

Annex 3.2 Internet Penetration and Macroeconomic Impacts¹

This annex provides an overview of the data and econometric approach underpinning the analysis of the impact of internet penetration on macroeconomic outcomes.

Digitalization holds the potential to promote economic growth and structural transformation. It reduces asymmetric information, transaction costs, and promotes economies of scale. Empirical work has widely corroborated the positive effect of digitalization on growth (Qiang and others, 2009; Czernich and others, 2011; Zaballos and López-Rivas, 2012), on services and non-routine² employment (Houngbonon and Liang, 2018; Autor and Dorn, 2009), and on female employment (Klonner and Nolen, 2008; Sovbetov, 2018). Micro-level analysis has also confirmed the productivity and employment gains from digitalization in sub-Saharan Africa (SSA) (Hjort and Poulsen, 2019).

We contribute to the literature by estimating the impact of digitalization (proxied by internet penetration) on macroeconomic outcomes by exploring the arrival of submarine cables in SSA as an exogenous source of variation for internet penetration at the country level.

Data and Sample

The data on internet penetration (percent of population with access to the internet) is obtained from the International Telecommunication Union. The macroeconomic variables of interest are obtained from the International Monetary Fund (real per capita GDP, PPP 2011 international dollar), United Nations (sector value added, constant 2010 prices), International Labor Organization (sector employment shares) and Penn World Tables 9.1 (total employment measured as number of persons engaged). The largest sample used in the regression analysis covers 33 SSA countries over 2005–17. The average internet penetration rate for the full sample increases from 5.0 percent in 2008 to 24.9 percent in 2017. Penetration rates in 2017 range from 1.3 percent to 62 percent, with a higher average for treatment countries (28.3 percent) than control countries (18.2 percent). Between 2008 and 2017 treatment countries experienced a faster increase in penetration (22 percentage points) than control countries (15.2 percentage points).³

Empirical strategy

We estimate the effect of internet penetration on real per capita income growth, sector value added, and employment shares. A key challenge in doing so is that higher internet penetration itself could be driven by higher income growth. To address this endogeneity, we explore a natural experiment—the large-scale arrival of internet submarine cables in SSA during 2009–12

¹ This online annex was prepared by Felix Simione and Yiruo Li, and is based on a forthcoming IMF working paper “Macroeconomic impacts of Internet penetration in SSA: evidence from submarine cables.”

² Non-routine jobs comprise tasks that are generally not codifiable through computers (see Autor and Dorn 2009 for details).

³ See next paragraph on the definition of “treatment” and “control”.

—which affected the pace of internet penetration across countries in different ways through faster speed and lower cost.⁴

The experiment we explore relates to the work of Hjort and Poulsen (2019), modified to account for the country- and macro-level setting of our analysis. Whereas Hjort and Poulsen’s analysis focused on whether a given firm is located near a terrestrial (inland) cable that is connected to a submarine cable in a landing (coastal) city, we focus on whether a given country is directly connected to a submarine cable. Hjort and Poulsen explore how their experiment affects employment rates across firms in 12 countries, whereas ours explore the effects on growth and employment shares across 33 countries. Moreover, Hjort and Poulsen estimate the effect of firms being located near a terrestrial cable, whereas we estimate the effect of countries’ level of internet penetration (instrumented by whether they are directly connected to a submarine cable).

We define as “treated” those countries that became directly connected to a submarine cable. The “non-treated” (control) countries are by exclusion those that are not directly connected. Treated countries are mostly coastal⁵, while control countries are landlocked. We construct two instrumental variables capturing (i) if a country is directly connected to submarine cable after 2009,⁶ and (ii) the data capacity of the submarine cables.

The analysis builds on two identification assumptions. First, absent the arrival of submarine cables, the difference in internet penetration rates between coastal and landlocked countries would have remained broadly unchanged. Second, the timing of the arrival of the submarine cables and their capacity depends little on macroeconomic conditions in countries they connect. A few confounders could challenge the identification strategies. We control for them in the regression analysis (see robustness analysis below). The model specification follows two-stage least square (2SLS):

$$Internet_{i,t} = \alpha_0 + \alpha_1 Treatment_i + \alpha_2 Post2009_t + \alpha_3 (Treatment * Post2009)_{i,t} + \alpha_4 X_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$Internet_{i,t} = \gamma_0 + \gamma_1 Cable_{i,t} + \phi_t + \vartheta_i + \gamma_3 X_{i,t} + \mu_{i,t} \quad (1')$$

$$Macro_{i,t} = \rho_0 + \rho_1 \widehat{Internet}_{i,t} + \rho_2 X_{i,t} + \omega_{i,t} \quad (2)$$

Equation (1) is the first-stage equation of the 2SLS, and is given by a fuzzy difference-in-differences specification (Duflo 2001) where $Internet_{i,t}$ is internet penetration in country i at time t , $Treatment_i$ is a dummy variable taking the value 1 if country i is directly connected to a

⁴ Submarine cables are a network of fiber cables, placed under the sea, which connect different countries and continents. They move internet traffic with greater efficiency (faster speed and lower cost) compared to satellite networks that prevailed in the past.

⁵ The exceptions are Rwanda and Uganda that, although being landlocked, are directly connected to a submarine cable.

⁶ From now onwards, the expression “after 2009” includes the year 2009.

submarine cable and zero otherwise. $Post2009_t$ is a dummy variable taking the value 1 if the time period is 2009 onwards and zero otherwise, $(Treatment * Post2009)_{i,t}$ is an interaction term, $X_{i,t}$ is a vector of control variables, and $\varepsilon_{i,t}$ is the error term. Equation (1) by design removes country- and time-fixed effects as it features two groups of countries that are observed in two time periods under a difference-in-differences setting. The parameter α_3 is the difference-in-differences effect on internet penetration of being directly connected to the submarine cables after 2009.⁷

Equation (1') explores an alternative instrumental variable where $Cable_{i,t}$ is the data traffic capacity of submarine cables. This specification controls for time- and country-fixed effects (\emptyset_t and ϑ_i) and other variables ($X_{i,t}$). Equation (2) is the second-stage equation. $Macro_{i,t}$ captures selected macroeconomic indicators (real GDP per capita growth, and sector shares in value added, and sectoral shares in employment). $\widehat{Internet}_{i,t}$ is the fitted internet penetration rate from the first stage equations (1) and (1'). $X_{i,t}$ is a vector of the same control variables used in the relevant first-stage equation. They include lagged per capita income, public investment, trade openness, terms of trade, population density, institutional quality, human capital, private investment and fiscal position. All equations are estimated with robust standard errors (clustered at the country level).

