe), resulting in better identification and verification of beneficiaries, reporting, and information management. Digital technologies can also contribute to achieving the Sustainable Development Goals (SDGs) in Africa, particularly in the field of energy. For example, in Guinea, the use of solar-powered mobile telecommunication antennas has reduced grid diesel consumption. Mobile money has also enabled users to pay for solar energy and bike-sharing. Finally, digitalization helps manage and reduce general waste (Nigeria, Kenya). Some startups promote more efficient water use by relaying information on water leaks and consumption to reduce waste. Similarly, navigation applications help reduce fuel usage by cutting the time drivers spend stuck in traffic jams thanks to better traffic and trip planning (South Africa, Kenya).

**Digital infrastructure and platforms will be key components of a modern economy.** Advanced economies are moving rapidly towards digitalization, building digital infrastructures such as data centers and high-speed internet networks, as well as forging digital platforms for industrial production and services. The future success of SSA's economies—and their diversification—will heavily rest on trade and services with advanced economies because of their large domestic markets. Building digital platforms that can be easily integrated into the international digital ecosystem will therefore be crucial to attract foreign direct investment and foster international business. For instance, many SMEs currently rely on global cloud service providers to conduct business. Ensuring a similar type of service locally will be important for the seamless transitions and business operations of those international enterprises in SSA, which requires fast internet connection and easy integration with international platforms.

### 3.3 Digitalization: A Driver of Economic Diversification and Growth through the Creation of New Sectors and New Jobs

**In addition to its enabling nature, digitalization itself is an engine of economic growth.** The digital sector has already been the fastest growing sector in leading SSA countries, including Nigeria, South Africa, Kenya, and Ghana, where the growth of the digital sector trumps that of the manufacturing sector. Digitalization also creates new types of economic activities across different sectors of the economy.

**Digitalization can help create new products and activities.** Digital technologies can promote the efficiency of resource allocation, including labor and capital allocation across sectors, by improving the use of capital, facilitating the acquisition of skills and knowledge, and reducing costs associated with matching producers and consumers. In the agricultural sector, for example, digital technologies can help improve the use of machinery and equipment; facilitating the acquisition of skills and knowledge; and improving farmers' decision making through accurate, timely, and location-specific price, weather, and agronomic data. The adoption of ICT by SMEs in the Democratic Republic of the Congo had the potential to increase the competitiveness and growth of agribusiness (Kabongo and Okpara, 2014). In Nigeria, Ghana, and Kenya, the platform *Hello Tractor* helps farmers connect with tractor owners over text messages and rent machines which they otherwise had to buy or to which they would not have access at all. This feature improves planning, usage rates, and cost sharing. Platforms such as *Digital Green*, *Plantix*, and *Value4Her*—which is aimed at female agribusinesses leaders—have dramatically increased agricultural productivity by making it easier for farmers to access learning advice and acquire new skills for monitoring and improving the quality of their crops. The proliferation of mobile phones also helps address persistent gaps in access to finance and knowledge, specifically benefitting women in agriculture, who are key contributors to rural economies and livelihood systems. The allure and promise of new technologies such as drones can help attract younger individuals into the agricultural sector, as it has been the case in Cote D'Ivoire.

**Digitalization stimulates the creation of new sectors.** New digital technologies, including mobile networks, internet of things, blockchain, artificial intelligence, big data analytics and cloud computing, have enabled the creation of completely new digital products and services (OECD, 2020). The set of emerging economic activities that exist solely thanks to digital technologies expands beyond the ICT sector. This includes business-offshoring processing, information technology outsourcing, as well as the so-called gig economy, based on flexible jobs involving connecting with clients through an online platform (such as Uber or Upwork), and the platform economy (such as Airbnb, eBay, and Alibaba). The construction of internet infrastructure, data centers, digital payment systems, and numerous other digital infrastructures generates new economic activities. For a digital economy to function, rolling out consumer devices such as smartphones to a critical mass of people is foundational, which in turn spurs trade, investment, and innovation.

