FONDATION POUR LES ÉTUDES ET RECHERCHES SUR LE DÉVELOPPEMENT INTERNATIONAL

Chair "Digital Trust"
Digital for Development Research Initiative

Digital Technologies for Small and Medium Enterprises and job creation in Sub-Saharan Africa

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Table of Contents

Executive summary

According to the IMF (2020), 20 million jobs per year have to be provided in Sub-Saharan Africa (SSA) to absorb the growing workforce in the subcontinent. Yet, the potential of simple digital technologies such as email, websites, and mobile money in terms of wealth and job creation has not been fully exploited by African firms. While the uptake of mobile phone technology has facilitated a multiplication of Internet-based innovations throughout the region, this dynamic is hampered by a large Internet divide and low penetration of these technologies among firms and individuals. In 2015, African countries' Internet penetration rates did not exceeding 60 percent of the population, with some countries like Niger, Sierra Leone, or Guinea-Bissau displaying penetration rates lower than five percent of the population.

In 2015 again, small African businesses were employing around 80% of the subcontinent's workforce (World Economic Forum, 2015). Yet, according to World Bank Enterprise Surveys conducted between 2013 and 2018, less than 60% of SMEs were using email for their business operations, and less than 30% used a website for business-related purposes. By comparison, 90% of large firms surveyed over the same period declared using email and/or a website during their activities. The development potential of digital technologies is therefore strongly constrained by their low diffusion and use among SMEs, which are as of yet the greatest job providers and wealth creators in the region.

This third report is an attempt to deepen the comprehension of the past, current and forthcoming transformations induced by the diffusion of digital technologies among African small and medium enterprises (SMEs). To be more specific, and compared to existing research-based analyses of African firm digitalisation, the report combines quantitative analysis and qualitative information to provide a bird's eye view of the contribution of digital technologies to African SMEs' performance, and of the perspectives offered by the ongoing digitalisation of the economy for private sector development and job creation.

Compared to existing empirical evidence on the impacts of digital technologies on African firms, the quantitative analysis hereafter undertaken presents various novelties. First, it investigates relationships between different usages of digital technologies – namely, email, websites, and mobile money – and various dimensions of firm performance – revenue, labour productivity, employment, and exports. Second, it exploits repeated cross-section survey data, drawn from the World Bank Enterprise Surveys covering a large sample of 40 African countries, surveyed between 2006 and 2018. Third, our empirical analysis separates the spillover effects of digital technologies diffusion from the consequences of their individual adoption. Fourth, to identify the impacts of email on firm performance, the report adopts an instrumental variable (IV) approach building on exogenous variations in international Internet connectivity induced by the staggered laying of submarine telecommunications cables (SMCs) and their exposure to external shocks.

This report also adopts a forward-looking approach of appraising digitalisation in Sub-Saharan Africa. To this end, it proposes a deeper dive on several promising key players currently pushing frontiers in the digitalisation landscape in Sub-Saharan Africa in general, and West Africa in particular, using cutting-edge technologies and digital innovations to improve small and medium enterprise (SME) development and job creation throughout the region. It draws a big picture of both domestic and international firms leveraging a diverse set of technologies, serving diverse communities, and offering a wide array of products and services destined for SMEs as well as consumers.

Expected gains from digitalisation for the African private sector

By reducing transaction costs and informational asymmetries, digital technologies are expected to boost firms' organizational and production capacities, to improve markets functioning and to correct government failures. They could also generate positive spillovers effects on their productivity, innovation, market outreach, and thereby, contribute to job creation. These spillovers could operate at both the industry and the location levels, within or across industries, between firms sharing similar features and firms operating in different environments. However, there is a risk digitalisation could be a source of a creative-destruction process, spurring entrepreneurship and the creation of new products and services, but also provoking the exit of firms operating in "old industries" becoming obsolete, or unable to take the path of digitalisation. Negative within and cross-industries spillovers can therefore be expected from digital technologies adoption and diffusion.

Micro, small, and medium enterprise (MSME) profiles

We use data from the World Bank Enterprise Surveys conducted between 2006 and 2018 over separate samples of small and medium enterprises (with 20-99 equivalent permanent full-time workers) on the one hand, and micro-enterprises (with less than five equivalent permanent full-time workers) on the other hand, to draw a general picture of MSMEs located in some 42 sub-Saharan African countries. These surveys are representative of the formal, non-agricultural, and urban African private sector. Therefore, the analysis of digital technologies' potential and SMEs performance proposed in this report does not reflect their impacts on informal firms, nor those on the African agricultural sector or in rural areas.

SMEs account for more than 90% of the universe of formal firms. The median SME employs 13 permanent and temporary workers. Among SMEs, manufacturing firms represent 46% of surveyed firms and 54% of the total workforce. The median small and medium manufacturer (SMM) is much larger than the median service firm, which respectively hire 17 and 10 employees. The shares of permanent and temporary workers in SMMs or service SMEs are similar, with permanent workers representing 84% and 87% of their respective workforces. Looking at the composition of the SMM workforce, 76% consists of production workers, among whom 60% are skilled.

Micro-enterprises (MEs) operating in the service sector represent 72% of MEs, and 92% of the total ME workforce. The ME workforce is principally made of permanent jobs, with temporary jobs representing approximately one quarter of manufacturing or service micro-firms' workforces.

SMEs in the manufacturing sector are on average more productive than in the service sector, which contrasts with MEs, which are found to be more productive in the service than in the manufacturing sector. African MSMEs are mostly inward-oriented and poorly integrated into international trade networks, with less than 10% exporting more than 10% of their total sales. Lastly, MSMEs declare that access to finance and electricity, competition from informal firms, insecurity, tax rates, and corruption are the main obstacles to running their businesses.

Patterns of digital technologies adoption by MSMEs

Three main technologies are addressed: email and websites, which are Internet-based ICTs, and mobile money, which is a digital financial service. Information on mobile money technology is only available in recent waves of standard enterprise surveys for a restricted sample of SMEs covering 14 countries.

Regarding Internet technologies adoption, there exists striking differences in Internet technology diffusion according to firm size, as 92% of large African firms declare using Internet during their operations, compared with 57% of the sample of SMEs and 44% of the sample of MEs. 92% of large African firms declare using the Internet during their operations, compared with 57% of the sample of SMEs and 44% in the sample of MEs. These numbers are driven by email technology adoption. The use of website technology is indeed much less prevalent, among large firms (72%), but particularly among SMEs (29%) and MEs (13%).

Regarding mobile money adoption, 44.5% of SMEs use mobile money (MM) during their operations, compared with 32.3% of large firms. Three of the four greatest obstacles to MM adoption identified by firms are related to the size of the MM users' network: the low penetration of the technology among customers, low technology penetration among suppliers, and the firm's ignorance of this technology. Receiving payment from customers is the most common usage of MM, made by 71% of SMEs using mobile money.

There are also disparities according to the firm's business sector. 54% of SMEs operating in the service sector declare having used email or website technologies, against 61% in the manufacturing sector. By contrast, Internet technology incidence is higher among MEs operating in the service sector (44%) than in the manufacturing sector (35%). SMEs operating in the service sector are slightly more inclined to use MM (45.7%) than are SMMs (40%).

Empirical analysis

The purpose of this empirical analysis is to provide an empirical overview of the contribution of digital technologies commonly used in the conduct of business by SMEs: Internet technologies and mobile money. A first novelty of this analysis is that we emphasize the effect of different types of Internet technologies, namely email and website adoption. Email technology is one of the most basic uses of Internet with probably the greatest impact on firm-level outcomes. This variable has the advantage of reflecting the use of digital technologies for an organization's internal matters, but also for external relationships with clients, suppliers, or administrations. On the other hand, the website use variable reflects a strategic use of Internet, costlier and therefore riskier, and depending on the nature of activities carried out by the firm, the intensity of the competition environment, and external support for the adoption of such technologies.

An additional empirical novelty is the separation between the individual effect of digital technology adoption by firms from the spillover effect resulting from its diffusion at the industry or local levels. It turns out from this analysis that the adoption of digital technologies by firms is likely to yield subsequent benefits in terms of revenue, productivity, exports, and employment. Our analysis of digital technology spillovers also stresses the existence of threshold effects of email industry-level and spatial diffusion on firm outcomes. In fact, U-shaped relationships were evidenced, stressing that below (above) a certain threshold of digital technology use incidence in a given industry and location, a larger diffusion of that technology may be detrimental (beneficial) to firms, whether they have adopted this technology or not. This evidence is however not exempt from estimation bias resulting from possible reverse causality between firm performance and email adoption as well as diffusion across sectors and locations.

A last specific contribution of this report is the IV approach, which exploits exogenous sources of variation in international Internet connectivity resulting from the staggered laying of submarine telecommunications cables (SMCs) and from their exposure to random shocks to estimate the causal effects of digital technologies on SME operations. This causal analysis supports the existence of a global positive effect of email use on sales, productivity and employment, and a negative effect on firms' exports. Separating the impact of individual use of email by SMEs from the spatial spillover effect of their diffusion within a given location, we find evidence of positive impacts of email adoption on a firm's sales and workforce size, concomitant to negative location spillovers on sales, sales per worker, exports, and employment. This evidence therefore suggests that digital technologies, especially email technology, may have not yet reached the critical mass of users necessary to yield positive spillovers. Moreover, a decomposition of these spatial spillovers into those prevailing between firms from the same industry and those within the remaining universe of firms supports that previous negative spillovers of email diffusion were driven by firms operating in the same location and industry. It therefore lends credibility to the hypothesis the email spatial diffusion increases competition between firms operating in the same sector, and primarily benefits the most highly performing firms.

Advancing digital frontiers in West African economies

The report concludes with a deeper dive on several first movers and key players pushing frontiers in the digitalisation landscape of Sub-Saharan Africa, with a particular focus on West African countries. This section takes the form of seven separate case studies, each focusing on one or more firms operating in a specific business sector or using a specific technology. Each case study begins with a discussion of the market failures and imperfections affecting the given sector in markets throughout the Sub-Saharan Africa region. This is followed by an in-depth description of an innovative digital technology currently being used to overcome these market failures. The third subsection describes the deployment of the firm or firms in question, with information on launching, the start-up phase, investment and financing, awards and recognitions, and preliminary impacts. For some case studies with more detailed information on impacts, the impacts are presented in a separate and fourth subsection. The fourth (fifth) subsection describes obstacles encountered by the firm during deployment or in the course of its business operations. The fifth (sixth) subsection describes perspectives and future directions, while the sixth (seventh) subsection concludes with a summary of the key takeaway points of the case study.

The first case study focuses on Jumia, an e-commerce firm offering buyers and sellers an online platform to make digital transactions, overcoming barriers to communication, imperfect information, and high transaction costs in over 15 countries across the African continent. The second case study discusses Lynk, a mobile application connecting informal or gig economy workers in Kenya with individual and SME clients seeking their services, and concludes with a discussion of several nascent gig economy and job platform firms in West African countries using a similar model. The third case study is focused on WorldCover, and Insurtech firm offering blockchain-enabled weather-indexed crop insurance to farmers in Ghana, Kenya, and Uganda. Automatic insurance payments are delivered to clients via mobile money if rainfall at a nearby weather station drops below a predetermined drought threshold. The fourth case study discusses Kobo360, a blockchain-enabled mobile application linking truck drivers, truck owners, cargo owners, and cargo recipients in Nigeria to improve optimisation of logistics and transportation networks in the country.

The fifth case study details two firms using unmanned aerial vehicles (UAVs) or drones to leapfrog missing transport and logistics infrastructures in SSA. The first firm, Zipline, provides blood and medical supplies to health centres and hospitals in Ghana and Rwanda, and the second firm, Investiv Group, uses drones equipped with sensors and aerial cameras to provide precision agricultural services to farmers in Côte d'Ivoire. The sixth case study discusses Lumos Global's solution to inefficient electricity infrastructure inherent in many SSA countries, providing off-grid solar home systems (SHS) to household and SME clients in Nigeria and Côte d'Ivoire. The SHS is equipped with an embedded SIM card for monitoring, and payments are made via airtime or mobile money. The seventh and final case study discusses two firms using mobile technology to optimise tax and utility payments. The first firm, Sudpay, enables SME customers to pay municipal taxes quickly and efficiently using its TownPay application, incentivizing clients to use the platform through offering an array of financial services and benefits. The second firm, CityTaps, offers smart water meters (CTMeters) to clients in Niger and other West African countries through a pay-as-you-go digital payments model with an integrated cloud-based software facilitating monitoring of usage by the utility.

1 Introduction

The future of African prosperity will probably depend on digital technologies[1] adoption and diffusion. Digital technologies are called upon to play a critical role where individuals and firms are strongly constrained in their daily interactions by significant transactions costs, informational asymmetries, missing infrastructures and high levels of uncertainty. These market imperfections, which are often structural in nature in Sub-Saharan Africa, have been accentuated by the Covid-19 crisis. In this context of current crisis and long-lasting handicaps to development, the digitization of African economies opens new perspectives for removing obstacles to private sector expansion and job creation, in particular for Micro, Small and Medium Enterprises (MSMEs).