Assumptions

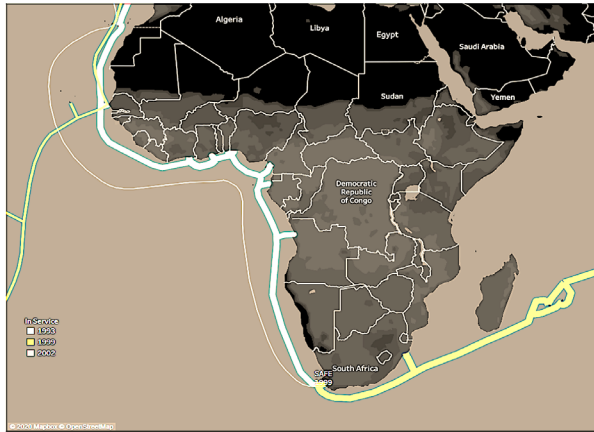
Relevance (first-stage regression)

Internet penetration increased substantially after 2009, and the increase is more rapid among the treatment countries (see Figure 3.6 in main text of SSA REO chapter). This coincides with the large-scale arrival of submarine cables (Figure 3.2.1). To investigate the varying pace of increase in internet penetration between the treatment and control group, we further perform the difference-in-differences analysis in a regression framework controlling for potential confounders. The difference-in-difference estimate is statistically significant and suggests that internet penetration increased by 3.2 percentage points more in treatment countries than in control countries in 2009-17 (Table 3.2.1, column 1). This finding is similar to the evidence in Cariolle (2018). A key reason why the control countries experienced a slower increase is the limited network spillovers from neighboring coastal countries. Each SSA country is typically covered by a single backbone network, so the transmission of internet content between two countries' networks is subject to existing legal and collaboration agreements, in the absence of which significant transit fees apply (Hjort and Poulsen, 2019).

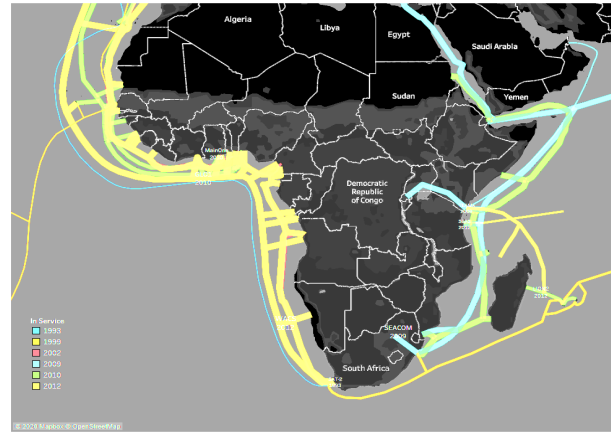
⁷ Under this fuzzy difference-in-differences specification (Duflo, 2001), control countries also get exposed to the “treatment” (i.e., at some point landlocked countries also connect to submarine cables indirectly through coastal countries), but the treatment outcome (internet penetration) is less pronounced than in treatment countries.

Annex Figure 3.2.1 The Arrival of Submarine Cables

Before 2009



2009 Onwards

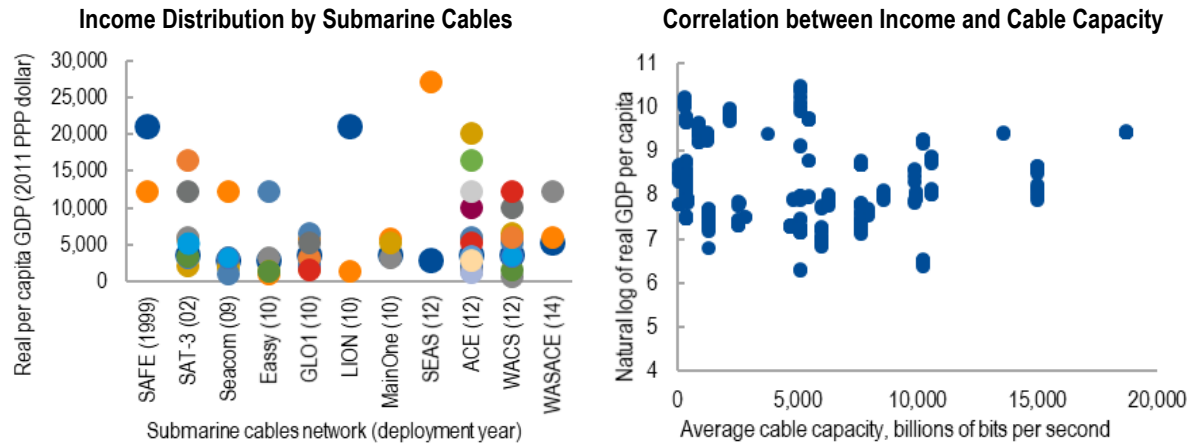


Internet penetration also responds to the installed capacity of submarine cables. The estimated coefficient is positive and highly statistically significant (Table 3.2.1, column 2). These findings suggest that the timing of arrival of submarine cables and the capacity of submarine cables available in each country are relevant instrumental variables for internet penetration.

Exogeneity

We also present evidence that both the arrival of the submarine cables and their capacity are quasi-exogenous to macroeconomic variables such as income. A scatterplot of income and cable capacity and a chart of country’s income by cable do not show a systematic relationship (Figure 3.2.2). This is not surprising as submarine cables are typically deployed regionally to take advantage of economies of scale (so it is rare that a cable would skip a low-income country along its route) and are usually funded internationally by large consortia that includes private and other non-government agencies. This weakens the connection, if any, between a county’s income level and being connected to a submarine cable. Furthermore, the most deterministic factor of submarine cable capacity is technology available at the time.

Annex Figure 3.2.2 Exogeneity of Instrumental Variables



Results

Estimates of the impact of internet penetration are shown in Table 3.2.1. Based on OLS-fixed effects regression results, we find that each percentage point increase in internet penetration is associated with 0.13 percentage point increase in the growth rate of real per capita GDP. The estimate is larger when we address endogeneity by employing as instrumental variable the capacity of the submarine cables: each percentage point increase in internet penetration is associated with 0.37 percentage point increase in growth, all else equal (column 6).⁸

We further look at the impact of internet penetration on the sectoral composition of output. The findings suggest that internet penetration boosts the share of services in total value added (column 7), while reducing the share of industry (column 9). The impact is insignificant for agriculture (columns 11 and 12).

Table 3.3.2 focuses on the impact of internet penetration on total employment, and its sectoral and gender composition. The findings are overall similar whether we use as instrumental variable the timing of arrival or the capacity of the submarine cables. There is no impact on the level of total employment (columns 1 and 2), but there are notable sectoral dynamics. Internet penetration does not have a significant impact on industry employment as a share of total employment (columns 3 and 4), but it does have a significant impact on services employment. The estimates suggest that each percentage point increase in internet penetration leads to an increase of 0.3-0.4 percentage points in the share of services employment (columns 5 and 6). We further find that the impact on services employment is higher for female than for male (columns 7, 9 and 10).