**Innovation hubs and similar vehicles can also facilitate on-the-job or peer learning to support entrepreneurs in building skills to develop new businesses.** According to AfriLabs, a network organization of more than 200 innovation centers across 47 African countries, as of October 2021, Africa had 1031 operational tech hubs comprised of accelerators, incubators, university-linked start-up support labs, maker parks and co-working sites.<sup>10</sup> Hubs are playing a catalytic role across Africa's cities. For example, one of the tech hubs of Lagos in Yaba, Nigeria's Silicon Valley, typically brings people together from sectors that ordinarily don't interact with the intention that they can come up with new products or services that can solve a well-defined and distinct problem. Also, Rwanda established a FinTech hub in the context of the Kigali International Financial Center, in which a regulatory sandbox enables fintech innovators to test their products and regulators and policymakers to adapt to the latest developments driving financial services innovation. As academic training struggles to prepare students for entrepreneurship, hubs purposefully fill a void by providing safe havens for the youth and forward-looking training centers that develop digital literacy and hands-on abilities.

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<sup>10</sup> A growth over 60 percent compared to 2019 (AfriLabs and Briter Bridges, 2021).

**Digitalization supports job creation.** Studies have shown that firms using emails have higher real annual sales than non-users and employ more workers than non-users, including less educated workers (Hjort and Pousen, 2019). Firm-level data also show that digitalization contributes to higher net job creation. Building infrastructure to improve access to fast and reliable internet may therefore be among the currently feasible policy options with the greatest potential of job creation in SSA. Job creation supported by further digitalization seems to also benefit women preponderantly. Bahia et al (2020) find that mobile broadband coverage generates higher labor force participation and employment, particularly among women in Nigeria.

### 3.4 Mutually reinforcing forces for a digital and inclusive post COVID-19 economy

**The enabling and driving forces from digitalization reinforce each other through access to finance and trade integration.** Productivity increases in incumbent sectors and creation of new sectors are intertwined, with the two forces reinforcing each other often through access to finance and trade integration. Digital technologies give smallholder farmers access to financial services that would allow them to grow their agribusinesses and increase their income. Digital technologies also give small firms access to international markets, facilitating the insertion in the international value chain but also expanding market size (Lanz et al., 2018). The expansion of e-government in SSA has been supporting the trade channel. For example, Nigeria reduced the time to export and import by further upgrading its electronic system and by launching e-payment of fees. Sierra Leone made trading across borders faster by upgrading its customs electronic data interchange system, thereby reducing the time for import documentary compliance. Finally, the integration of artificial intelligence (AI) into various aspects of international trade presents significant potentials to improve efficiency. Digitalization and AI are in fact two sides of digital transformation. While digitalization transforms information data into digital formats, AI allows people and businesses to enhance their ability to collect and analyze a large amount of data, hence supporting better decision-making. Those examples showcase how enabling and driving forces can reinforce each other, with very often, the enabling factor allowing the driving factor to take place.

**However, several enabling conditions are required to fully reap the benefits of digitalization and catalyze digital-diversification mutually reinforcing forces.** Empirical studies show examples of these preconditions, including (i) adequate level of education (Donou-Adonsou, 2018); (ii) an enabling business environment and access to electricity and good infrastructure (Apulu and Ige, 2011); and (iii) enabling ICT-related laws and policy environment (Pick and Sarkar, 2015).

## 4. Policies to Support Digitalization and Diversification

### 4.1 Policy Areas

**Policies to support digitalization in pursuit of diversification** must cater to the following multidimensional needs and challenges:

- i. **Strong, skilled, and adequately specialized human capital.** This entails sound enabling horizontal policies such as ensuring broad-based adequate basic education that would in turn facilitate learning digital specific skills; high and gender-balanced labor force participation (LFP) that would support adequate LFP in

the digital sector; and appropriate social and job protection that would facilitate digital sector job growth. Additionally, this dimension entails vertical policies such as targeted job training and skill building on digital technologies to further digital literacy and specialty know-how. It also requires a forward-looking approach that ensures that the level and type of education of future workers meet labor market needs and take advantage of the mutually reinforcing and two-way impact in which education also benefits from digitalization.