According to the IMF (2020), 20 million jobs per year have to be provided in Sub-Saharan Africa (SSA) to absorb the growing workforce in the subcontinent. Yet, the potential of simple digital technologies such as email, websites, and mobile money in terms of wealth and job creation has not been fully exploited by African firms. While the uptake of mobile phone technology has facilitated a multiplication of Internet-based innovations throughout the region, this dynamic is hampered by a large Internet divide and low penetration of these technologies among firms and individuals. In 2015, African countries' Internet penetration rates did not exceeding 60 percent of the population, with some countries like Niger, Sierra Leone, or Guinea-Bissau displaying penetration rates lower than five percent of the population.

In 2015 again, small African businesses were employing around 80% of the subcontinent's workforce (World Economic Forum, 2015). Yet, according to World Bank Enterprise Surveys conducted between 2013 and 2018, less than 60% of SMEs were using email for their business operations, and less than 30% used a website for business-related purposes. By comparison, 90% of large firms surveyed over the same period declared using email and/or a website during their activities. The development potential of digital technologies is therefore strongly constrained by their low diffusion and use among SMEs, which are as of yet the greatest job providers and wealth creators in the region.

In SSA, expanding digital technologies such as the mobile money are often depicted as "leapfrogging technologies". From a historical perspective, the *leapfrogging theory* (Brezis et al., 1993) has pinpointed the role of technological revolutions in spurring a reversal of fortunes among nations at a global scale. This theory states that, in the context of a major technological change, an "advanced" country's dependence on old technologies may make a new technology unattractive in the short term, as it is less profitable, thus delaying its adoption. On the other hand, countries lagging behind in the old technology, which are less wealthy and have lower wage levels, have a much stronger incentive to forego the old technology and adopt the new technology, which is much more profitable from their perspective. The adoption of new technologies by lagging nations leads to increases in productivity, employment and output in sectors using the new technology. The countries that were previously lagging behind then take the lead in sectors with a high technological content.

Could digital technologies induce a "reversal of fortune" for Sub-Saharan Africa (SSA)? While it seems relevant to consider mobile-based technologies having a strong leapfrogging potential in the African context of market imperfections and missing infrastructures, the realization of a digital-induced growth miracle in the region is still premature (Rodrik, 2016). Many challenges indeed have to be addressed by African countries to move out of the under-industrialized trap they have been caught in, and to stimulate job creation and economic transformations through digital: improving digital connectivity and depth[2],

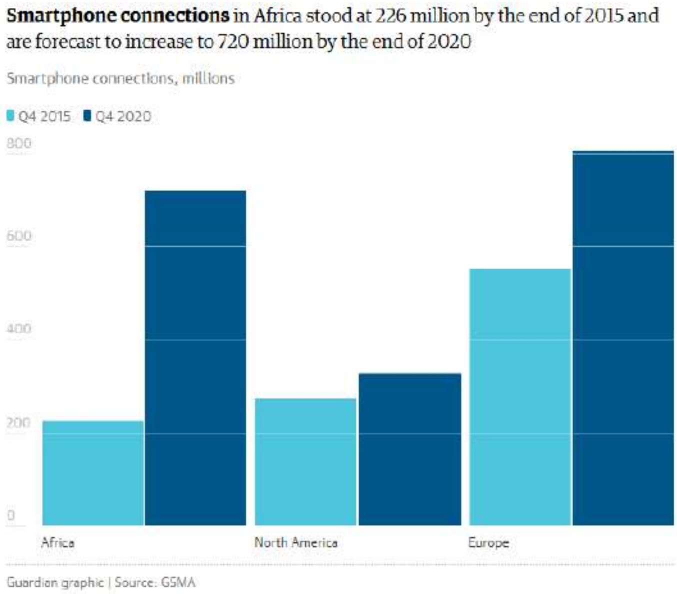
[1] Goldfarb and Tucker (2019) define digital technologies as "the representation of information in bits […] rather than atoms", which "reduces the cost of storage, computation and transmission of data" (p.3).

[2] The IMF's Regional Economic Outlook (2020, Chapter 3, p.2) defines *digital connectivity* as "the ability to access and use technologies to connect to the Internet and share digital information", and *digital depth* as "the extent to which economic activities, transactions, and policies are becoming digital, including through more online, interconnected, and automated systems."

building human capital, in particular digital skills, targeting digitization policies towards small-size and informal firms with the aim of improving productivity and encouraging their formalization, and extending social protection systems to cushion low-skilled workers from potential job losses and economic marginalization caused by digitization (Rodrik, 2016; Choi et al., 2020, IMF, 2020; World Bank, 2019).

Keeping in mind these challenges, the leapfrogging theory nevertheless provides some keys to understand the potential of the digital economy's expansion for spurring Africa's take-off. On the one hand, the continent's connection to global high-speed Internet through the deployment of high-capacity submarine telecommunication cables (Cariolle, 2020b), combined with the deficit in terrestrial wireline telecommunications infrastructure (Schuman & Kende, 2013; Bates, 2014), has made the mobile phone a common device for facilitating cheaper telecommunications, including Internet communications (Aker & Mbiti, 2010; ITU, 2016). As a result, by 2020, more than 700 million smartphone connections are projected in Africa - more than twice the number projected in North America and close to the total in Europe - according to GSMA, an association of mobile phone operators (Figure 1).

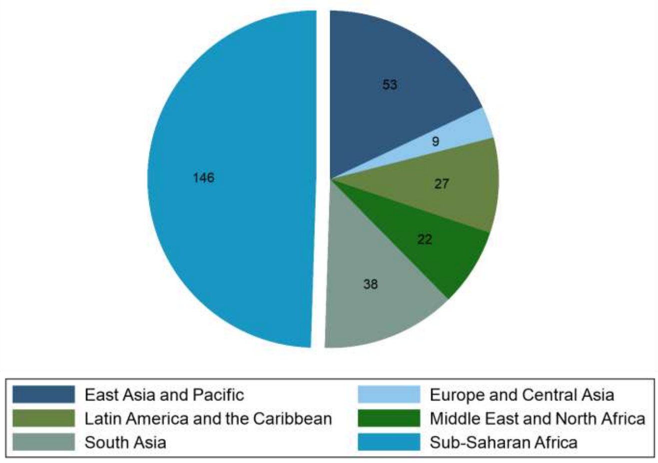
FIGURE 1. COMPARATIVE FORECASTS OF SMARTPHONE CONNECTIONS IN AFRICA BY 2020.



On the other hand, the widespread use of mobile telephone technology on the continent, concomitant to large infrastructure gaps in the financial, educational, agricultural and health sectors, has spurred the adoption and provision of new innovative financial, agricultural, educational, and health services based on mobile phone and mobile Internet technologies: mobile money, mobile banking, mobile health, mobile-based agricultural extension services, and so on.[3] For instance, the strong dynamism of digital innovations in Africa compared to the rest of the world is particularly striking in the area of digital financial inclusion, as evidenced by the proliferation of mobile money systems throughout the region (Figure 2).[4] This abundance of digital innovations based on mobile Internet is however not confined to provision of financial services, and constitutes a tremendous potential for the development of African firms and for employment (Ndung'u, 2018; Choi et al., 2020; IMF, 2020).

[3] See companion Report #1.
[4] See companion Report #2.

FIGURE 2. NUMBER OF MOBILE MONEY SYSTEMS IN SSA AND THE REST OF THE WORLD.



Source: Authors. Source: Mobile Money Tracker, GSMA, 2019. Note: 294 mobile money systems.

This third report is an attempt to deepen the comprehension of the past, current and forthcoming transformations induced by the diffusion of digital technologies among African small and medium enterprises (SMEs). It provides an overview of the contribution of digital technologies to SME performance in Sub-Saharan Africa and of the perspectives offered by the ongoing digitization of the economy for private sector development. The report is divided into four sections. Following this first introductory section, the second section consists of a brief review of the literature to draw a general picture of the expected consequences of digitization on private sector development. Then, the third section provides a descriptive overview of African SMEs, their size, domestic and export performance, and their degree of digitization. The fourth section is dedicated to an investigation of the effects of the adoption and diffusion of basic digital technologies – i.e. email, websites and mobile money – on total sales, labour productivity, exports, and the workforce of SMEs. In the fifth section, the report takes a forward-looking approach through case studies on cutting-edge technologies and digital innovations adopted by several avant-gardist African firms or start-ups. This section consists of a review of the experiences of e-commerce, digital platforms, Insurtech, drone technologies, tax and bill payment, and other digital innovations, highlighting their deployment contexts, obstacles, impacts and development potential. The sixth section concludes.

2 The consequences of digitization for SMEs in Sub-Saharan Africa

The diffusion of digital technologies within and across firms has led to a range revolutions in the way firms, industries, socio-economic interactions are shaped (Marsh et al, 2017). The reasons why basic digital technologies such as email, websites, or mobile money, but also more sophisticated ones such as blockchain technology, cloud computing, or artificial intelligence, can unleash the growth potential of African firms mainly lie in their capacity to improve the inner functioning of the firm and to address market and government failures.[5] In addition to the firm-level benefits of digital technologies adoption, their diffusion across spaces and industries likely has indirect consequences on firm performance, explained by the various spillovers expected from their rollout. Moreover, the individual and spillover effects of digital technologies adoption and diffusion are likely heterogeneous among firms and workers, and likely benefit educated workers and firms endowed with a skilled labour force, so that their

[5] As stressed in section 23.1 of the companion report #1 "The use of digital for public service provision in sub-Saharan Africa"

absorption by the private sector could lead to a polarization of the labour market and increased economic inequality. These issues are reviewed in this section.

2.1 Digital technologies adoption and business operations

First, digital technologies can be instrumental to **firm's inner functioning**. The penetration of digital technologies within the firm such as computer and mobile technologies' applications – i.e. email, website, spreadsheet software, social networks, digital platforms, and so on – has changed its organizational structure, production processes, communication protocols, and contributed to the creation of the firm's own digital knowledge. This results in in fluidized communication and coordination between firm's workers, improved input usage and innovation processes, and eased access to critical information for decision making and operations' expansion into new markets (Paunov & Rollo, 2015, 2016; Islam et al., 2018ab). This is particularly true for Internet-related technology which, in addition to improving the firm's efficiency in input use and innovation, strongly facilitates the collection of information on administrative procedures (e.g. business licenses), on market and political risks, on the tax system structure, tariffs and non-tariff measures, customer and competitor profiles, and so on. Interestingly, these benefits are likely to be substantial for Small and Medium Enterprises (SMEs), the object of this report, which could be more able to absorb these technologies thanks to more flexible management practices and organisational structure (Sadowski et al., 2002; Destafano et al., 2018).

However, due to their high costs, Internet technologies might be unaffordable for smaller African enterprises. By contrast, mobile phone-related technologies, especially mobile money, have experienced a large diffusion among small firms, especially in Africa, due to their low cost and ease of use (Aker & Mbiti, 2010). The use of mobile phones as a simple communications technology has been found to be improve microenterprise performance and especially productivity in low-income countries by reducing information search and other transaction costs (Bertolini, 2002; Duncombe & Heeks, 2002; Islam et al., 2018) and by improving risk-sharing (Patnam & Yao, 2020). Beyond the use of mobile phones as an ICT, a particular digital financial innovation that received wide attention from researchers and organizations and gained important success among smaller-sized African firms is mobile money (Aker & Mbiti, 2010; Aron, 2018; Suri, 2017). Mobile money is a digital financial service that enables firms to participate in various types of electronic financial transactions – payment of bills, fees, salaries, social transfers, etc. – by using SMS, therefore not requiring an Internet connection. The relatively high diffusion of mobile money among smaller-sized African firms can be explained by the low access of these firms to formal financial services, due to the large financial transaction costs and informational asymmetries that have typically precluded them from being considered by the traditional banking sector, and the various market imperfections that are ubiquitous in many African economies (Higgins et al., 2012; Aker, 2017; Aker & Blumenstock, 2014).[6] The literature that investigates the impacts of mobile money on (small) firms operating in non-agricultural sectors is however burgeoning. The few studies addressing the consequence of mobile money adoption for firms point to the positive effect of this technology on investment (Islam et al., 2018b), labour market outcomes (De Gasperin et al., 2019), and access to credit and innovation (Lorenz & Pommet, 2020).[7]

Adoption of more sophisticated digital technologies might also be particularly instrumental to a firm's productivity and expansion potential, depending on the strategic nature of these technologies for the firms' operations. For instance, website adoption may help firms save time and money spent on communicating with business partners, thereby increasing the firm's sales and foreign market shares.

[6] See companion report #2, as well as companion report #1 (section 3.4).

[7] Most of the literature on mobile money often address its consequences for rural households and individuals. See for instance Aker and Wilson (2013), Jack and Suri (2014), Aker et al. (2016), Batista and Vicente (2020ab), among others.

Blockchain technology is demonstrating strong development potential for firms and administrations operating in sectors such as health, education or digital financial services because of the decentralized, transparent, and encrypted nature of information transmitted through this technology (UNECA, 2017; Lee & Muller, 2018).[8] Big data, Artificial Intelligence (AI), and cloud computing are also new digital technologies demonstrating a strong leapfrogging potential for firms by revolutionizing their decision making processes in environments where the availability and quality of information is poor (Wakunuma & Masika, 2017).