⁸ Several studies estimate the relationship between growth and broadband internet penetration. The estimated coefficients range between 0.05 and 0.2, with very few exceptions of negative coefficients. However, most of the studies rely on a broader country sample (mostly non-SSA), and do not address the endogeneity between income and internet penetration. The ITU (2012) and World Bank (2016) provide an extensive review of the empirical work. The estimated large effect potentially reflects the fact that our sample consists fully of SSA countries (where growth returns to digitalization are arguably higher than in advanced economies), whereas other studies consider mostly advanced economies.

Robustness

The difference-in-differences impact of cable arrival on internet penetration is statistically insignificant in the pre-treatment period (2000-2008), which supports the identification strategy. The treatment period (post-2009) coincides with two external shocks that might have affected growth differently across treated and control countries: (1) the 2014-15 terms of trade shock and (2) the 2008-09 financial crisis. We addressed the potential bias from (1) by including terms of trade as a control variable in the regressions. To address (2), we run alternative regressions excluding countries heavily affected by the financial crisis, and find that the results still hold. The results are also robust to the inclusion of access to electricity (an input to growth correlated with internet penetration) as an additional control variable, and to the exclusion from the sample of outlier top performers on internet penetration. The results also hold when adjusting the sample end-year to different years in 2013-2017.

Annex Table 3.2.1 Internet Penetration, GDP Growth, and Sector Share of Total Value-added

Dependent variable:	First Stage		Second Stage										
	Internet Penetration		Real per capita GDP growth						Services and trade		Manuf. and similar		Agriculture
									(% of GDP)		(% of GDP)		(% of GDP)
	(1)	(2)	(3: FE1)	(4: FE2)	(5: IV1)	(6: IV2)	(7: IV1)	(8: IV2)	(9: IV1)	(10: IV2)	(11: IV1)	(12: IV2)	
Treatment*Post2009	3.1707** (1.3288)												
Treatment	-1.5677 (1.0563)												
Post2009	3.6847*** (1.1272)												
Cable Capacity	0.0008*** -0.0002												
Internet use (% pop.)			0.1344* (0.0680)	0.1054 (0.0905)	0.0530 (0.0628)	0.3749** (0.1661)	0.1634* (0.0875)	0.0162 (0.1763)	-0.3233** (0.1359)	-0.0796 (0.2226)	0.0365 (0.1176)	0.0626 (0.1205)	
Lagged Real Per capita GDP (log)	4.7816*** (0.6177)	15.3078** -7.4566 (3.7979)	-16.1115*** (3.7979)	-19.2055*** (5.2539)	-0.8094 (0.6866)	-23.6526*** (5.3957)	1.4160 (1.6148)	1.7902 (3.5898)	7.7093* (4.1317)	11.0699** (4.5717)	-6.7858*** (2.3792)	-8.5469** (3.8618)	
Investment	-0.0770* (0.0398)	-0.0509 -0.12867 (0.0621)	0.0920 (0.0684)	0.0311 (0.0684)	0.0655*** (0.0215)	0.0484 (0.0748)	-0.0284 (0.0997)	0.0680*** (0.0199)	0.0186 (0.1145)	-0.1275*** (0.0487)	0.0915 (0.1084)	0.0473 (0.0333)	
Years of schooling	0.9560*** (0.2238)	4.2246 -6.5026 (1.7438)	-1.2587 (1.7438)	-1.0246 (1.6105)	0.0215* (0.0112)	0.1212*** (0.0298)	-0.0055 (0.0296)	-0.0325 (0.0219)	0.1343*** (0.0515)	0.0453 (0.0426)	-0.1613*** (0.0339)	-0.0284 (0.0253)	
Trade openness (% GDP)	-0.0319** (0.0137)	-0.0917* -0.0506 (0.0213)	0.0632*** (0.0283)	0.0865*** (0.0283)	0.0020 (0.0024)	-0.0058 (0.0393)	0.9403 (1.8348)	-0.5990 (0.9941)	-4.5714 (2.7859)	0.2175 (1.4045)	-3.0569 (2.1557)	-2.0673** (0.9546)	
Institutional quality	2.8751*** (0.7938)	1.0618 -2.8658 (1.3279)	2.8133** (1.814)	2.5739** (1.814)	2.1367*** (0.6999)	1.8312 (1.2742)	0.1823 (0.6427)	-0.2663 (1.5653)	0.8988 (1.1629)	2.3146 (2.1766)	-2.0119** (0.9646)	1.0066 (1.1473)	
Terms of trade, change	-0.0205 (0.0199)	-0.0119 -0.0177 (0.0113)	0.0059 (0.0113)	0.0150 (0.0106)	0.0331 (0.1594)	-2.2996 (2.8593)	-0.0077 (0.0151)	-0.0056 (0.0069)	0.0199 (0.0202)	0.0149 (0.0109)	-0.0140 (0.0157)	-0.0172*** (0.0061)	
Population density (people per square Km)	0.0046 (0.0032)	-0.0028 -0.0794 (0.0290)	-0.0132 (0.0373)	-0.0219 (0.0373)	0.0207* (0.0117)	0.0185 (0.0115)							
Private credit	0.2773*** (0.0363)	0.3369 -0.3204 (0.0940)	-0.2013** (0.0940)	-0.1306 (0.0912)	-0.0716** (0.0301)	-0.1920 (0.1569)							
Fiscal balance	-0.0066 (0.0549)	-0.0168 (0.0579)	0.0920** (0.0452)	0.0664 (0.0473)	0.0967*** (0.0327)	0.0823* (0.0443)							
Sample	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	
Year/Country fixed effects	Yes ¹	Yes	Yes	Yes	No ¹	Yes	No ¹	Yes	No ¹	Yes	No ¹	Yes	
Observations	395	265	395	265	395	265	406	268	406	268	406	268	
R-squared	0.5792	0.824	0.313	0.416	0.1119	0.3174	0.1345	0.9495	0.4454	0.9406	0.5755	0.9736	
No. of countries	32	21	32	21	32	21	33	21	33	21	33	21	

Source: Authors' estimates
 ***, ** and * denote statistical significance at 1%, 5% and 10% level, respectively. Standard errors are in parenthesis and are clustered at the country level. The IV is defined as being directly connected to a submarine cable in post-2009 (IV1) and total installed capacity of submarine cables (IV2). Fixed effects (non-IV) estimates are shown in columns 3 (whole sample) and 4 (coastal + Rwanda and Uganda).
 1/ Two-period two-group difference-in-differences specification in the first stage removes fixed effects