- ii. **Enabling business environment and digital regulatory framework conducive to innovation.** Keeping up with the speed of global digital innovation, large investment cost, and appropriate adaptation to the SSA-specific challenges and needs requires a healthy and thriving private sector, including a digital private sector, at the forefront of leading changes. This, in turn, entails vertical policies such as empowering and agile frameworks that incentivize and reward entrepreneurship, R&D, and investment in digital activities. Enabling horizontal policies will be essential to maintaining a viable corporate ecosystem, including fair access to financing, adequate digital connectivity, one-stop shop information portals, adequate bankruptcy laws, fair competition, and good governance.
- iii. **Redistributive capacity.** The issue of taxation of digital activities and goods is very much an ongoing discussion. While sufficient consideration must be given to closing the digital gap and facilitating broad-based digital literacy, revenue collection should benefit from the expansion of digital activities, boosting fiscal space to finance redistributive initiatives. Taxation, including that of the digital sector and digital-related activities, must also be conducive to job creation.
- iv. **Infrastructure building, international cooperation, coordination, and collaboration.** The nature and large size of investment needed in digital technologies, typically cross-border scale savings and spillovers, and global and immaterial activities require international cooperation to tame risks and amplify positive spillovers. Investment in basic infrastructure (electricity, broadband coverage, roads, buildings, water) is required, as well as investment in sector-specific infrastructure (high-speed internet in targeted areas, service hubs, and networks). Those investments in turn call for better coordination and collaboration among development partners, notably in the field, and for the potential use of public-private partnerships (PPPs). Altogether, international cooperation, coordination, and collaboration will guarantee that efforts do not get duplicated, and resources (both in terms of financial support and technical assistance) are effectively and efficiently used towards infrastructure building, especially in fragile context, where those scarce resources are the most needed.
- v. **Cybersecurity, privacy protection, and risk management.** It is essential to foster safe and secure digitalization for economic development, and ultimately economic diversification. Governments need to promote actions to bring awareness on cybersecurity (of critical digital infrastructure) and privacy consideration and build capacity to address digital crimes as well as cyber wars that can undermine digitalization efforts. Digital regulatory frameworks should evolve to cater to such emerging risks while being careful not to discourage innovation.

**To be fully efficient, these policies should be integrated and mutually reinforcing within a broad framework that embeds digitalization in a growth and diversification strategy.** Most SSA countries have a national development strategy or plan, usually encompassing policies to promote diversification. While several countries have also adopted a digital strategy, the latter is often not integrated with the development strategy or plan. The required investment in basic infrastructure, as discussed previously, can then benefit from a big push from the integration of such digital strategy within the growth and development strategy. An efficient development and digitalization strategy should include both horizontal and vertical

policies related to the five key policy areas discussed above and designed to work in tandem. Prioritization of policy actions should be tuned to country-specific considerations, including the country's policy gaps, sectoral distribution, structural bottlenecks, and political economy constraints.

## 4.2. Examples of horizontal and vertical policies for short-term economic resilience and long-term economic diversification

Annex I provides examples of horizontal and vertical policies that have supported the role of digitalization in reinforcing short-term economic resilience and as well as diversification.

**Governments have utilized digitalization for resilience**, including during the COVID-19 pandemic when it has been leveraged to improve the coverage and delivery of social safety nets (SSNs) as well as the efficiency of broader government services.

- **Horizontal policies.** Measures included the implementation of government digital cash transfers, setting up national ID systems, promoting digital tax payment, as well as supporting greater access to services and transparency. For example, Togo's all-digital end-to-end cash transfer program (NOVISSI) was deemed as a model in delivering contactless emergency cash transfers, increasing accessibility, efficiency, safety, and transparency of transfers. Togo is also working on setting up a digital identification system for all, similarly to Kenya. In South Africa, Kenya and Senegal, a digital platform allows users to file their tax returns and pay their taxes, saving time and reducing costs. In Kenya, South Africa, Madagascar, Uganda, and Mauritius, digitalization improved transparency and the quality of public services through e-procurement portals, increasing the quality of statistics and improving access to government services.
- **Vertical policies.** Measures to develop digital payments and digitally-enabled climate resilience tools (using technology to enhance resilience to natural disasters and climate change) have supported structural transformation. For example, in Kenya, Nigeria, South Africa, and Madagascar, mobile payment platforms and the launch of digital currencies strengthened payment systems and increased financial inclusion and transparency. In Mauritius, Kenya, and Madagascar, satellite technology and management systems are being used to anticipate and mitigate natural disasters.