Second, digital technologies may also be instrumental to firm performance and job creation by **improving the business environment**.[9] Basic Internet technologies can indeed be very conducive to business operations by fluidizing the coordination between market actors and reducing price dispersion (Aker, 2010; Aker & Fafchamps, 2014), easing access to formal financial services (Kpodar & Andrianaivo, 2011), and improving access to basic public services (Aker, 2017; Cariolle, 2020). Email adoption by a firm may improve coordination with customers and suppliers, facilitate interactions with the government and bureaucracy, and thereby help reduce informational asymmetries and the monetary and non-monetary costs associated with the firm's bilateral transactions. Website ownership may be particularly instrumental to improving the market and global value chain positioning of firms without requiring pre-existing business relationships (Sadowski et al., 2002; Harrison & Waite, 2006), thereby reducing communication and information search costs to reach customers and suppliers. In the same way, more sophisticated technologies such as digital platforms, e.g. job platforms or digital marketplaces, are called upon to improve market functioning by bringing together suppliers and customers at low cost. These expected systemic effects of digital technologies suggest that spillovers could arise from their diffusion among private firms.

2.2 Digital spillovers

Digital spillovers are the indirect positive or adverse consequences, also called externalities, of the diffusion of digital technologies and digital knowledge outside the firm. They are inherent to digital technologies being general purpose technologies (Bresnahan & Trajtenberg, 1995) and network goods (Katz & Shapiro, 1985; Crémer et al, 2000; Björkegren, 2019), whose applications spread across all branches of an economy and benefits increase with the size of user's network (Marsh et al, 2017). For instance, the emergence of digital job platforms, such as Lynk in Keyna, are helping formal and informal workers to find jobs and improving the allocation of the workforce in places and across various industries, while e-commerce firms like Jumia in West Africa are supporting local retailers and handicraft to expand their market outreach. The diffusion of simpler technologies like email, website, and mobile money outside the firm also are also accelerating and densifying economic transactions between firms and industries, facilitating their access to capital and competencies, but also intensifying the competition environment and spurring structural change. Therefore both positive and negative externalities can be expected from the diffusion of digital technologies.

First, positive digital spillovers may result from **network effects**, induced by a higher penetration of digital technologies among firms, contributing to multiply and accelerate interactions between adopters of these technologies (Stiroh, 2002; Grace et al, 2004). ICTs are indeed network goods whose derived benefits depends on the technology adopter's network size (Crémer et al, 2000; Björkegren, 2019; Goldfarb & Tucker, 2019). The greater the number of a digital technology users in a given location or a given industry, the greater the socio-economic benefits derived from its adoption by users. As an illustration, the benefits derived from mobile phone, mobile money or email adoption depend on the

[8] Darryn Pollock, "Africa's Blockchain Potential Untapped, But How Can It Be Implemented?", Forbes, Oct 23, 2018

[9] See Companion report #1, section 2.1.

number of people within the adopters' network who actually use these technologies. Moreover, given the role played by social networks in SSA in structuring economic interactions (Fafchamps, 2004), including SMEs interactions, a higher incidence of digital technologies could be source of social capital that help firms leveraging a number of obstacles such as the fixed costs related to export activities, constrained access to credit or economic uncertainty (Biggs & Shah, 2006; Islam et al, 2018a).

Second, positive **digital knowledge spillovers** result from the sharing of information, good practices, processes, and innovations related to digital technologies (Harrison et al, 1996; Paunov & Rollo, 2015, 2016). Digital knowledge spillovers fall within two categories (Marsh et al, 2017): on the one hand, the knowledge originating from competitors, also called (within-)industry spillovers, and on the other hand, the knowledge created from outside the industry, also called cross- or inter-industry spillovers. While the first type of information spillovers has received a large attention from theoretical and empirical research (Stiroh, 2002; Paunov & Rollo, 2015, 2016), the second type of information spillovers is less documented and suggests that the creation and circulation of knowledge also spread across industries, when for instance upstream and downstream industries communicate and exchange ideas, processes, practices and so on (Marsh et al, 2017). According to Gorg & Greenaway (2004) three mechanisms drive technological knowledge spillovers: skills acquisition, imitation behaviours, and competition. Imitation relates to the integration of technologies and related processes in their production function by non-adopters or less-performing technology adopters. Skills acquisition are related to the creation and/or the transfer of digital knowledge permitted by inter-firm worker flows in given location or industry. Regarding competition, increased competition from firms adopting a new technology may put pressure over non adopters to adopt them, or adopter to better use them. Each mechanism is interrelated since the imitation mechanism can for instance result from the hiring of workers with strong digital skills within a highly competitive environment.

Third, **negative digital spillovers** may prevail if an increased used of related digital technologies by other firms translate into greater competition, which in turn may translate into revenue loss for firms with limited technology absorptive capacity (Görg & Greenaway, 2004; Marsh et al., 2017). In fact, a faster adoption and a more efficient use of digital technologies by first-movers or dominant firms, by larger and/or more skills-endowed competitors, may reduce other firms' market share or even provoke their exit from foreign or domestic markets. This limited absorptive capacity can be explained by a lack of digital skills within the firm, by the delayed diffusion of positive digital technologies within industries, by a low exposure to international competition, or by limited research and development (R&D) activities (Görg & Greenaway, 2004; Marsh et al., 2017). The diffusion of digital technologies and knowledge may also induce structural change, i.e. "persistent change in the relative size of different sectors and occupations" (Hjort & Poulsen, 2019, p.1036), causing the decline of industries using obsolete technologies or made obsolete by technological shift (Choi et al, 2020). Gorg and Greenaway (2004) also argue that negative spillovers may arise because of distance-related transaction costs, exacerbated in environment where transport and telecommunication infrastructures are missing, confine expected positive digital spillovers only to the local level.

Fourth, network effects and information spillovers may therefore be confined to a delimited geographical perimeter, through **agglomeration economies** (Duranton & Puga, 2004; Malmberg et al, 2006; Frenken et al, 2007)[10], because infrastructures, administrations, and institutions aimed at reducing transaction costs and informational asymmetries are missing elsewhere. These agglomeration economies, which play within or across industries, embrace three distinct spatial dynamics (Malmberg et al, 2006; Frenken et al, 2007):

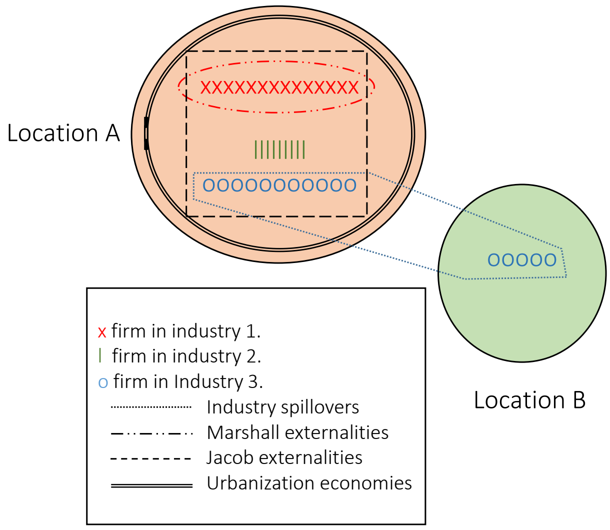
[10] According to Frenken et al (2007, p.687), agglomeration economies are "economies from which a firm can benefit by being located at the same place as one or more other firms".

1. *Localization economies or Marshall externalities*, related to the digital spillovers between firms operating in the same industry or in similar activities and located in the same place. For instance, geographical proximity may favour the spread of digital knowledge that fluidize business interactions in a given industry.
2. *Jacobs externalities*, related to the digital spillovers between firms operating in diverse but complementary industries in a given location. For instance, network effects induced by the rollout of a digital technology at a given place may favour cross-industry linkages, and *vice versa*.
3. *Urbanization economies*, related to the digital spillovers induced by urban size and density, but independent from industries' structure or complementarity, such as externalities related to the presence of connectivity infrastructure or to the geographical concentration of the workforce endowed with digital skills.

Therefore, industry and spatial spillovers can be imbricated through the existence of localization (dis)economies. However, digital spillovers may have a spatial dimension without being confined to a specific industry, as supported by the possibility of local scale economies, Jacobs externalities or urbanization economies. This is true for positive spillovers, induced by network effects or knowledge spillovers, but also for negative spillovers, which can have a spatial dimension and cross-industrial transmission. A striking example of negative spatial cross-industry spillovers is when the diffusion of digital technologies among firms from the same place operating in new ICT-intensive industries spur **structural change**[11] and cause the decline of "old industries" made obsolete by the digitization process (World Bank, 2019; Choi et al, 2020).

Overall, Figure 3 below synthetizes how industry and spatial spillovers interact with each other. It depicts the existence of industry spillovers between firms from industry 3 in locations A and B. It also represents in location A the localization effects between firms from industry 1, concomitant to Jacob externalities resulting from the diversity and complementarity between industries 1, 2 and 3, and urbanization economies related for instance to the presence of connectivity infrastructures in that location.

FIGURE 3. INDUSTRY AND SPATIAL SPILLOVERS OF DIGITAL TECHNOLOGIES



Source: authors

[11] Defined as "a persistent change in the relative size of different sectors and occupations" (Hjort & Poulsen, 2019, p.1036).

2.3 Digital technologies and the "skill-biased technological change" hypothesis in Africa

While digital technologies may contribute to growth and employment by stimulating the creation of new businesses, products, tasks and jobs, they can also be a factor of some industries' decline and job destruction, because of the substitution of ICT capital for low-skilled jobs, and of traditional services or products made obsolete by digital innovations (Banga & De Velde, 2018, World Bank, 2019). On the one hand, digital platform companies such as Jumia in West Africa (see Section 5.1) compete with traditional retail stores, but on the other hand, act as catalyst for interactions between customers, producers and traders, thereby creating new job and production opportunities. Mobile money systems such as MPesa in Kenya, or Insurtech companies such as Worldcover in Ghana (see Section 5.3), have destroyed jobs in the financial sector, but have simultaneously spurred entrepreneurship and production in rural areas by lowering market imperfections and reducing transaction costs (Chio et al., 2020).[12]

Evidence on the net contribution of digital technologies to job creation in Sub-Saharan Africa is recent in nature and scarce (Hjort & Poulsen, 2019; De Gasperin et al., 2019), but several studies conducted in other contexts highlight the potentials and warn about the risks of digital economy expansion for the job market. Recent studies conducted in industrialized economies (Michaels et al., 2014; Akerman et al., 2015; Acemoglu & Restrepo, 2016) hypothesize that the introduction and penetration of digital technologies contributes to the polarization of the labour market by increasing the demand for skilled and educated workers at the expense of less-skilled and less-educated workers.

Would this hypothesis of "**skill-biased technological change**" (SBTC) hold in SSA?

As part of a Schumpeterian innovation process, the growth of the mobile industry in Africa, by increasing the supply of new digital services – i.e. digital financial services, mHealth, mobile-based extension programs, e-commerce, etc. – is a factor of both job creation and destruction (Choi et al., 2020). Studies conducted in industrialized countries and other developing areas tend to support the idea that the growth of digital innovations may favour skilled job creation in the short term at the expense of the unskilled workforce, and therefore carries the risk of widening economic inequalities. This potential short-term adverse effect on employment nevertheless prefigures long-term structural changes towards a service economy employing a more skilled workforce through widespread use of digital technologies.

While some researchers duly question these optimistic long-run perspectives and the possibility of an "African growth miracle" based on (digital) services expansion (Rodrik, 2016), others expose nuanced expectations for the digitisation of African economies and their job markets (Banga & Te Velde, 2018; Choi et al., 2019; WDR, 2019; Hjort & Poulsen, 2019; IMF, 2020). The latter studies stress that digitisation in Africa may be more beneficial to less skilled/educated workers for several reasons. First, the low share of manufactures in African economies reduces the likelihood that digitisation may destroy manufacturing jobs to a significant degree through increased automation of tasks. Second, the relatively lower cost of unskilled labour in Africa compared with other regions of the world is another factor reducing the possibility of unskilled labour substitution with ICT capital in the short term. Third, the demand for many products and services, contrary to the situation in many developed economies, is not satiated and therefore more responsive to costs and price reduction driven by digital-induced productivity improvement. Fourth, many (mobile-based) digital technologies that have benefitted from a large diffusion among low-income households and informal enterprises in Africa – e.g. mobile money, mobile-based agricultural extension systems (see section 4) – do not require strong literacy and

[12] See companion reports #1 and #2.

numeracy skills while at the same time having a strong leapfrogging potential. This type of digital innovation could therefore benefit less educated/skilled workers.

The most comprehensive study of the contribution of broadband Internet to employment in SSA has been conducted by Hjort and Poulsen (2019). These authors tracked the progressive deployment of telecommunications submarine cables in a sample of 12 SSA countries and stressed the positive impact of the resulting improvement in broadband Internet access on employment, including on unskilled jobs, but more pronounced on the skilled workforce. In particular, they highlight three transmission channels of the positive effect of better Internet access on employment: productivity, enterprise creation and increased exports. Therefore, the literature tends to confirm the potential of the digital economy's expansion in terms of net job creation. According to the authors, this effect can be explained by the increase in firm productivity, by the creation of new firms and by the increase in their exports.