Annex Table 3.2.2 Internet Penetration and Sector Employment Shares

Dependent variable:	Total employment (log)		Percent of total employment							
			Industry		Services		Services, Male		Services, Female	
	(1: IV1)	(2: IV2)	(3: IV1)	(4: IV2)	(5: IV1)	(6: IV2)	(7: IV1)	(8: IV2)	(9: IV1)	(10: IV2)
Internet use (% pop.)	0.0150 (0.0124)	0.0003 (0.0036)	0.0629 (0.0821)	-0.0305 (0.0768)	0.3377** (0.1321)	0.3627** (0.1556)	0.1968* (0.1106)	0.2431 (0.1579)	0.4944*** (0.1752)	0.4962*** (0.1632)
Lagged Real Per capita GDP (log)	-0.3503 (0.4557)	0.1080 (0.0795)	3.2641** (1.5109)	3.6296* (2.1618)	13.7796*** (2.6638)	-2.1886 (4.6890)	11.2349*** (2.2891)	-2.7987 (4.4350)	16.8909*** (3.7181)	-1.6997 (5.1854)
Investment	0.0257 (0.0164)	-0.0005 (0.0007)	-0.0319 (0.0706)	0.0012 (0.0191)	-0.2781** (0.1184)	-0.0365 (0.0441)	-0.2336** (0.1149)	-0.0469 (0.0402)	-0.3456** (0.1433)	-0.0250 (0.0565)
Years of schooling	0.2031* (0.1135)	0.0051 (0.0284)	0.0420 (0.0312)	0.0088 (0.0113)	0.0515 (0.0580)	0.0562** (0.0248)	0.0278 (0.0616)	0.0450* (0.0234)	0.0839 (0.0658)	0.0628** (0.0289)
Trade openness (% GDP)	-0.0163 (0.0099)	-0.0009* (0.0005)	0.9652 (2.1154)	-1.4338** (0.5890)	2.1187 (3.3216)	-1.4920 (1.3153)	0.3203 (2.7491)	-1.1813 (1.2457)	4.8166 (4.3954)	-1.6220 (1.4242)
Institutional quality	-0.1706 (0.6315)	-0.0443*** (0.0168)	-0.3556 (0.7198)	-0.2901 (0.5447)	-0.8498 (1.0119)	-3.8713** (1.8852)	-0.0610 (0.9113)	-3.0809** (1.5527)	-1.8883 (1.2781)	-4.8883* (2.5561)
Terms of trade, change	0.0050** (0.0025)	0.0000 (0.0001)	-0.0151 (0.0120)	0.0017 (0.0031)	-0.0289 (0.0182)	-0.0051 (0.0071)	-0.0329** (0.0160)	-0.0069 (0.0064)	-0.0257 (0.0270)	-0.0026 (0.0081)
Sample	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17	2005-17
Year/Country fixed effects	No ¹	Yes	No ¹	Yes	No ¹	Yes	No ¹	Yes	No ¹	Yes
Observations	401	268	406	268	406	268	406	268	406	268
R-squared	0.1295	0.9997	0.2269	0.9774	0.5840	0.9761	0.5192	0.9670	0.5858	0.9815
No. of countries	32	21	33	21	33	21	33	21	33	21

Source: Authors' estimates

***, ** and * denote statistical significance at 1%, 5% and 10% level, respectively. Standard errors are in parenthesis and are clustered at the country level. The IV is defined as being directly connected to a submarine cable in post-2009 (IV1) and total installed capacity of submarine cables (IV2).

1/ Two-period two-group difference-in-differences specification in the first stage removes fixed effects.

The underlying data of employment is from Penn World Tables 9.1 (columns 1 and 2) and ILO (remaining columns).

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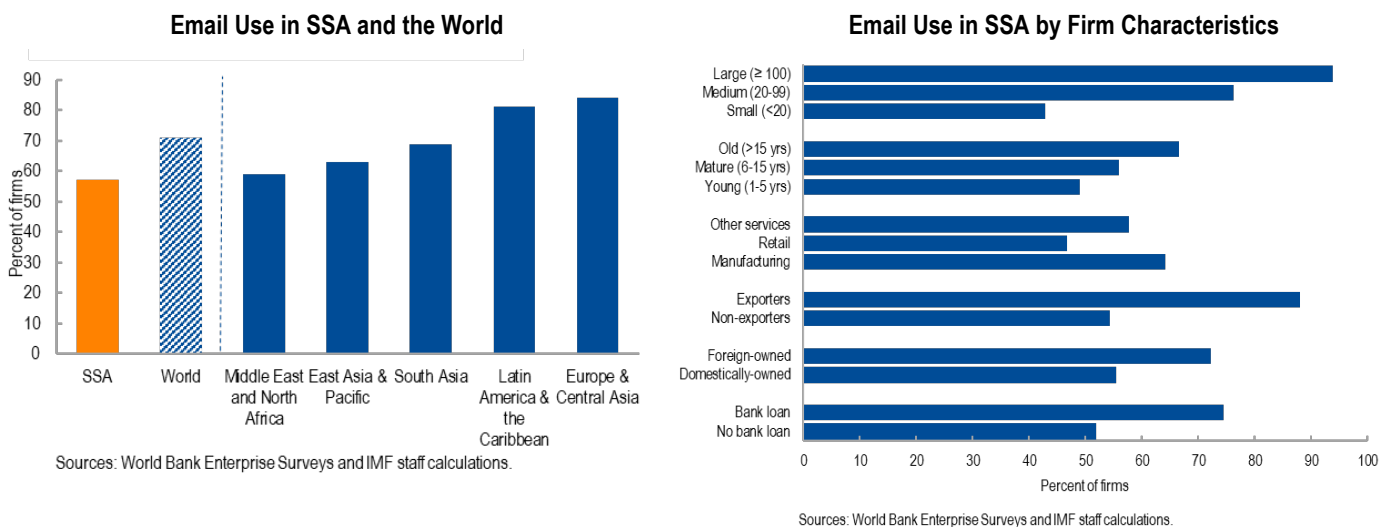
Annex 3.3. Digital Connectivity and Firm Performance in sub-Saharan Africa⁹

This annex provides an overview of the data and econometric approach underpinning the analysis of the impact of digitalization on firm performance.

Digital connectivity creates opportunities for improving firms' performance. Yet, the literature on the effects of internet use on firms' outcomes in sub-Saharan Africa (SSA) is embryonic. Using worldwide firm-level data, Clarke and others (2015) find that internet use increases firms' growth and labor productivity, particularly for small firms. Tackling a different angle, Hjort and Poulsen (2019) show that increased broadband internet penetration has stimulated job creation by increasing firms' entry, exports and productivity. Recently, Cariolle, Le Goff, and Santoni (2019) analyze the impact of email use on firm performance using a larger sample of developing countries and find positive effects on firms' sales and the number of full-time workers. We contribute to the literature by focusing on firms located in SSA countries.

Our analysis uses the World Bank Enterprise Surveys (WBES), a rich database covering a representative sample of firms operating in the formal manufacturing and services sectors. Since sending/receiving emails is the most basic way of accessing the internet, we measure firms' digital connectivity by the use of email to communicate with clients or suppliers. We find that 57.2 percent of firms in SSA use email for business purposes, which is below the world average of 71 percent, but comparable to take-up by firms in the Middle East and North Africa. In SSA, email user tends to be more prevalent among large and experienced firms, as well as firms that are foreign-owned and export to international markets (Annex Figure 3.3.1).