**Governments have also utilized digitalization to reinforce the role of diversification in fostering structural transformation and long-term economic growth and resilience.**

- **Horizontal policies.** Digitalization can enhance the impact of broader horizontal diversification policies that underpin long-run sustainable growth. Kenya's pioneering Digital Literacy Program is a good example of investment in digital skills at basic education level. Rwanda's Saving and Credit Cooperative Society is a useful experience in promoting financial inclusion through digital technologies. If well-designed, short-term measures such as setting up digital identification and government cash transfers could also support long-term growth. For example, Togo's implementation of the Unique Identification Number or NIU (digital identification) is expected to improve access to finance, as banks accept the NIU as identification (ID)—previously only 3 out of 8 million Togolese had a national ID card. Similarly, the above-mentioned e-government and climate tech measures can enhance resilience both in the short run and long run. In addition, these measures can also foster structural transformation and long-term growth by improving governance and reducing the risks of corruption—many studies have shown that good governance supports investment and long-term growth (Amine et al. 2019).

- **Vertical policies.** Strategically designed vertical policies to develop the digital sector can foster structural transformation. Several channels stand out. First, the digital sector can create a higher demand for digital skills, which in turn would prompt investment in basic education. Second, it can serve as a gateway to international collaboration, as digital technologies tend to diffuse and disseminate faster than other technologies. Third, integrating digital technologies into agriculture may generate structural change. Using digital technologies to improve agricultural productivity, including by enhancing agricultural condition monitoring, reducing supply chains barriers, and moving agricultural products up the value chain, could invigorate traditional agriculture.

## 5. Policy Players

**Cross-country collaboration, both regional and international, is critical.** Given that digitalization requires heavy and expensive investment that often spans across several countries (e.g., marine cables) and digital technologies evolve quickly, cross-country (regional and international) collaboration is important. Regional and international operability of digital technologies is also critical, especially that digital platforms are not well integrated across SSA countries or internationally.<sup>11</sup> Multinational corporations (MNCs) could play a leading role in that regard. This is even more relevant for digitalization than for other industries. Collaboration in R&D (for example, creating Public Research Institutes with donors' help) and knowledge sharing (for example, leveraging the diaspora using and working in tech in Europe and the US) could also accelerate digitalization trends.

**The role of the public sector is crucial in all the policy dimensions.** This includes carefully choosing supportive public investment and establishing an enabling environment to facilitate private sector investment and development, as well as setting up frameworks for cross-country and cross-institutional collaboration. Adequate policies should first embody good governance, promote transparency, and nurture trust to allow institutions to develop and support an adequate business and risk framework conducive to long-term growth. Measures ensuring good governance, including using technology in government services (e-government), can successfully enhance the impact of short- and long-term policies that support diversification and structural transformation.

**In conclusion, low-income countries have a unique opportunity to explore various angles in the realm of digital technologies.** Digital money can revolutionize access to financial services, empowering individuals and businesses to participate in the formal economy. Additionally, integrating digital identification systems can play a transformative role and enhance access to public services, facilitate financial inclusion, and enable targeted delivery of social welfare programs. It can also contribute to improved governance, data management, and cybersecurity. Also, a supportive environment for Intellectual Property rights is needed to promote local innovation, attract investments, and create an ecosystem that encourages the development of digital solutions tailored to specific country's needs.

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<sup>11</sup> For instance, the East African Payment System and the West African Monetary Zone Payment System have limited interoperability. In contrast, the cross-border financial market infrastructure Pan-African Payment and Settlement System (PAPSS) specializing in payment transactions in Africa can offer significant improvements.