In a nutshell #1: Expected gains from digitization for the African private sector

- By reducing transaction costs and informational asymmetries, digital technologies are expected to boost firms' organizational and production capacities, improve market functioning, and correct government failures.
- Digital technologies diffusion among firms could generate positive spillover effects on their productivity, innovation, and market outreach, therefore contributing to job creation. These spillovers could operate at both the industry and the location levels, within or across industries, between firms sharing similar features and firms operating in different environments.
- Digital technologies could however be a source of a creative-destruction process, spurring entrepreneurship and the creation of new products and services, but also provoking the exit of firms operating in "old industries" becoming obsolete, or unable to take advantage of the digitisation process because of missing telecommunication infrastructures and/or lack of digital skills. Negative within and cross-industry spillovers can therefore also be expected from digitisation.
- The increased within-industry competition and the structural transformations resulting from the diffusion of digital technologies across space and industries could mostly benefit the most skilled and educated workforce.
- However, there is reason to believe that this hypothesis of "skill-biased technological change" might not hold in the African context. Low industrialization, the large domestic market potential, and the high absorption capacity of basic digital technologies are possible factors that could make digitisation beneficial to the whole African population, including low-skilled workers.

3 Overview of African micro, small and medium enterprises: Descriptive evidence

This section provides an overview of the characteristics of micro, small and medium enterprises (MSMEs)[13] in Sub-Saharan African (SSA). The below statistical analysis relies on two separate survey datasets. On the one hand, the core analysis is focused on small and medium enterprises (SMEs) using the standardized World Bank Enterprise Survey (WBES) datasets, which cover 27,436 SMEs[14],

[13] Micro-enterprises are defined by the World Bank as firms with less than five permanent full-time workers, small enterprises as firms with less than 20 permanent full-time workers, and medium enterprises as firms with 20-99 permanent full-time workers.

[14] This survey sample includes 846 micro-enterprises, i.e with less than 5 workers.

interviewed through 11 survey rounds conducted between 2006 and 2018 in 42 SSA countries. This initial analysis is complemented by a separate survey dataset of 1,495 micro-enterprises (MEs) conducted by the World Bank in six African countries[15] over a similar survey periodicity. Appendix A provides a description of the composition of the SME and ME sample by country and by business sector.

Surveys are stratified according to i) business sector, ii) firm size, and iii) firm geographical location. Stratification by firm size divides the population into small firms (5-19 employees), medium firms (20-99 employees), and large firms (100 or more employees). Regarding business sector stratification, the sample is split between manufacturing and non-agricultural firms in very small economies; between manufacturing, retail, and other non-agricultural firms in small economies; between the four largest manufacturing industries, other manufacturing, retail, and other non-agricultural firms in medium-size economies; and between the six largest manufacturing industries, other manufacturing, retail, and other non-agricultural firms in large-size economies.[16] Lastly, stratification by geographical location reflects the geographic distribution of non-agricultural economic activities, which is often located in the country's main demographic centres or more dynamic regions.

Therefore, the analysis of the potential of digital technologies and MSME performance proposed in this report does not reflect the important impact of these technologies on informal firms, nor impacts on the African agricultural sector and rural areas, which have been highlighted in a companion report (Cariolle, 2020a)[17].

3.1 Micro and SME (MSME) characteristics in SSA

3.1.1 MSMEs and employment in SSA

In the standard Enterprise Survey sample, meant to be representative of the whole non-agricultural private economy, SMEs account for more than 90% of the universe of formal firms (Table 2). The median firm employs 13 permanent and temporary workers, which is similar to the standard definition of a medium SME according to the World Bank. Among SMEs, the median number of employees in manufacturing firms is much larger than that of service firms, which respectively hire a median of 17 and 10 employees. The difference in size between the manufacturing and service sectors is however not significant in the sample of micro-enterprises.

Moreover, Figure 4 stresses that small and medium sized manufacturers (SMM) represent 54% of the total SME workforce, and that the shares of permanent and temporary workers in SMMs and service sector SMEs are similar, with permanent workers representing 84% and 87% of their respective workforces. Figure 5 presents the same information for MEs, but stresses that despite the smaller size of MEs in the first nine deciles of their workforce distribution, micro service firms contribute to 92% of the total workforce in MEs. This workforce is principally composed of permanent jobs, with temporary jobs representing approximately one quarter of the workforce of manufacturing or service micro firms. Lastly, information on the workforce composition of small and medium manufacturers (SMMs)[18] is represented in Figure 6. It stresses that the SMM workforce mostly consists of permanent production workers (76%), among whom 60% are skilled workers.

[15] Democratic Republic of the Congo, Ethiopia, Kenya, Mozambique, Rwanda, and Zimbabwe.

[16] Very small economies are economies whose GNI is lower than $15 billion, small economies have a GNI of between $15-100 billion, medium-size economies have a GNI of between $100-500 billion, and large-size economies have a GNI exceeding $500 billion.

[17] See Aker (2010, 2011) among others, and companion report #1 (section 3.1).

[18] This information is not available for service firms.

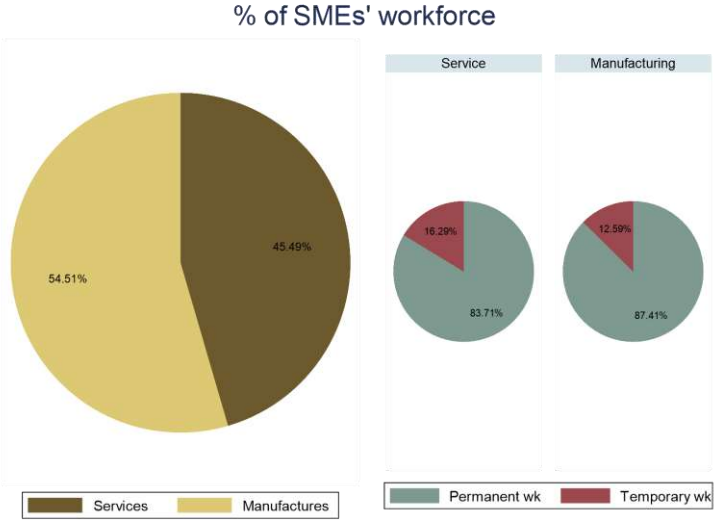
TABLE 2. FIRM SIZE IN SSA

	Variable: firm size (# permanent + temporary workers)						
Countries	25%*	50%*	75%*	90%*	Average*	Obs.	T-test p-values**
All firms (standard WBES)	7	13	30	82.3	37.07	30,037	-
SME	6.8	12	24	50	19.7	27,079	-
Large firms	120	155	274	480	239.98	2,958	
Micro enterprises	2	3	4	6	3.96	1,478	
Manufacturer SMEs	8	17	35	64	25.62	12,517	0.00
Services SMEs	6	10	19	32	15.50	14,562	
Micro manufacturers	3	4	5	7	4.72	416	0.52
Micro service firms	2	3	4	6	3.91	1,062	

* Median sample weights to variable distribution

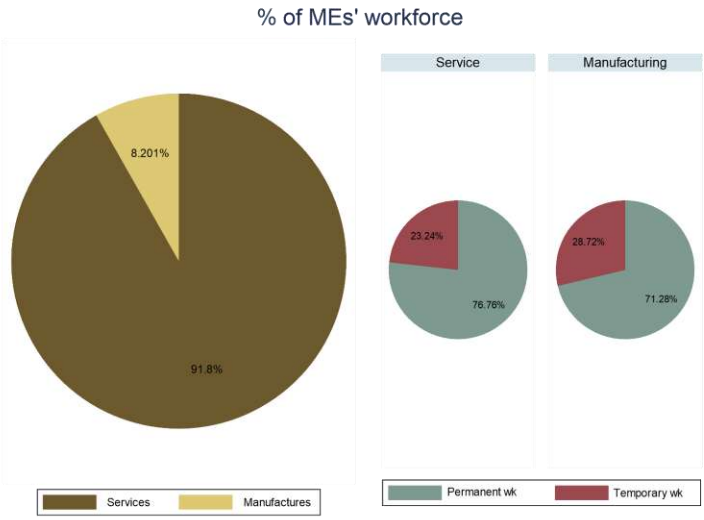
** Number of permanent and temporary workers. H0: diff = 0, HA: average diff ≠ 0. Based on unweighted averages.

FIGURE 4. SMALL AND MEDIUM ENTERPRISES' CONTRIBUTION TO EMPLOYMENT



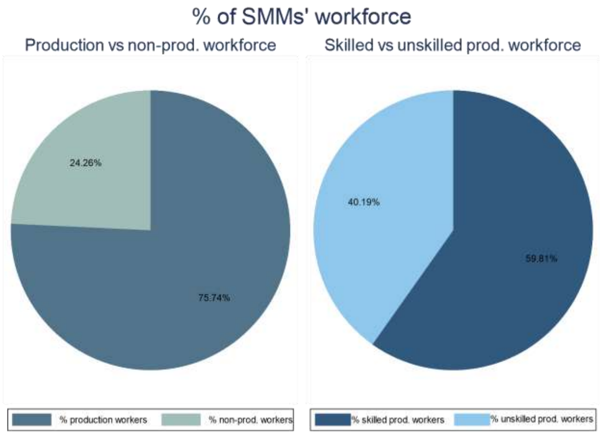
Source: Authors. Sample: 27,079 SMEs, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied. Wk: worker.

FIGURE 5. MICRO-ENTERPRISES' CONTRIBUTION TO EMPLOYMENT



Source: Authors. Sample: 1,475 MEs, 6 SSA countries, survey rounds covering 2011 to 2018. Probability sample weights applied. Wk: worker.

FIGURE 6. SMALL AND MEDIUM MANUFACTURERS (SMM) WORKFORCE COMPOSITION



Source: Authors. Sample: 12,517 manufacturers, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied.

3.1.2 Sales and labour productivity of African MSMEs

Next, we turn to the comparative analysis of African MSMEs' output distribution. We use two measures of firm output, the logarithms of firms' total sales (converted in USD) and labour productivity. Our measure of labour productivity is the ratio of the firm's total sales, converted to USD, over the number of permanent and temporary full-time workers.

Table 3 synthetizes the information on the firms' output distribution across different groups of firms. It stresses that, unsurprisingly, total sales for SMEs are lower than those of large firms, but that sales of MEs are higher than those of SMEs. This evidence can be explained by the higher income levels of several of the five countries where micro-enterprises have been surveyed: the Democratic Republic of the Congo, Ethiopia, Kenya, Mozambique, and Rwanda.[19] The t-test conducted on the subsamples of service and manufacturing SMEs does not reveal any significant difference in average sales. However, the t-test conducted on the service and manufacturing MEs suggests that micro service firms have on average larger sales than those operating in the manufacturing sector.

Table 4 describes the distribution of labour productivity among the same samples of firms. It stresses that labour productivity is lower in SMEs than in large firms, in line with the findings of Van Biesebroeck (2005). The t-test also shows that SMEs in the manufacturing sector are on average more productive than those in the service sector, in contrast to MEs, which were found to be more productive in the service than in manufacturing sector.

TABLE 3. MSME TOTAL SALES IN SSA

	Total sales: Ln (1+Annual sales (USD))					
Countries	25%*	50%*	75%*	Average*	Obs.	T-test p-values**
All firms	6.33	7.94	9.59	8.116	25,824	-
SMEs	6.17	7.73	9.17	7.80	23,067	-
Large firms	10.37	11.62	12.65	11.53	2,757	
Micro enterprises	7.90	9.02	10.33	9.14	929	
SMMs	6.78	8.48	9.68	8.35	10,923	0,54
Services SMEs	5.86	7.24	8.53	7.36	12,144	

[19] Zimbabwe was not included because of the non-convertibility of Zimbabwean dollars into US dollars.

Micro manufactures	7.67	8.76	9.70	8.82	273	0.00
Micro service firms	7.90	9.02	10.33	9.16	656	

* Average sample weights applied
**Number of permanent and temporary workers. H0: diff = 0, HA: average diff ≠ 0. Based on unweighted averages.

TABLE 4. MSME LABOUR PRODUCTIVITY IN SSA

	Labour productivity: Ln (1+ (sales (in real USD) / perm. + temp. worker)					
Countries	**25%***	**50%***	**75%***	**Average***	**Obs.**	**T-test p-values****
All firms	4.11	5.40	6.41	5.39	25,265	-
SMEs	4.02	5.29	6.29	5.31	22,874	-
Large firms	5.37	6.40	7.22	6.32	2,391	
Micro enterprises	6.80	8.00	9.17	8.10	929	
SMMs	4.37	5.48	6.45	5.51	10,869	0,00
Services SMEs	3.70	4.92	6.07	5.04	12,010	
Micro manufactures	6.58	7.80	8.41	7.64	273	0.00
Micro service firms	6.85	8.01	9.23	8.13	656	

* Average sample weights applied
**Number of permanent and temporary workers. H0: diff = 0, HA: average diff ≠ 0. Based on unweighted averages.

3.1.3 SME export orientation in SSA

Thirdly, we emphasize export orientation for SMEs and the relation between a firm's features and its labour productivity.[20] Table 5 reports the distribution of direct and indirect export share in total sales, according to firm size and business sector. This table stresses that only 10% of firms export more than 10% of their total sales, and that this statistic falls to 5% of total sales for SMEs, in contrast to 40% of sales for large firms, and 20% of sales for SMMs.