Annex Figure 3.3.1. Email Use by sub-Saharan African Firms



⁹ This online annex was prepared by Sampawende Jules Tapsoba and Martha Tesfaye Woldemichael based on a forthcoming IMF working paper “Digital Connectivity and Firm Performance in sub-Saharan Africa,” co-authored with Joël Cariolle (FERDI) and Maëlan Legoff (Banque de France), with the collaboration of Olivier Santoni (FERDI).

We formally assess the impact of digital connectivity on private-sector performance by estimating the following model using an instrumental variables (IV) approach:

$$Y_{j,l,s,t} = \alpha_0 + \alpha_1 Email_{j,l,s,t} + \alpha_2 X_{j,l,s,t} + (\gamma_j \times \rho_s \times \delta_t) + \theta_l + \varepsilon_{j,l,s,t}$$

where subscripts j , s , l , t refer to the country, sector, location, and survey year, respectively. $Y_{j,l,s,t}$ is the dependent variable measuring either annual sales or the number of workers in firm i operating in sector s . For the latter, we also distinguish between permanent and temporary workers, and, for the sub-sample of manufacturing firms, (i) between permanent production and non-production workers and (ii) skilled and unskilled production workers. $Email_{j,l,s,t}$ is a dummy equal to one if firm i in sector s reports using email to communicate with its clients or suppliers at the time of the survey. $X_{j,l,s,t}$ is a vector of control variables. It includes the firm's age, size (number of full-time permanent employees when the firm started operations), foreign ownership, exporting status, experience of the top manager, access to bank financing, and distance to the closest submarine cable landing station or internet exchange point. We also include country-sector-year ($\gamma_j \times \rho_s \times \delta_t$) and location (θ_l) fixed effects. $\varepsilon_{j,l,s,t}$ is a random error term.

The identification strategy borrows from Cariolle, Le Goff and Santoni (2019). It is built on the assumption that (i) firms' digital connectivity via the internet is directly affected by the country's submarine cables network exposure to seismic risks, and (ii) firms are heterogeneously affected by such vulnerability to internet disruptions based on their distance to international telecommunications infrastructure nodes. Studies have shown that maritime seismic events can cause submarine cable wear and breaks (Carter and others, 2009; Carter and others, 2014; Clark, 2016; Aceto and others, 2018), and that locations distant from key infrastructure nodes are more vulnerable to telecommunications disruptions (Grubestic and Murray, 2006; Grubestic and others, 2003; Cariolle, 2019). Therefore, the variable used to instrument email use is the interaction between the annual frequency of seaquakes and the firm's distance to the closest connectivity infrastructure defined as either a submarine cable landing station or internet exchange point.¹⁰

$$\text{Instrument}_{j,l,s,t} = \text{Seaquake frequency}_{j,t} \times \text{distance to infrastructure node}_{j,l,s,t}$$

While the IV strategy precludes testing the exclusion restriction due to the availability of a single instrument, we calibrate the latter such that the likelihood of meeting the exclusion restriction is maximized. Specifically, we only consider seaquakes whose epicenter is located at least 100 km but less than 1,000 km away from the submarine cable landing station to ensure a reasonable probability of disruption to the submarine cables network without a direct damage to the coast. In addition, we only consider seaquakes of medium intensity, i.e., those with a magnitude below

¹⁰ While firms in the same location share the same nodes, each survey round from WBES is administered to a nationally representative sample of firms, usually covering businesses operating in different cities within the same country, thus providing sufficient variation for running regressions.

6.5 on the Richter scale to avoid a direct devastating impact on coastal areas that would violate the exclusion restriction.

The analysis covers more than 18,000 observations from 39 SSA countries. Standard errors are clustered at the country-location-sector level. Geographical coordinates of submarine cable landing stations and internet exchange points are culled from Telegeography, PCH and Peering DB, while data on seaquakes are taken from the Northern California Earthquake Data Center of the University of Berkeley.

Annex Table 3.3.1 summarizes the results. First-stage regressions confirm a negative and statistically significant relationship between email use and digital vulnerability to seaquakes. We find that firms using email for business record sales 2.6 times higher than non-users' and employ eight times more workers than non-users. They create jobs by hiring more permanent, full-time employees while cutting their demand for temporary workers. The results also show that email use shifts the composition of the manufacturing workforce in favor of non-production workers (e.g., administrative and support staff) and skilled production workers.

Our results suggest that email use boosts firms' sales and employment performance. Digitally connected firms hire more workers on permanent positions, hence expanding the job-secure workforce. However, digitally connected manufacturing firms tend to increase less rapidly the size of their production workforce, and only hire skilled production workers, suggesting a skill-biased effect of digitalization. These results emphasize the importance of addressing the skills shortages and mismatch that typically characterize labor markets in sub-Saharan Africa so that countries can fully reap the digital dividend.

Annex Table 3.3.1. Impact of Email Use on Firms' Sales and Employment

	All Firms				Manufacturing Firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log real sales	Log # workers	Log # temporary workers	Log # permanent workers	Log # perm. non-production workers	Log # perm. production workers	Log # skilled production workers	Log # unskilled production workers
Email use	0.965*	2.100***	-2.140***	2.229***	2.555***	1.160***	3.795***	-8.877***
	(0.567)	(0.554)	(0.315)	(0.565)	(0.708)	(0.326)	(0.883)	(2.333)
Log age	0.345***	0.159***	0.100	0.149***	0.191***	0.195***	0.148**	0.288*
	(0.039)	(0.029)	(0.065)	(0.029)	(0.051)	(0.032)	(0.075)	(0.152)
Log initial # employees	0.683***	0.371***	0.459***	0.334***	0.291***	0.451***	0.123	1.361***
	(0.085)	(0.058)	(0.060)	(0.059)	(0.063)	(0.044)	(0.110)	(0.232)
Foreign ownership	0.589***	0.084	0.332***	0.067	0.216**	0.139***	0.062	0.772***
	(0.141)	(0.055)	(0.086)	(0.057)	(0.085)	(0.045)	(0.115)	(0.273)
Direct exporter	0.716***	0.032	0.894***	-0.044	-0.029	0.164**	-0.415	1.554***
	(0.181)	(0.108)	(0.195)	(0.110)	(0.155)	(0.078)	(0.335)	(0.599)
Log manager experience	0.111***	0.049*	0.079	0.043	0.014	0.092***	0.038**	0.243***
	(0.034)	(0.026)	(0.080)	(0.027)	(0.038)	(0.013)	(0.017)	(0.046)
Bank loan	0.430***	0.014	0.575***	-0.033	-0.051	0.096*	-0.507***	1.782***
	(0.114)	(0.073)	(0.112)	(0.076)	(0.125)	(0.051)	(0.187)	(0.493)
Log distance to telecom node	0.030	0.004	-0.071	0.002	-0.098***	-0.006	-0.038	0.203**
	(0.025)	(0.022)	(0.058)	(0.026)	(0.030)	(0.037)	(0.088)	(0.095)
First-stage regressions								
Sequake freq. X log distance	-0.702***	-0.781***	-0.655***	-0.702***	-0.384***	-0.384***	-0.385***	-0.385***
	(0.112)	(0.117)	(0.117)	(0.112)	(0.093)	(0.093)	(0.101)	(0.101)
Number of observations	16,501	18,614	17,794	18,403	7,681	7,716	7,090	7,581
Number of countries	38	39	39	39	30	30	26	30
RMSE	1.392	0.974	1.453	1.001	1.114	0.723	1.573	3.757
Kleibergen-Paap F-stat	39.48	44.75	31.31	44.37	17.21	17.22	14.53	14.65
Country-sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Impact, rel. to non-email users ¹	2.6	8.2	0.1	9.3	12.9	3.2	44.5	0.0
Impact, in percent	162%	717%	-88%	829%	1,187%	219%	4,348%	-100%