## Annex I. Examples of Policies

Table 1. Horizontal and Vertical Policies

	Horizontal policies (with cross-sectoral implications)	Vertical/Sectoral policies (to support structural transformation)
<b>Short-term policies</b> Digitalization as a resilience and transparency tool	<p><b>Government cash transfers</b></p> <ul style="list-style-type: none"> <li>Togo: <a href="#">Novissi</a> end-to-end digital platform to deliver contactless, emergency cash transfers based on machine learning techniques and mobile money.</li> <li>Madagascar: The <a href="#">Tosika Fameno</a> cash transfer program based on mobile banking transfer to reduce contact risk.</li> </ul> <p><b>Digital identification</b></p> <ul style="list-style-type: none"> <li>Kenya: digital system <a href="#">Huduma Namba</a>, aimed at biometrically registering everyone in the country via digital fingerprints and photo.</li> <li>Ghana and Senegal: ECOWAS <a href="#">National Biometric Identity Card</a> (ENBIC), used for identification to access several services.</li> <li>Togo: setting up of biometric ID or Unique Identification Number (NIU) for all.</li> </ul> <p><b>Tax payment</b></p> <ul style="list-style-type: none"> <li>Kenya: online portal <a href="#">iTax</a> for tax payment.</li> <li>Senegal: platform <a href="#">M-tax</a> allows taxpayers to file their tax returns online and pay their taxes by mobile phone.</li> <li>South Africa: Portal <a href="#">eFiling</a> for online processing of tax submissions, refund payments, and customs declarations which save time and reduce costs.</li> </ul> <p><b>Transparency and better quality of public services</b></p> <ul style="list-style-type: none"> <li>Kenya: portal <a href="#">e-Citizen</a> allows citizens and foreign residents to access a range of government services; digitalization of land transactions through the <a href="#">Ardhisasa</a> project; online access to information on government tenders through the <a href="#">E-procurement</a> portal.</li> <li>South Africa: procurement by SOEs, provinces, and local governments is aligned to the central government digital portal <a href="#">eTenders</a> to promote transparency and competition, and support law enforcement agencies.</li> <li>Madagascar: digitalization of budget reports and spending; digitalization to improve the quality of statistics (new household survey).</li> <li>Uganda: <a href="#">E-Procurement</a> portal.</li> <li>Mauritius: <a href="#">Digital Government Transformation Strategy 2018-2022</a>.</li> </ul>	<p><b>Development of digital payment systems</b></p> <ul style="list-style-type: none"> <li>Kenya: <a href="#">M-Pesa</a>, first mobile payment platform in SSA, launched in 2007 (closely followed by Tanzania, Senegal, Cote d'Ivoire, Uganda, Rwanda and Zambia, and Ghana)</li> <li>Nigeria: Launch of the central bank digital currency <a href="#">e-Naira</a>. Aimed at increasing efficiency in cross-border payments, increasing financial inclusion, facilitating remittances, and reducing informality.</li> <li>South Africa: pilot of the <a href="#">Fintech Unit of the SARB</a> for interbank clearing and settlement using distributed ledger technology; participation in the pilot project <a href="#">Dunbar</a> for a central bank digital currency for international settlements.</li> <li>Madagascar: <a href="#">e-Ariary</a> central bank digital currency project, aimed at supporting financial inclusion objectives, improving the control of the money in circulation and strengthening the efficiency, safety and robustness of the national payment system.</li> </ul> <p><b>Digital technology to enhance resilience to natural disasters and climate change</b></p> <ul style="list-style-type: none"> <li>Mauritius: satellite launched into space in 2021 which will collect imagery and data relevant to anticipate climate shocks.</li> <li>Kenya: Satellite and mobile spectrophotometry technologies were successfully deployed to combat recent invasions of army worms and locusts.</li> <li>Madagascar: Identity Management system project to increase the resilience to climate change by reducing the vulnerability of digital systems and public services to natural disasters.</li> </ul>