Moreover, Figure 7 below shows that indirect exports represent 62% of exports of small and medium exporters (i.e. SMEs directly or indirectly exporting 10% of their total sales), and that 85% of the total workforce is employed by small and medium non-exporters. Figure 8 stresses that exporters represent 14.5% of SMMs and 20.7% of their workforce, compared to 6.2% of service SMEs and 8.2% of their workforce. Therefore, these statistics support that African MSMEs are mostly inward orientated and poorly integrated into international trade networks, although integration is somewhat higher for manufacturers.

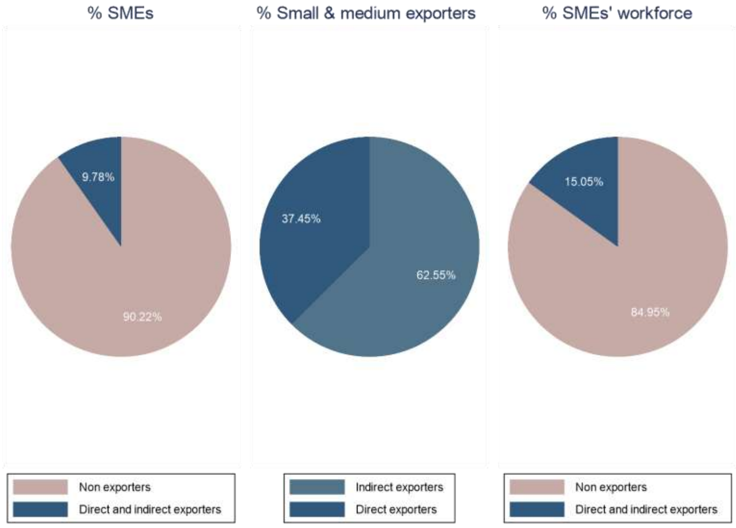
TABLE 5. SME'S EXPORT ORIENTATION IN SSA

	Direct and indirect exports (% total sales)						
Countries	25%*	50%*	75%*	90%*	Average*	Obs.	T-test p-values**
All firms	0	0	0	10	4.9	29,842	-
SMEs	0	0	0	5	4.2	26,542	0,00
Large size	0	0	15	40	12.9	3,300	
SMMs	0	0	0	20	4.3	8,497	0,00
Services SMEs	0	0	0	0	5.9	18,045	

* Average sample weights applied
**Number of permanent and temporary workers. H0: diff = 0, HA: average diff ≠ 0. Based on unweighted averages.

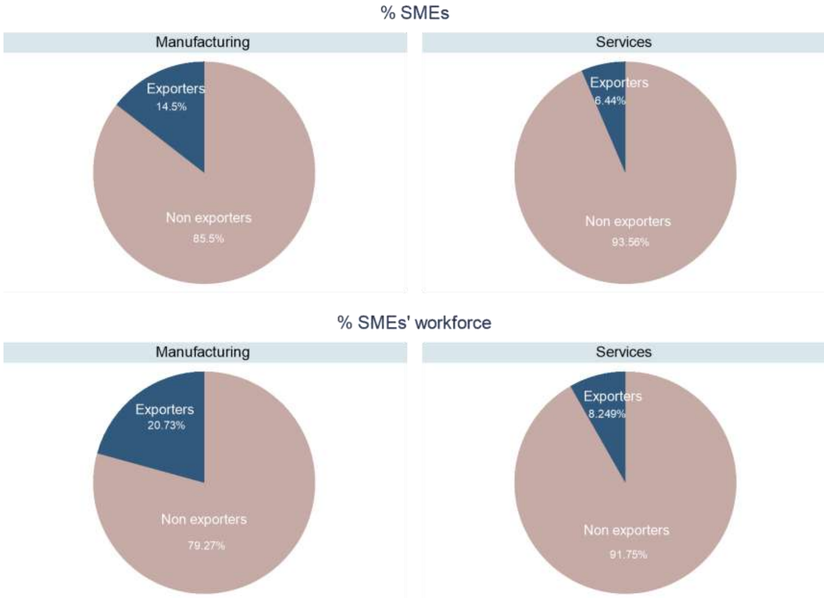
[20] Micro-enterprise surveys do not include information on firm export orientation.

FIGURE 7. EXPORT ORIENTATION AND SME WORKFORCE (1/2).



Source: Authors. Sample: 27,079 SMEs, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied.

FIGURE 8. EXPORT ORIENTATION AND SME'S WORKFORCE (1/2).



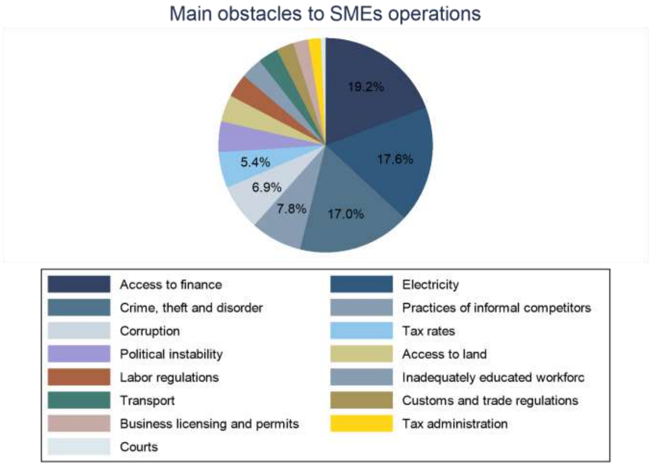
Source: Authors. Sample: 27,079 SMEs, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied.

3.1.4 Obstacles to SMEs in Africa

We end this overview of ME and SME characteristics by addressing the main obstacles faced by these firms during their operations. The graphs below represent the hierarchy of these obstacles, as reported by surveyed firms. In the standard and micro enterprise surveys, firms were asked to identify the greatest obstacle to their operations, among a range of predefined obstacles such as access to finance, electricity, and transport, political instability, corruption, and so on.

Figure 9 reports the main obstacles to effective operations for SMEs. Three main obstacles stand out among the ensemble of SMEs surveyed. Namely, 19.2% of SMEs declared that access to finance is their principal obstacle to conduct their business, 17.6% identify access to electricity as their greatest obstacle, and 17.0% consider that an insecure environment is the most important impediment. The next three obstacles in order of magnitude are competition from the informal sector, corruption, and tax rates, with respectively 7.8%, 6.9%, and 5.4% of SMEs declaring them as their principal obstacle.

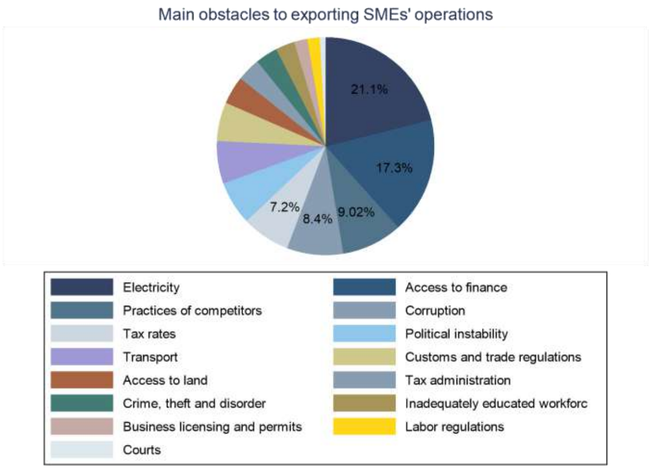
FIGURE 9. SME MAIN OBSTACLES TO BUSINESS OPERATIONS



Source: Authors. Sample: 27,079 SMEs, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied.

Next, we look at the same declarations from a restricted sample of exporting SMEs. In fact, this specific category of firms, under-represented in our sample (Figure 9), may face particular obstacles specific to their exportation activities. Figure 10 shows the hierarchy of these obstacles for SMEs reporting at least 10% of direct and indirect exports in their total sales. Again, electricity (21%) and access to finance (17.3%) clearly appear as the two greatest obstacles faced by these firms, followed by competition from the informal sector (9.0%), corruption (8.4%), tax rates (7.2%) and political instability (6.5%).

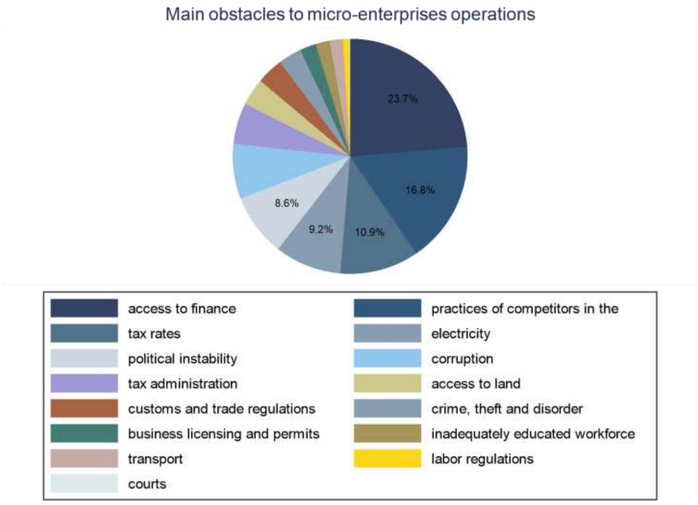
FIGURE 10. EXPORTING SME MAIN OBSTACLES TO BUSINESS OPERATIONS



Source: Authors. Sample: 2,794 SMEs, 42 SSA countries, survey rounds covering 2006 to 2018. Probability sample weights applied.

Lastly, we present the same information on MEs drawn from the micro-enterprise surveys in Figure 11. Interestingly, the main obstacles reported by micro firms are quite similar to those reported by exporting SMEs. In fact, 24% of MEs have responded that access to finance is their greatest obstacle, with 17% reporting competition from informal firms and 11% declaring tax levels are their greatest impediments. Access to electricity is the fourth greatest obstacle to ME operations, with 9.2% of firms declaring this as their main obstacle.

FIGURE 11. ME MAIN OBSTACLES TO BUSINESS OPERATIONS



Source: Authors. Sample: 1,450 MEs, 6 SSA countries, survey rounds covering 2011 to 2018. Probability sample weights applied.

In conclusion, the majority of MSMEs declare that access to finance and electricity, competition from informal firms, insecurity, tax rates, and corruption are the most important obstacles to conducting their businesses. These obstacles induce a range of transaction costs and are the result informational asymmetries that can be addressed through digital technology adoption. The next subsection aims to provide an overview of digital technology adoption and diffusion in MSMEs.

In a nutshell #2: MSME main characteristics

- Permanent workers represent approximately 75-85% of the workforce in MSMEs.
- 52% of the SME workforce is employed in manufacturing, while 92% of the ME workforce is employed in the service sector.
- 76% of the workforce in small and medium manufacturers consists of production workers, among whom 60% are skilled.
- SMEs in the manufacturing sector are on average more productive than those in the service sector, in contrast to MEs which are found to be more productive in the service than in manufacturing sector.
- African MSMEs are mostly inward orientated and poorly integrated into international trade networks, as less than 10% export more than 10% of their total sales.
- MSMEs declare that access to finance and electricity, competition from informal firms, insecurity, tax rates and corruption are their main obstacles to effectively conducting their businesses.

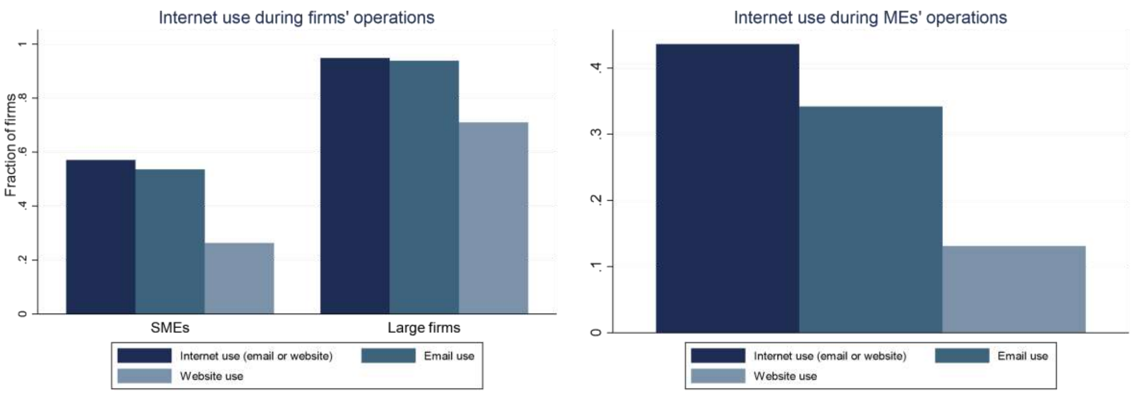
3.2 Digital technology adoption by African SMEs

In this subsection, we provide descriptive evidence on the diffusion of digital technologies among African MSMEs. Three main technologies are addressed: email and website information technologies on the one hand, and mobile money financial technology on the other hand. Information on mobile money technology is only available in recent standard enterprise surveys for a restricted sample of SMEs.