Sources: World Bank Enterprise Surveys, Telegeography, PCH, PeeringDB, Northern California Earthquake Data Center, and IMF staff calculations.

Notes: ***, ** and * indicate statistical significance at 1, 5 and 10 percent level, respectively. Standard errors are clustered at the country-location-year level. Instrumental variable is the interaction between the frequency of seaquakes and the log distance of the firm to the closest connectivity infrastructure.

¹ Impact obtained by exponentiating the coefficient on the binary variable for email use.

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Annex 3.4. Impact of Digitalization on Fiscal Revenues¹¹

This annex provides an overview of the data and empirical approach underpinning the analysis of the impact of digitalization on government revenue.

We use the proportion of households with internet access and the share of mobile cellular subscriptions per 100 people to capture the level of digitalization. The following regression equation is estimated:

$$Revenue_{i,t} = \alpha + \beta Digitalization_{i,t-1} + \theta X'_{i,t-1} + v_i + \varphi_t + \varepsilon_{i,t}$$

Where $Revenue_{i,t}$ is government revenue as a percentage of GDP for country i in time t . We use two fiscal variables: total government revenue excluding grants, and tax revenue. The data are from the IMF's World Economic Outlook (WEO). $Digitalization_{i,t-1}$ is the digitalization variable of interest—either the proportion of households with internet access and the share of mobile cellular subscriptions per 100 people extracted from UN's International Telecommunication Union database, $X'_{i,t-1}$ is a vector of other controls, and v_i and φ_t are country and time effects. The control variables include traditional determinants of government revenue such as the level of development captured by the logarithm of GDP per capita, economic growth, trade openness measured by the sum of imports and exports in percentage of GDP, terms of trade, the size of the agriculture sector (in percentage of GDP), the index of corruption, the inflation rate and education. All these variables are from the IMF's WEO and the World Bank's World Development Indicators.

To estimate the equation, we use an instrumental variable approach (two-stage least squares) to deal with the issue of endogeneity stemming from the reverse causality, the omission of variables and the measurement errors. To this end, we exploit the exogenous deployment of submarine cables to instrument for the level of fixed broadband subscriptions. As explained in Section II, the arrival of submarine cables has significantly contributed to expanding the use of the internet and mobile phones on the African continent. We define a binary variable taking the value of 1 if the country is connected to a submarine cable and 0 otherwise.

The results are reported in Annex Table 3.4.1. The estimates are performed on a sample of 37 sub-Saharan African countries over the period 2000-18. Columns 1-4 estimate the impact of digitalization on government revenue excluding grants, and tax revenue in sub-Saharan Africa using the traditional panel fixed-effects model. Columns 5-8 employ the two-stage least squares method.

The results show that digitalization is associated with an increase in government revenue as the coefficient associated with digitalization is positive and significant in all columns. A move from the 25th to 75th percentile of the level of digitalization is associated with an increase in government revenue excluding grants by up to 2.1 percent of GDP (column 3).

¹¹ This online annex was prepared by Rasmane Ouedraogo, with Mehmet Cangul and Nadia Esham.

Annex Table 3.4.1. Impact of Digitalization on Government Revenue

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS, Panel fixed-effects				IV			
	Access to internet		Mobile phone subscription		Access to internet		Mobile phone subscription	
	Total revenue excluding	Tax revenue	Total revenue excluding	Tax revenue	Total revenue excluding grants	Tax revenue	Total revenue excluding grants	Tax revenue
Digitalization, t-1	0.0411*** (0.011)	0.0269** (0.012)	0.3781* (0.209)	0.2645* (0.155)	0.0814* (0.042)	0.1240*** (0.030)	0.6743** (0.271)	0.5740*** (0.184)
GDP per capita, Log, t-1	2.5190* (1.368)	2.0205 (1.251)	4.9805*** (1.561)	2.7499** (1.120)	-1.0787 (0.992)	2.8826*** (0.596)	-0.1223 (0.784)	1.4574*** (0.537)
GDP growth, t-1	0.0553 (0.054)	0.0504 (0.049)	-0.0085 (0.042)	0.0164 (0.040)	0.0995 (0.104)	0.1324 (0.083)	-0.0273 (0.082)	0.0721 (0.068)
Terms of trade, t-1	0.0146 (0.009)	0.0096 (0.009)	0.0151 (0.010)	0.0106 (0.010)	0.0294 (0.020)	0.0307 (0.020)	0.0337* (0.018)	0.0206 (0.017)
Trade openness, t-1	0.0595*** (0.020)	0.0477*** (0.016)	0.0458*** (0.016)	0.0456*** (0.014)	0.0937*** (0.014)	0.0953*** (0.013)	0.0850*** (0.011)	0.0891*** (0.010)
Agriculture sector, t-1	-0.1478*** (0.057)	-0.1427*** (0.053)	0.0024 (0.073)	-0.0863* (0.050)	-0.2881*** (0.058)	-0.3421*** (0.041)	-0.2387*** (0.045)	-0.2817*** (0.035)
Corruption, t-1	-1.4141* (0.800)	0.5019 (0.852)	-1.3318* (0.706)	0.9085 (0.846)	-2.7948*** (0.883)	-2.7211*** (0.752)	-2.3246*** (0.762)	-2.2582*** (0.655)
Inflation, Log, t-1	0.4951 (0.497)	0.7385 (0.481)	0.0251 (0.667)	0.0152 (0.602)	-2.3929*** (0.656)	-2.5326*** (0.519)	-2.3916*** (0.509)	-2.5242*** (0.385)
Education, t-1	0.4348** (0.171)	0.4887*** (0.163)	0.5387** (0.266)	0.5070** (0.243)	1.2218*** (0.314)	1.1170*** (0.221)	1.1988*** (0.287)	1.0950*** (0.209)
Constant	-4.9756 (10.982)	-5.3501 (9.001)	-26.1061** (12.828)	-9.3483 (8.311)	30.0943*** (10.256)	43.6770*** (6.438)	20.7919*** (7.364)	30.8840*** (5.293)
<i>First stage</i>								
Submarine cable					1.3871*** (0.383)	1.3871*** (0.383)	0.0484*** (0.014)	0.0511*** (0.013)
Observations	321	321	393	390	321	321	374	371
Number of countries	37	37	37	37	37	37	37	37
R-squared	0.374	0.401	0.378	0.418	0.519	0.589	0.549	0.616
Hansen, p-value					0.743	0.933	0.589	0.319
Cragg-Donald Wald F statistic					18.129	18.129	132.251	130.356
Anderson-Rubin Wald test, p-value					0.015	0.011	0.052	0.026