<b>Long-term policies</b> Digitalization as a diversification tool	<p><b>Legal framework for internet and data security</b></p> <ul style="list-style-type: none"> <li>Kenya: <a href="#">Computer Misuse and Cybercrimes Act (2018)</a> and <a href="#">Data Protection Act (2019)</a></li> </ul> <p><b>Invest in basic education</b></p> <ul style="list-style-type: none"> <li>Kenya: <a href="#">Digital Literacy Program</a> launched in 2016 with the objective of creating a tech savvy workforce for the future by integrating ICT in formal education.</li> <li>Rwanda: Basic digital skills included in the national competency-based curriculum (CBC) at both primary and secondary school level, and schemes such as One Laptop per Child (OLPC) and the SMART Classrooms initiative have sought to boost access to devices in school.</li> <li>Senegal: Vocational training in the use of digital technologies.</li> </ul> <p><b>Policies to improve business environment</b></p> <ul style="list-style-type: none"> <li>Kenya: Promotion of private sector investment in network infrastructure, which resulted in the connection to the rest of the world by four undersea fiber optic cables and having internet services that are among the fastest and most reliable in the region.</li> <li>Rwanda: Study on consumer payment behavior and the pricing of digital payment services to assess the reasonableness of the pricing of payment services offered by banks and non-banks, determine the optimal pricing of payment services that would support further digital adoption by consumers and merchants while also preserving the business sustainability of digital payment providers.</li> </ul> <p><b>Policies to support access to finance</b></p> <ul style="list-style-type: none"> <li>Rwanda: Retail interoperability project and the automation of <a href="#">Savings and Credit Cooperatives (SACCOs)</a>.</li> <li>Togo: implementation of the digital identification or the Unique Identification Number (unique digital number assigned to all who live in the country) is expected to greatly increase access to finance, as banks are expected to accept the NIU as a proof of identification, required for loan applications.</li> </ul> <p><b>Policies to attract investors</b></p> <ul style="list-style-type: none"> <li>Kenya: one-stop shop web portal for investors in <a href="#">Special Economic Zones</a> to facilitate access to information.</li> <li>Namibia: <a href="#">Namibia Investment Promotion and Development Board (NIPDB)</a>, one-stop shop for foreign investors.</li> </ul>	<p><b>Policies to enhance regulatory framework</b></p> <ul style="list-style-type: none"> <li>Kenya: <a href="#">Unmanned Aircraft Systems Regulation (2020)</a>, which set standards for drone usage.</li> <li>Senegal: <a href="#">Code of Electronic Communications (2018)</a>.</li> </ul> <p><b>Enabling policies for the digital sector</b></p> <ul style="list-style-type: none"> <li>Kenya: ICT has been identified as a key foundation sector under <a href="#">Kenya Vision 2030</a>.</li> <li>Senegal: dedicated digitalization strategy, the <a href="#">Senegal Digital strategy (SN 2025)</a>, to promote innovation and the development of digital services, the development of artificial intelligence and strengthening of digital infrastructures.</li> <li>Rwanda: The <a href="#">National Strategy for Transformation (NST1)</a> recognizes ICT as a cross-cutting enabler for development.</li> <li>Mauritius: Ebene "Cyber" City, originally designed to attract companies operating in the ICT sector, becoming also home to several banks, offshore companies, accounting and consulting firms.</li> </ul> <p><b>Investing in digital skills</b></p> <ul style="list-style-type: none"> <li>Mauritius: <a href="#">Early Digital Learning Program</a> to attract digital-skilled labor through ICT education hub for students; and the <a href="#">National Training Fund</a>, to incentivize on-the-job training.</li> </ul> <p><b>Creation of digital jobs</b></p> <ul style="list-style-type: none"> <li>Kenya: government's <a href="#">Ajira</a> program to provide one million youth with digital jobs; climate-technology start-ups are producing innovative localized solutions and creating jobs (<a href="#">Kenya Climate Innovation Center (KCIC)</a>, <a href="#">Kenya Climate Ventures (KCV)</a>, and the Kenya Business Model Diffusion Pilot); digital agriculture startups such as <a href="#">Twiga Foods</a> have created jobs and streamlined the agri-sector value chain.</li> </ul>