3.2.1 Information technologies: email and website adoption

This subsection addresses the diffusion of Internet-based information technologies, such as email or websites, among MSMEs. First, we compare the incidence of internet technology adoption, i.e. email or website adoption, among MEs, SMEs, and large firms in Figure 12. This figure highlights striking differences in terms of information technology diffusion among these three categories of firms, as 92% of large African firms declare using Internet during their operations, compared to 57% of the sample of SMEs and 44% in the sample of MEs. These numbers are driven by email technology adoption. Website technology is indeed much less prevalent, among large firms (72%), but particularly among SMEs (29%) and MEs (13%).

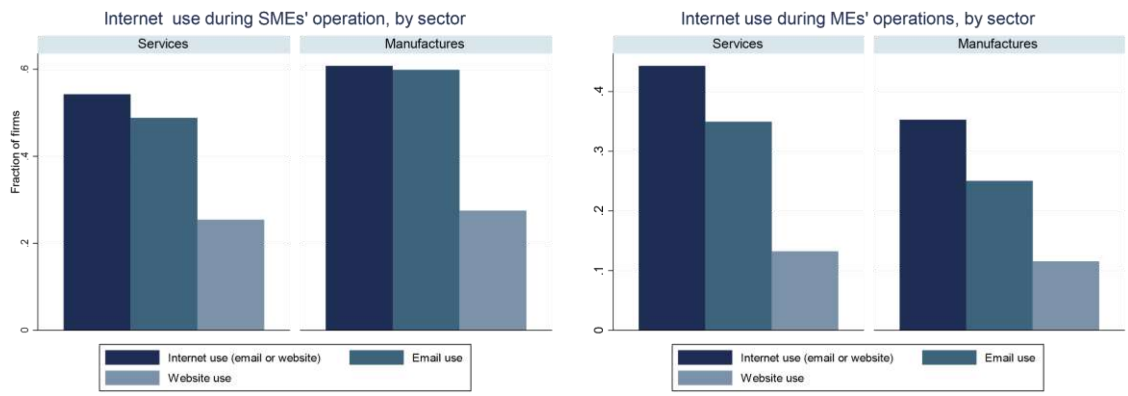
FIGURE 12. INTERNET TECHNOLOGY DIFFUSION ACROSS FIRM SIZES, 2013-2018 PERIOD.



SMEs sample: 12,239 (Internet), 11,497 firms (Email), 12,197 (Website). Large firm sample: 1,531 (Internet), 1,377 (Email), 1,563 (Website). Data on SMEs from the standard surveys conducted between 2013 and 2018 in seven African countries. Micro-enterprise sample: 1,393 (Internet), 1,383 (email), 1,393 (website). Probability sampling weights applied.

The next figure compares Internet technology diffusion among service firms and manufacturers. Among surveyed SMEs, 54% of service firms declare having used email or website technologies as compared to 61% in the manufacturing sector. Again, these numbers are driven by email adoption, as website adoption is basically the same in the service and manufacturing sectors (25% and 27% of firms respectively). By contrast, Internet technology incidence is higher among MEs operating in the service sector (44%) than among micro manufacturers (35%). These numbers are also driven by differences in email adoption, since website adoption lies around 12-13% in both micro service firms and micro manufacturers.

FIGURE 13. INTERNET TECHNOLOGY DIFFUSION ACROSS FIRM SIZES, MANUFACTURING VS SERVICES, 2013-2018 PERIOD.

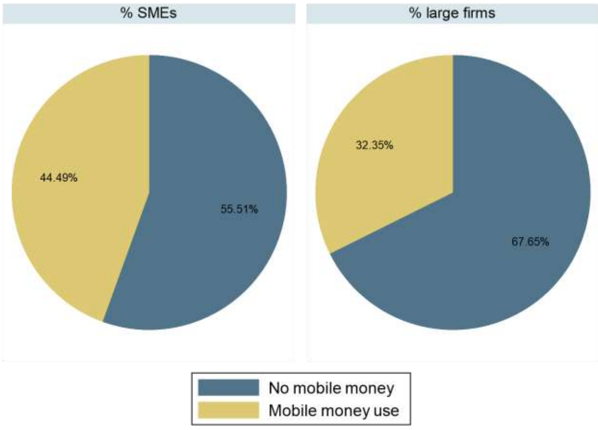


Source: Authors. SME service sample: 6,945 (Internet). SME manufacturer sample: 5,294 (Internet). ME service sample: 994 (Internet). ME manufacturer sample: 399 (Internet). Data on SMEs from the standard surveys conducted between 2013 and 2018. Probability sampling weights applied.

3.2.2 Mobile money adoption and usage

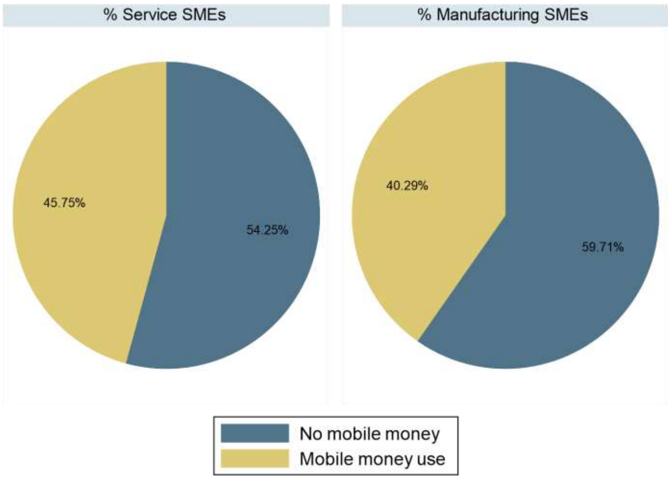
In this section, we present statistics, drawn from the standard enterprise surveys, on the extent of mobile money adoption in SMEs from 14 African countries.[21] First, we compare the incidence of this technology diffusion among SMEs and large firms in Figure 14. According to our data, 44.5% of SMEs use mobile money during their operations, compared with 32.3% of large firms. In Figure 15, we compare the same numbers splitting the sample between small and medium manufacturers (SMMs) and small and medium service firms (SMSs), and see that SMSs are slightly more inclined to use mobile money (45.7%) than SMMs (40%).

FIGURE 14. MOBILE MONEY ADOPTION ACROSS FIRM SIZES.



Sample: 5,778 firms (5,046 SMEs), 14 SSA countries. Probability sampling weights applied.

FIGURE 15. MOBILE MONEY ADOPTION ACROSS SECTORS.

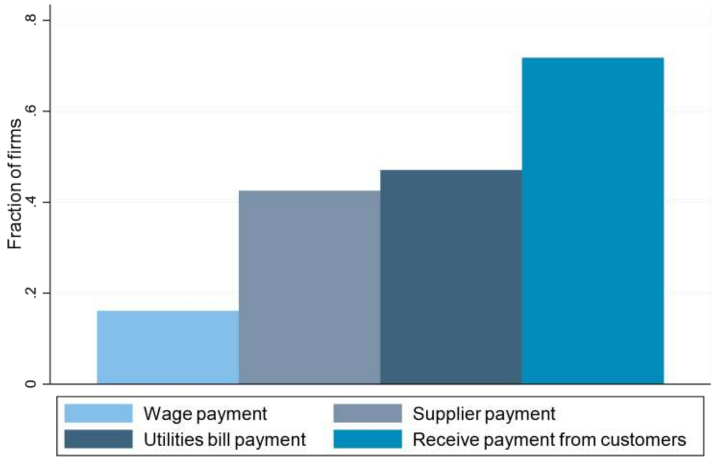


Sample: 5,046 SMEs, 14 SSA countries. Probability sampling weights applied.

We now turn to analyse the different usages of mobile money by SMEs. The Figure 16 below stresses that receiving payment from customers is the most common usage of mobile money, made by 71% of SMEs using mobile money. The second and third usages of mobile money are payments of utilities bill (47%) and suppliers (42%). Wage payments remain nascent, with only 16% of mobile money users declaring having used these transactions through mobile money.

[21] See Appendix A.5 for information on sample composition.

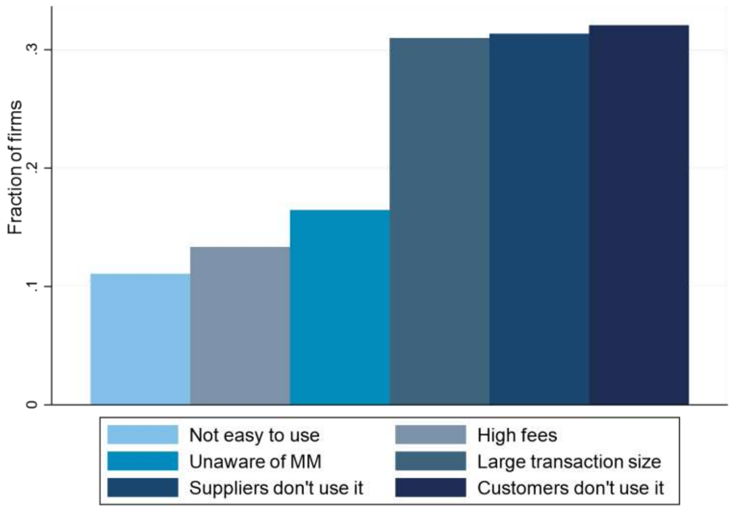
FIGURE 16. MOBILE MONEY TRANSACTION TYPES.



Sample: 2,245 SMEs using mobile money. Probability sampling weights applied. Firms were asked whether their use of mobile money was related to each of four predefined transaction types (Yes/No).

The next figure reports the greatest obstacles to mobile money adoption according to SME owners. Surveyed firms identified three main obstacles in approximatively the same proportions: the low penetration of the technology among their customers (32%), among their suppliers (31%), and large size of transactions (31%). The fourth obstacle is related to the firm's unawareness of this technology. Therefore, three of the four greatest obstacles identified by firms are related to the size of the mobile money user network.

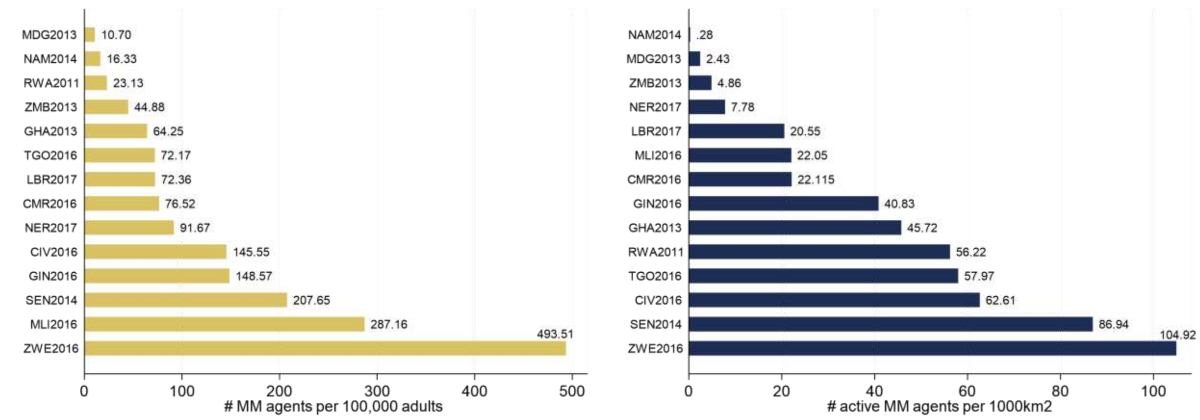
FIGURE 17. GREATEST OBSTACLES TO MOBILE MONEY USE



Sample: 2,245 SMEs using mobile money. Probability sampling weights applied. Firms were asked if they have failed to use mobile money because of one of the six reasons mentioned in the figure (Yes/No).

Many studies have pointed out the crucial importance of the mobile money agent network as a precondition for reaching a critical mass of mobile money users and for maximizing the welfare impacts of this technology (Jack et al., 2013; Jack & Suri, 2014; Suri & Jack, 2016; Suri, 2017). To illustrate disparities in the size of mobile money agent networks across African countries, Figure 18 reports the number of active mobile money agents per 100,000 adults (the network demographic density, left-hand side graph) and the number of active mobile money agents per 1000 km^2 (the network geographic density, right-hand side graph) in surveyed countries. It stresses that the mobile money agent network's demographic and geographic densities are highest in Zimbabwe. Senegal ranks third in terms of MM agent network demographic density (207 agents per 100,000 adults) and second in terms of geographic density (86.9 agents per 1000 km²). Mali ranks third in terms of network demographic density while Côte d'Ivoire ranks third in terms of geographic density.

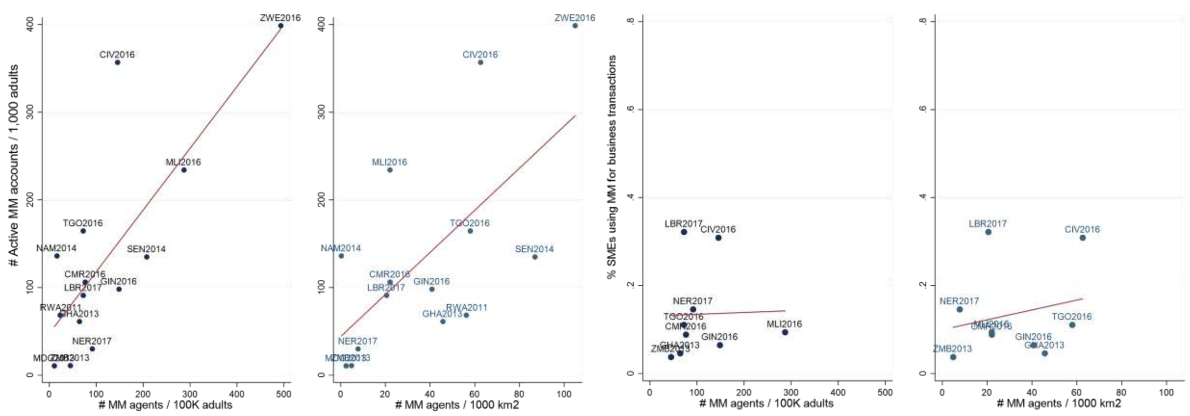
FIGURE 18. MOBILE MONEY (MM) AGENT NETWORK DENSITY, BY COUNTRY/SURVEY-YEAR.