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

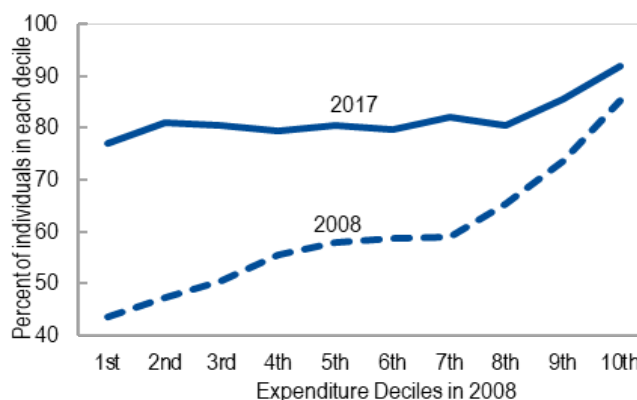
Annex 3.5. Mobile Phone Ownership and Welfare: Evidence from South Africa's Household Surveys¹²

Household surveys provide a potential “window” into understanding whether digitalization has positive effects on welfare. Variations in the structure and the still evolving coverage of variables related to digitalization in household surveys for sub-Saharan African countries limit the scope for cross country analysis. Consequently, this analysis is based on one country with relatively large survey data—South Africa¹³—and a level of mobile phone ownership that was most suited for the analysis.

Greater mobile phone ownership has likely had positive effects on welfare in South Africa. Household surveys show that mobile phone ownership over the past decade has grown faster among less affluent individuals (Figure 3.5.1). Moreover, individuals who owned a mobile phone in 2008 were more likely to move up the expenditure distribution by 2017 (Figure 3.5.2).

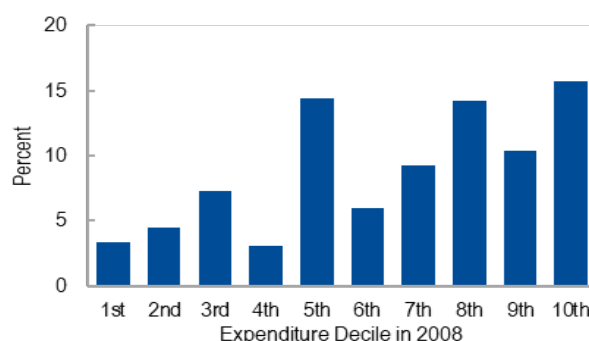
The literature suggests mobile phone ownership could increase households' welfare through several channels. Mobile phones help save on travel time and costs (76 percent), in finding work (around 40 percent), and accessing free education content (8 percent), according to surveys in Africa (World Bank 2016). Mobile phones provide greater and more affordable access to information, which can increase market efficiency (e.g., by sharing information on agricultural prices and labor markets), facilitate networking and starting a business, and increase disposable

Annex Figure 3.5.1. Cellphone Ownership in 2008 and 2017 by Expenditure Decile



Source: National Income Dynamic Survey South Africa and author's calculations.

Annex Figure 3.5.2. Excess Probability for Cellphone Owners of Moving to Higher Expenditure Deciles from 2008 to 2017



Source: National Income Dynamic Survey South Africa and author's calculations.

Note: Unconditional probability differential to probability conditional on cellphone ownership. For decile 10, probability of remaining in decile 10.

¹² This online annex was prepared by Ken Miyajima.

¹³ South Africa's National Income Dynamic Survey data include 5 waves in about 2-year increments (2008–17) with unique individual IDs.

income, particularly for the most vulnerable. Mobile money fosters risk sharing but direct evidence of the promotion of welfare and savings is less robust (Aron 2018).

Empirical analysis suggests that mobile phone ownership tends to be associated with increases in consumption. Analyzing the impact of mobile phone ownership on the log of real expenditure level, using South Africa’s household surveys and controlling for macroeconomic conditions and individuals’ characteristics, shows that having a mobile phone would lead to a rise in real expenditure by about 10 percent over two years. The positive impact appears to accrue more for less affluent mobile phone owners. Different specifications were tried for this analysis, including gender, ethnicity, employment status, access to finance (store card, credit card, access to different types of loans), per capita GDP (log level), location, location-by-time, and time. Lagged real expenditure (log level) was included in a bid to control for the potential reverse causality that mobile phone ownership may be motivated by resource availability.

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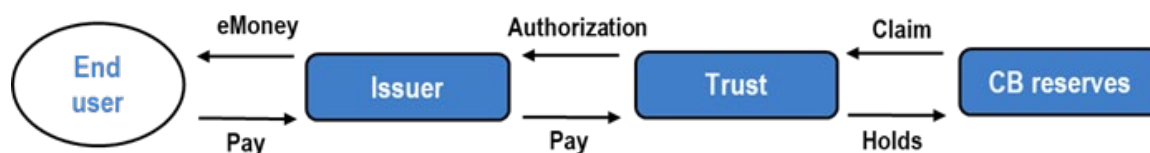
Annex 3.6. Role of Central Bank Digital Currencies¹⁴

The role of central bank digital currencies (CBDC) in sub-Saharan Africa is in its very early stages. A CBDC is a currency issued digitally by the central bank to serve as legal tender. Some research points to the potential for CBDCs to lower the cost of cash, increase financial inclusion, make payment systems more stable, improve market competition, and enhance monetary policy transmission.

Several operational challenges could emerge with the full-fledged implementation of CBDCs. In these circumstances, central banks would have a significant increase in their responsibilities, including performing customer due diligence, offering or vetting wallets, developing underlying technology, offering a settlement platform, managing customer data, monitoring transactions, and interacting with customer requests, complaints, and questions (Adrian 2019). Implementation of CBDCs would come with large exposure to risks of glitches and cyberattacks and put central banks' credibility at risk. There are also risks to financial stability due to the potential disintermediation of the banking sector, a higher potential for bank-runs, and changes in central banks' balance sheet and liquidity provision functions.

Alternatively, central banks could opt for synthetic CBDCs. Such a system could rely on the existing e money infrastructure, building on a public-private partnership between e money providers and the central bank. This could provide broadly similar benefits but with relatively lower operational challenges than CBDCs (Adrian 2019) as some operational issues would be outsourced to the private sector (e.g., customer management and screening and monitoring). Central banks would be responsible for settlement between trust accounts and for regulation and supervision including on e-money issuance (Annex Figure 3.6.1).