Source: IMF staff.

## Annex II. The Enhanced Digital Access Index (EDAI)—versions of 2015 and 2019

The EDAI is a multidimensional index that seeks to gauge the level of digital connectivity across countries over time (IMF, 2020). It should be used as a complement to other digital-related datasets such as the World Bank's Digital Adoption Index, ITU Digital Access Index and Global Cybersecurity Index, UN E-Government Development Index (EGDI), among others. The EDAI focuses on the foundational dimensions of digitalization (i.e., the enabling factors) rather than on end-products such as access to e-commerce, e-government, and other e-services.

### Data

All indicators were collected from a time-period of 6 years prior (for example, the 2015 database includes data from 2009-2015). The 6-year band was chosen to allow for the creation of the most complete dataset (at least one data point per indicator per region) in the shortest band. This range was then extended to capture at least one variable per indicator per region until 2006 and any older variables were discarded.

**Table 1: Indicators of the EDAI<sup>1</sup>**

Indicator	Sub-Indices
1 Fixed broadband Internet monthly subscription price % GDP Per Capita	Affordability
2 Mobile cellular prepaid - price of SMS (off-net) % GDP Per Capita	Affordability
3 Mobile-cellular prepaid - price of a one-minute local call (peak; off-net) % GDP Per Capita	Affordability
4 Mobile-cellular prepaid connection charge % GDP per Capita	Affordability
5 USB_1GB; prepaid; price of the plan % GDP per capita	Affordability
6 Fixed-telephone subscriptions 100 inhabitants	Infrastructure
7 Mobile-cellular suscriptions per 100 in habitants	Infrastructure
8 Percentage of the population covered by a mobile-cellular network	Infrastructure
9 Percentage of the population covered by at least a 3G mobile network	Infrastructure
10 Percentage of the population covered by at least an LTE/WiMAX mobile network.	Infrastructure
11 Gross Enrollment Ratio	Knowledge
12 Adult Literacy (%)	Knowledge
13 Expected Year of Schooling	Knowledge
14 Mean Year of Schooling	Knowledge
15 Active mobile-broadband subscriptions per 100 inhabitants	Internet Usage
16 Fixed broadband subscriptions per 100 inhabitants	Internet Usage
17 Internet users (%)	Internet Usage
18 Fixed (wired)-broadband speed; in Mbit/s	Quality
19 International bandwidth per Internet user	Quality
20 USB_1GB; postpaid; Speed; in Mbit/s	Quality

Source: IMF staff.

<sup>1</sup> Total number of data points: 3700; number of countries: 185; and number of regions: 17.

In the case of missing data, an average of the indicator for that region was used. The year of each existing indicator was not accounted, so for example, 2014 data may have been averaged with 2011 data to produce a missing data point for 2015.

### Computation

The index is based on the Adjusted Mazziotta-Pareto Index (AMPI). Once the dataset is generated, the polarity of each indicator in relation to its sub-index (i.e., the impact of each indicator on the phenomenon being measured) is determined. For example, the indicator, *internet users*, has a positive impact on the sub-index *Internet Usage* (as the indicator increases, the EDAI increases). All indicators have a positive polarity except for those of the sub-index *Affordability*. The data is normalized as follows:

#### Normalized Matrix Construction

$$x_{i,j}^{+/-} = \begin{cases} \frac{x_{i,j}^+ - \text{Min}_{i,j}}{\text{Max}_{i,j} - \text{Min}_{i,j}} \times 60 + 70 \\ \frac{\text{Max}_{i,j} - x_{i,j}^-}{\text{Max}_{i,j} - \text{Min}_{i,j}} \times 60 + 70 \end{cases} \quad (1)$$

$$\begin{aligned} \text{Min}_{x_j} &= \text{Ref}_{x_j} - \Delta \\ \text{Max}_{x_j} &= \text{Ref}_{x_j} + \Delta \end{aligned} \quad (2)$$

$$\Delta = \frac{(\text{Highest value} - \text{lowest value})}{2} \quad (3)$$

Where:

1. The Delta is the difference between the highest and the lowest value of an indicator in each individual time-period divided by two.
2. The Ref value<sup>12</sup> selected here are the average values in 2015 for each indicator. This is the value that allows for a comparison of the EDAI values over time.
3. Depending on the polarity, the formulas in (1) are used to calculate the normalized value of each indicator.

### Sub-Index Calculation

$$\text{AMPI}_i = M_{r_i} - S_{r_i} \text{cv}_i \quad (4)$$

<sup>12</sup> Sometimes referred to as 'goalposts' in the literature.

Each sub-index was then calculated using the above formula.  $M$  is the mean of all the normalized indicator values in a sub-index,  $S$  is the respective standard deviation, and  $cv$  is the coefficient of variation ( $S/M$ ). The subtraction is used to penalize countries which have unbalanced indicators in their sub-indices with a lower index value.

### Final EDAI Calculation

The final EDAI is calculated from the sub-indices using the final AMPI calculation once again. Then the EDAI and all the sub-indices are rescaled between 0 and 100 using the following formula.

$$\frac{x - \min(x)}{\max(x) - \min(x)} \times 100 \quad (5)$$

The rescaling is to allow for noticeable variation between the sub-indices as otherwise values clump together with very small differences.

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