Is higher mobile money network density associated with a higher penetration of mobile money technology? To answer this question, the correlation between these two measures of mobile money agent network density and a measure of the penetration of MM is plotted in Figure 19. The strongly positive graphical correlations shown in the figure stress that both demographic and geographic densities matter for MM penetration in the population (Figure 19a). However, replacing the penetration measure of active mobile money accounts in the population by the country-year penetration of mobile money among SMEs (Figure 19b), we do not see a clear-cut relationship between mobile money agent network density and mobile money penetration in SMEs. Beyond the difference in the nature of the two MM outcome variables, this low correlation could be explained by a possibly lower mobile money adoption rate among firms operating in urban centres and/or in non-agricultural industries, which constitute the survey sample. In fact, Mothobi and Grzybowski (2017) provide evidence that mobile phone users located in areas remote from physical infrastructures are more likely to use mobile money than individuals close to the infrastructure, because of the higher transaction costs incurred by the former to access formal and "brick-and-mortar" financial service providers.

FIGURE 19. MOBILE MONEY (MM) AGENT NETWORK DENSITY AND MOBILE MONEY PENETRATION, BY COUNTRY-YEAR.

a. MM penetration in the population b. MM penetration among firms



In a nutshell #3: Patterns of digital technologies adoption by MSMEs

- 92% of large African firms declare using Internet (email or website) during their operations, as compared to 57% of the sample of SMEs and 44% of the sample of MEs.
- Taken alone, website technology is much less prevalent, especially among SMEs (29%) and MEs (13%).
- 54% of SMEs operating in the service sector declare having used email or website technologies, against 61% in the manufacturing sector.
- By contrast, Internet technology incidence is higher among MEs operating in the service sector (44%) than in the manufacturing sector (35%).
- 44.5% of SMEs use mobile money (MM) during their operations, against 32.3% of large firms.
- SMEs operating in the service sector are slightly more inclined to use MM (45.7%) than SMMs (40%)
- Receiving payments from customers is the most common usage of MM, made by 71% of SMEs using mobile money.
- Three out of the four greatest obstacles to MM adoption identified by firms are related to the size of the MM user network: the low penetration of the technology among their customers, among their suppliers, and the firm's ignorance of this technology.
- There is a high correlation between the MM agent network size and MM penetration in the population.

4 SME performance and digitisation in Sub-Saharan Africa: Econometric analysis

In this section, we undertake an econometric analysis of the effect of digital technologies on the performance of African SMEs. The contribution of this empirical section is fourfold. First, we separate the different usages of digital technologies by SMEs by addressing the adoption of three distinct technologies, namely email, websites, and mobile money. Second, we analyse the relationships between the adoption of these technologies by firms and multiple firms-level outcomes, namely sales, labour productivity, exports, and employment outcomes. Third, one specific contribution of this empirical analysis is the separation of the effect of individual adoption and use of digital technologies from the spillover effects induced by their spatial and industry-level diffusion. Fourth, this empirical analysis also proposes a new identification strategy for the impact of email adoption and diffusion on SME outcomes, exploiting exogenous country-level variations in internet connectivity induced by the staggered rollout timeline of submarine telecommunications cables, and their exposure to shocks, following a methodology similar to those of Cariolle et al. (2019) and IMF (2020).

4.1 Model and Data

In this section, we provide empirical evidence on the effect of digital technologies adoption on African firm outcomes, by estimating the following general model:

$$Y_{i,j,k,l,t} = \alpha_0 + \alpha_1 DT_{i,j,k,l,t} + \alpha_2 X_{i,j,k,l,t} + d_{i,j,k,l,t} + d_{i,j,k,l,t} + \varepsilon_{i,j,k,l,t} \quad (1)$$

Where the subscripts i, j, k, l, and t respectively refer to the firm, country, industry, location, and year of survey. $Y_{i,j,k,l,t}$, $DT_{i,j,k,l,t}$, and $X_{i,j,k,l,t}$ are respectively the firm's outcome variable, a dummy variable of digital technology (DT) adoption during firm operations (email, website or mobile money), and a vector of firm-level characteristics. This equation also includes country-industry-year dummies ($d_{j,k,t}$), and location-year dummies ($d_{j,l,t}$). These dummies allow us to significantly reduce the probability of omitted variable bias by controlling for a wide range of unobserved time-variant and time-invariant country-specific, sector-specific and location-specific characteristics. $\varepsilon_{i,j,k,l,t}$ is a random error term.

Variables used in our standard model are drawn from a homogenised composite World Bank Enterprise Survey (WBES) repeated cross-sectional dataset. These surveys cover an original representative sample (random stratified sampling) of 27,436 firms from 42 sub-Saharan African countries, operating in the formal economy's manufacturing and service sectors, surveyed over the period 2006-2018. In each country, data were gathered by an extensive and internationally comparable questionnaire administered by face-to-face interviews with business owners and senior managers. The design of the survey is initially suited for cross-country comparison, but not for firm-level panel data analysis because of missing panel identification numbers. However, the data set has a pseudo-panel structure since stratification industries and locations are constant over time, which enables controlling for a wide range of unobserved characteristics related to the firms' environments (see eq.(1)). Descriptive statistics are reported in Table 6 below. Appendix A provides detailed information on the SME sample composition and reports the variable correlation matrix.

4.1.1 SME performance ($Y_{i,j,t}$)

We measure SME performance using several different output variables. First, we investigate the effect of DT use on the logarithm of the firm's total annual sales (in USD), which is a proxy for firm's global revenues. Secondly, given the expected effect of DTs on the firm's activity, we focus the analysis on labour productivity, measured by the logarithm of the firm's total sales per full-time permanent and temporary employee (in USD). Thirdly, since DT use is likely to increase the firm's capacity to reach foreign markets, we also look at the effect of DT use on SME annual direct and indirect export sales[22] (in USD). This specific export variable is constructed by combining data on the firms' total sales (in USD) and data on the firms' share of direct and indirect exports in total sales.[23]

Moreover, since we are particularly interested in the potential of digital technologies for job creation, we also use as main employment outcome variables the logarithm of the numbers of permanent and temporary workers, taken together or separately. Taken separately, these numbers inform us on the quality of jobs created, the number of temporary workers being associated with more precarious positions when compared to the number of permanent workers.[24] Last but not least, we further the study of the consequences of digital technologies adoption on the job market by using four additional employment variables, provided by the standard WBES, documenting manufacturer workforce composition:

- the logarithm of the number of permanent production workers in manufacturing firms
- the logarithm of the number of permanent non-production workers in manufacturing firms
- the logarithm of the number of permanent skilled production workers
- the logarithm of the number of permanent unskilled production workers

This last set of employment variables therefore enables us to draw a more comprehensive and qualitative picture of the employment benefits, at least for African manufacturers, of digital technologies diffusion.

[22] Only for SMEs, not MEs. Information on exports was not available in the ME surveys.

[23] Calculated as follows: *Annual direct and indirect export sales (in USD) = % of direct and indirect exports × annual total sales (in USD)*. Since it is derived from two survey variables subject to measurement errors, results associated with this dependent variable should be considered with due caution.

[24] Keeping in mind that labour laws differ greatly across income groups and regions.

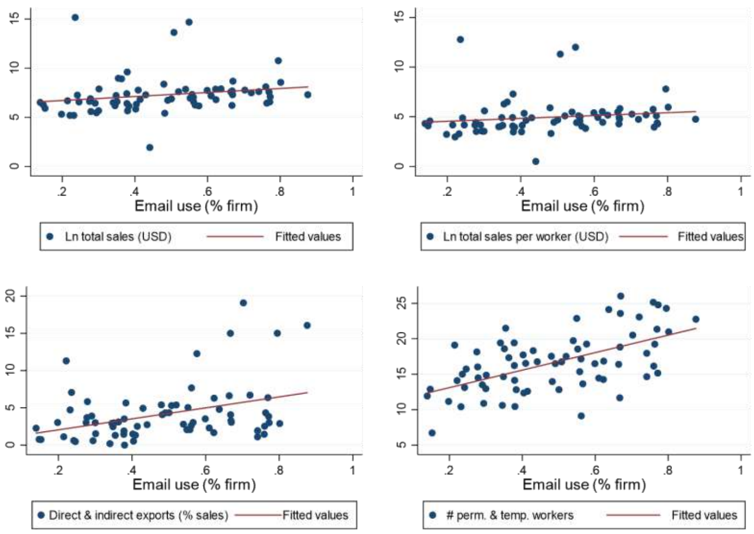
4.1.2 Variables of interest ($DT_{i,j,t}$)

Our variables of interest are drawn from the World Bank Enterprise Surveys and reflect the three most common usages of digital technologies in the African private sector: email use, website use, and mobile money use. Each variable is a dummy equal to one if the firm i declares using the technology during its operations at the time of the survey.

The email use variable reflects one of the most basic uses of Internet technology with probably the greatest impact on firm outcomes. This variable has the advantage of reflecting the use of digital technologies for organization's internal matters[25], but also for external relationships with clients, suppliers, or administrations. By contrast, the website use variable reflects a strategic use of Internet, costlier and therefore riskier, and depending on the nature of activities carried by the firm, the intensity of the competition environment and external support for the adoption of such technologies (Sadowski et al., 2002). Moreover, Sadowski et al. stress that email adoption differs from website adoption, in that "establishing a website presence is different from communicating via email where control over use is somewhat relegated to individual corporate users" (2002, p.77). Lastly, while email adoption is expected to be conducive to firm performance by improving the firm's inner functioning as well as its interaction with the business environment, website adoption should be particularly instrumental to firm's market positioning.

Figures 20 and 21 represent the graphical correlations between the incidence of email and website adoption at the country-year level, and country-year averages of firm performance variables. This graphical evidence suggests a positive relationship between adoption of email or websites by firms and their sales, sales per worker, exports, and workforce size.

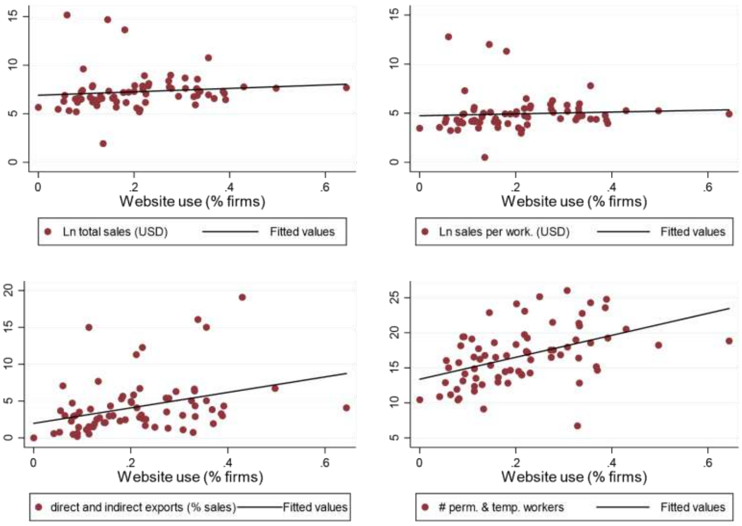
FIGURE 20. EMAIL TECHNOLOGY ADOPTION AND FIRM PERFORMANCE, BY COUNTRY-YEAR.



Source: data from WBES. Average sample weights applied.

[25] For instance, Galliano and Roux (2008), using a survey of French firms, examine the determinants of Internet/email use intensity within the firm, measured by the share of employees using Internet/email. Unfortunately, the WBES dataset does not allow such an analysis.

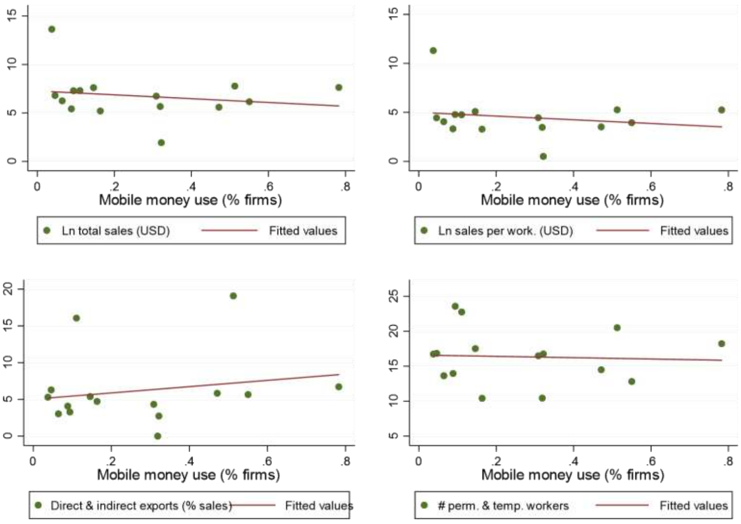
FIGURE 21. WEBSITE TECHNOLOGY ADOPTION AND FIRM PERFORMANCE, BY COUNTRY-YEAR.