Annex Figure 3.6.1. E-money with Trust to Protect Client Funds



Source: Adrian and Mancini-Griffoli (2019)

Synthetic CBDCs could help with regulation and supervision of e-money. First, central banks can ensure the interoperability of payments, and thus protect consumers from risks associated with the growth of e money monopolies and enhance its supervisory role. Second, the system would allow mobile network operators to overcome market and liquidity risks, as they would rely on the central bank. Third, monetary policy transmission could be more effective if

¹⁴ This online annex was prepared by Pranav Kumar Gupta.

central banks opt to set an interest rate on the reserves held by e money providers and e-money providers pass on interest received on their reserve accounts to their customers. Finally, central banks should establish supervision and oversight rules to e money providers.

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Annex 3.7. Selected Country Experiences with Digital Reforms¹⁵

Many countries in sub-Saharan Africa are pursuing policy reforms to advance digitalization. Among these efforts, the experiences of Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Niger, Rwanda, and Sierra Leone demonstrate the range of actions and progress across the region.

Burkina Faso has adopted several digital initiatives, including its 2013 Digital Development Strategy. The authorities acknowledge the role of ICTs, including cellular phones to which access quadrupled between 2008 and 2016 and in turn contributed to the growth in the use of mobile money services. The number of mobile money agent outlets increased by five-fold during 2014–17, opening an alternative opportunity to financial inclusion at a time when security shocks posed operational risks for traditional banking in remote areas. Looking forward, the authorities' commitments in digitalization include connecting all public agencies, schools, and health facilities and setting up a unique digital identification for each citizen and company.

Côte d'Ivoire launched “E-impôts” in 2018, a digital tax payment platform for corporate taxpayers to enable about 80 percent of taxes to be paid online. A second initiative, supported by IMF technical assistance, is digitalizing the Directorate General for Taxation to (i) facilitate fulfillment of taxpayers' tax obligations through online declarations and payments; (ii) develop interoperability of information systems to enable interactions with third parties to identify corporate taxpayers; and (iii) strengthen data collection and analysis capacity using blockchain and artificial intelligence. Through this new system, the authorities are implementing an e-invoicing process to improve value-added tax (VAT) performance using connected object technologies (IOT) to enable real-time acquisition of information. A pilot phase will be deployed in supermarkets in 2020.

Ghana's digitalization strategy aims to (i) reduce informality and (ii) enhance delivery and targeting of public services through improved governance.¹⁶ Led by the Ministry of Communications, its key initiatives include:

- *National Digital Property Addressing System (Ghana PostGPS)*. Tagging locations with unique digital addresses to support growth in online and financial services, enhance property and credit registries, and facilitate tax collection.
- *Paperless port system*. Streamlined customs procedures to cut administration costs and clearance times, and facilitate cross-border trade.

¹⁵ This online annex was prepared by Mehmet Cangul, M. Astou Diouf, Jose Gijon, Frederico Lima, Monique Newiak, Felix Simione, and Martha Tesfaye Woldemichael.

¹⁶ See, for example, Ghana's 2020 Budget Speech: <https://www.mofep.gov.gh/budget-statements/2020>.

- *Biometric national ID cards (Ghana cards)* linked to the provision of public services and are part of a larger effort to create an integrated database with passport, tax ID, driver's license, and pension data.
- *Government e-services*, including vehicle registration, driver's license and passport renewal, and a digital 2020 census to facilitate access to government services, reduce waiting times, and eliminate bribery.

Kenya's *Digital Economy Blueprint* launched in May 2019 by the Ministry of Information, Communications and Technology, covers five pillars: (i) digital government, (ii) digital business, (iii) infrastructure, (iv) innovation-driven entrepreneurship, and (v) digital skills and values.

Digital solutions implemented include creating online services platforms for citizens (Huduma, G2C) businesses (Keninvest, KenTrade), and government (e-tax), and promoting the creation of digital companies. This has been facilitated by enabling policies in key areas:

- Investment in connectivity (the National Optic Fiber Backbone Infrastructure) and electricity—the government vowed to expand the national energy grid from its current 70 percent coverage.
- Training in digital skills, including technology, software development, and entrepreneurship, offered by several local universities and private institutions (Moringa school, AkiraChix, Andela, Tupanda Institute).

Strengthening of the legal framework to enforce contracts, resolve disputes, and protect consumers, including with data protection and consumer protection bills.

Niger's digitalization strategy, launched in July 2017 and led by the National Agency of Information Society, is anchored around three pillars: (1) smart villages; (2) a new tech center, and (3) e-government.

- *The smart villages initiative* aims, with support from the World Bank, to digitally connect more than 80 percent of the population to reliable internet powered by off-grid solutions, including solar panels.
- *The tech center* includes a coding academy to help develop information, communication, and technology (ICT) solutions to local problems. It aims to eventually integrate a drone academy and a tablet assembly line; consolidate tech startups in the same location; and connect with existing innovative agricultural solutions on site.
- Finally, *the e-government* project aims to introduce digital services to a limited set of government agencies, including e-declarations and e-payment of select taxes, by the end of 2020.

Rwanda has adopted several strategies since 2000, including three national information and communications infrastructure plans and two ICT Sector Strategic plans—sought to create an enabling environment for ICT, expand digital infrastructure and services, and promote digital skills.

The SMART Rwanda 2020 Masterplan, adopted in 2015, focuses on: (i) business and innovation; (ii) national economic digital transformation (digitalize government by 2018, broadband for all by 2020, digital literacy); (iii) planning (research and development for exports and digital transformation in big data analytics, drone technology, and cyber security). These strategies enabled Rwanda to:

- enhance digital connectivity, including increased Internet broadband and mobile phone penetration, which has benefited mobile money adoption and furthered financial inclusion;
- create a one-stop portal for e-government services (e.g., e-visa, online application for national IDs and birth and marriage certificates); and
- use drone technology for blood delivery in remote areas or spraying insecticides to fight malaria.

Sierra Leone launched its *National Innovation and Digitization Strategy* in November 2019, aimed at leveraging technology to tackle policy challenges and support the government's National Development Plan. The strategy is led by the Directorate of Science Technology and Innovation. Key initiatives include:

- *Tackling infrastructure gaps*, with the launch of a new drone corridor in November 2019, the first in West Africa, to monitor agricultural conditions and enable rapid delivery of medicines.
- *Addressing data and information gaps*, especially in rural areas, through a new Integrated Geographic Information System portal to support more effective policies and interventions.
- *Strengthening Public Finance Management* by using online systems. For example, a new Teacher Application, Approval, and Allocation Portal upgrades the paper-based teacher recruitment processes.
- *Combatting corruption* by digitalizing the recording and analysis of public officials' asset declarations, and applying artificial intelligence to trace suspicious transactions.