Source: data from WBES. Average sample weights applied.

The mobile-money (MM) use variable is also of great interest, despite not being a communication technology, due to its widely-documented effects on financial market imperfections and transaction cost reduction (Aker & Mbiti, 2010; Jack & Suri, 2014; Aker, 2017)[26]. This variable is however only available for a restricted sample of countries and survey rounds (See Appendix A.3).[27] Figure 22 plots the graphical correlations between the incidence of mobile money adoption at the country-year level and country-year averages of firm performance variables. Based on this simple graphical correlation, the relationship between mobile money adoption and firm performance is not striking. The relatively low number of observations related to this digital technology and other concomitant determinants of firm performance could possibly act as confounding factors. The next subsection describes the set of control variables used in the subsequent multivariate regression analysis.

FIGURE 22. MOBILE MONEY ADOPTION AND FIRM PERFORMANCE, BY COUNTRY-YEAR.



Source: Authors, data from WBES. Average sample weights applied.

[26] See companion reports #1 and #2.

[27] In the ME surveys, this variable is only available for a small sample of Kenyan firms interviewed in 2013, so that we focus the analysis of MM impacts on SMEs, not MEs.

4.1.3 Control variables ($X_{i,j,t}$)

We control for the various determinants of firm performance, evidenced by the literature on firm performance in developing countries (Dollar et al., 2006a, Paunov & Rollo, 2016):

- the **number of full-time permanent employees when the firm started operations**, to control for the firm's initial size.
- the **firm's age** (in years), to control for the firm's longevity.
- the top **manager's experience** (in years), to control for firm management quality.
- the **ownership structure (public and foreign ownership)**, to control for the influence of foreign and public entities on the firm's decisions and performance.
- the **share of direct and indirect exports in total sales** (only indirect exports when the dependent variable is the share of direct exports), to control for the firm's outward orientation.
- the **firms' financial liabilities**, measured by a dummy equal to one if the firm has a credit line or loan from a financial institution, to control for access to finance, the firm's greatest obstacle to its operations (Figures 5, 6, 7).
- the **losses due to electrical outages**, expressed as a share of total sales, to control for power access, the firm's second biggest obstacle to its operations (Figure 5).
- the **firm's security costs**, expressed as a share of total sales, to control for insecurity in business operations, the firm's third biggest obstacle to its operations (Figure 5).

In the export equation, the firm's security costs variable is replaced by a dummy variable equal to one if the firm considered that **competition from informal firms** was their greatest obstacle. In fact, Figure 9 stresses that exporting firms face different obstacles to operations than the majority of firms, and that electricity access, credit access and competition from informal firms were exporter's three greatest obstacles.

In the export and employment equations, we additionally control for the logarithm of sales per worker, to check whether estimated relationships between Internet technology adoption and exports/employment are affected by the introduction of this intermediary outcome variable. Summary statistics of standard WBES variables used in regression analysis are reported in Table 6 below.

TABLE 6. SUMMARY STATISTICS, STANDARD WBES VARIABLES.

Variables	Obs.	Mean	Std. Dev.	Min	Max
Firm outcomes (Y)					
Real annual sales (USD)	25,824	7.722791	3.096417	0	22.77724
Real annual sales / worker (USD)	25,265	4.990914	2.624424	0	19.27467
Direct & indirect exports (USD)	25,362	1.949829	4.691562	0	25.43689
# of (perm. & temp.) workers (ln)	30,037	2.915142	1.074056	0	8.281724
# of temp. workers (ln)	28,932	.8421107	1.267256	0	6.685861
# of perm. workers (ln)	30,037	2.849935	1.069593	0	8.243019
# perm. prod. workers (ln)	12,308	2.819584	1.175813	0	7.955425
# perm. non prod. workers (ln)	12,232	1.654273	1.240822	0	6.679599
# perm. skilled prod. workers (ln)	12,043	2.34194	1.182316	0	7.523481
# perm. unskilled prod. workers (ln)	11,954	1.425075	1.436463	0	7.601402
DT adoption (DT)					
Email use (0/1)	29,736	0.5093826	0.4999204	0	1
Website use (0/1)	30,593	0.2655509	0.4416333	0	1
Mobile money use (0/1)	5,778	0.2987193	0.4577361	0	1
Controls (X)					

% of state ownership	26,034	0.0281459	0.9526359	0	99
% of foreign ownership	30,465	0.124046	0.3222716	0	1
% dir. & indir. Exports in sales	29,842	6.87902	20.78617	0	100
Firm's age (ln, years)	29,924	2.379598	.8544128	0	5.247024
Initial # perm. FT employees (ln)	25,560	2.311279	1.074509	0	8.517393
Manager experience (ln, years)	30,012	2.383814	0.7915623	0	4.094345
Bank loan (0/1)	29,855	0.203651	0.4027191	0	1
Elec. outages losses (% annual sales)	30,512	5.610514	10.8377	0	90
Insecurity losses (% annual sales)	27,720	1.352022	5.097488	0	100
Greatest obstacle: informal compet.	29,966	.3311753	0.4706438	0	1

4.2 OLS estimations - baseline estimations

4.2.1 Internet technology adoption and SME performance

Equation (1) is estimated by OLS, with White robust standard errors, clustered at the country-year-industry level, run over a baseline sample of 14,991 SMEs, surveyed between 2006 and 2018, from 40 SSA countries. Information on estimation sample composition is provided in Appendix A. Estimates are reported in Table 7. In columns (1) to (3), we included the internet use variables separately (columns (1) and (2)) and simultaneously (column (3)), i.e. the email and website interest variables, to check whether these two usages of Internet have distinct effects on total firm sales. Estimates in columns (3) to (6) suggest that uses of email and websites during firm operations are separately, strongly, significantly and positively correlated with total firm sales, labour productivity, exports, and all types of employment. The relationships between sales-related variables and email use (columns (1), (3) and (4)) are stronger than with website use, while the relationship between exports and website use is stronger than with email use.

According to our estimates, email adoption by firms is associated with a 70% increase in total sales (column (3)), a 44% increase in sales per worker (column (4)), a 72% increase in direct and indirect exports (column (5)), and an approximately 21-22% increase in the number of workers, whether permanent or temporary (columns (6) to (8)). Regarding website adoption, using this technology is associated with a 50% increase in total sales (column (3)), a 25% increase in sales per worker (column (4)), a 152% increase in direct and indirect exports (column (5)), and a 23% increase in the total workforce (column (6)), with a smaller increase in the number of temporary workers (column (7)).

TABLE 7. OLS BASELINE ESTIMATIONS: EVIDENCE FROM SMES (1/2)

	(1)	(2)	(3)	(4)	(5)
Dep. Var (ln):		Total sales (USD)		Total sales / worker	Exports (USD)
Email use	0.863***		0.698***	0.442 ***	0.719***
	(0.0638)		(0.0718)	(0.0526)	(0.128)
Website use		0.755***	0.498***	0.247***	1.520***
		(0.0531)	(0.0558)	(0.0492)	(0.366)
Control variables					
% of state ownership	0.124	0.118	0.113	0.0719	0.331
	(0.150)	(0.149)	(0.146)	(0.114)	(0.225)
% of foreign ownership	0.303*	0.335**	0.300**	0.292***	1.410***
	(0.163)	(0.147)	(0.147)	(0.1006)	(0.228)
% dir. & indir. exports in sales	0.0064**	0.00587**	0.00492*	0.0047**	-
	(0.0029)	(0.0028)	(0.00289)	(0.0024)	-
Firm's age (ln, years)	0.305***	0.266***	0.272***	0.105***	0.583***
	(0.0290)	(0.0258)	(0.0269)	(0.027)	(0.140)
Initial # perm. FT employees (ln)	0.620***	0.660***	0.598***	0.105**	0.258***
	(0.0519)	(0.0556)	(0.0531)	(0.042)	(0.044)

Manager experience (ln, years)	0.125***	0.154***	0.133***	0.0504*	0.408**
	(0.0374)	(0.0320)	(0.0345)	(0.0307)	(0.215)
Bank loan dummy	0.413***	0.478***	0.398***	0.192**	0.365**
	(0.107)	(0.0947)	(0.0998)	(0.099)	(0.143)
Elec. outages losses (% annual sales)	-0.0117***	-0.0107***	-0.0120***	-0.0100***	-0.003
	(0.00293)	(0.00266)	(0.00273)	(0.0030)	(0.008)
Insecurity losses (% annual sales)	-0.0278***	-0.0257**	-0.0275***	-0.025***	-
	(0.0103)	(0.0101)	(0.0101)	(0.0077)	-
Obstacle informal competitor	-	-	-	-	-0.339***
	-	-	-	-	(0.126)
N	14,991	15,558	14,965	14,762	14,901
R^2	0.737	0.722	0.743	0.728	0.180

TABLE 7. OLS BASELINE ESTIMATIONS: EVIDENCE FROM SMES (2/2)

	(6)	(7)	(8)
Dep. Var (ln):	# of (perm. & temp.) workers	# of temp. workers	# of perm. workers
Email use	0.223***	0.210***	0.213***
	(0.0342)	(0.0206)	(0.0353)
Website use	0.227***	0.148***	0.222***
	(0.0192)	(0.0311)	(0.0213)
Control variables			
% of state ownership	0.0324	0.0270	0.0296
	(0.0333)	(0.0427)	(0.0295)
% of foreign ownership	0.00254	-0.135*	0.0115
	(0.0476)	(0.0730)	(0.0475)
% dir. & indir. exports in sales	0.000349	0.0077***	-0.000143
	(0.0012)	(0.0026)	(0.0011)
Firm's age (ln, years)	0.141***	-0.0002	0.143***
	(0.0218)	(0.0328)	(0.0201)
Initial # perm. FT employees (ln)	0.458***	0.186***	0.455***
	(0.0196)	(0.0319)	(0.0191)
Manager experience (ln, years)	0.0848***	0.0397	0.0803***
	(0.0108)	(0.0313)	(0.0106)
Bank loan dummy	0.177***	0.265***	0.163***
	(0.0327)	(0.0745)	(0.0350)
Elec. outages losses (% annual sales)	-0.00102	0.0018	-0.0013
	(0.00142)	(0.0024)	(0.0014)
Insecurity losses (% annual sales)	-0.00276	0.0089***	-0.0045**
	(0.00218)	(0.0023)	(0.0019)
N	16,548	16,037	16,548
R^2	0.607	0.158	0.614

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. In column (5), the share of direct and indirect exports is excluded from the set of control variables because this control variable was used to construct the dependent variable.

In a nutshell #4: Baseline OLS estimations

- Evidence of a consistent, significant, positive relationship between internet technology adoption and firm performance.
- Distinct effect of email and website adoption on firm performance, the former being more strongly correlated with labour productivity and the latter more strongly correlated with exports.

4.2.2 Digital technologies, the manufacturing sector, and skill-biased technological change

In this subsection, we test whether relationships between digital technologies adoption and firm outcomes differ according to the firm's sector of operation. We also exploit information on manufactures' workforce composition to test the 'skilled-biased technological change' hypothesis.

Manufacturing versus service firms

First, we test whether the relationship between email/website adoption and SME performance differs according to the firm's business sector. In fact, the descriptive analysis undertaken in the previous section has shown that small and medium manufacturers are more export-oriented, have larger workforces, and tend to be more inclined to use the Internet during their operations than their counterparts in the service sector. On the other hand, the literature supports that digitalisation could be particularly detrimental to manufacturers by allowing the automation of repeated tasks (Rodrik, 2016; Banga & Te Velde, 2018; Choi et al., 2020, IMF, 2020; World Bank, 2019). We therefore try to identify possible conditional relationships between internet use and firm performance depending on the firm's business sector. To do so, we add to Equation (1) an interaction term between a dummy indicating whether the firm operates in the manufacturing sector (in the service sector otherwise) and the email/website use variables:

$$Y_{i,j,k,l,t} = \alpha_0 + \alpha_1 email_{i,j,k,l,t} + \alpha_2 website_{i,j,t} + \alpha_3 X_{i,j,k,l,t} + \alpha_4 email_{i,j,k,l,t} \times manufacture_{i,j,k,l,t} + \alpha_4 website_{i,j,k,l,t} \times manufacture_{i,j} + \alpha_4 manufacture_{i,j} + d_{j,k,t} + d_{j,l,t} + \varepsilon_{i,j,k,l,t} \quad (2)$$

Results are reported in Table 8. They stress that, contrary to what some studies would suggest, the positive association between email use and sales, exports or workforce size is stronger when SMEs operate in the manufacturing sector. Results regarding the use of websites by manufacturing firms are more mixed, since this particular usage of Internet is associated with lower total sales (column (1)) but higher exports (column (3)) in manufacturing than in service firms. Overall, our estimates point that, compared to service firms, manufacturers that adopt email technology have 28% higher sales, 77% higher exports and a 16-17% larger (permanent) workforce. Moreover, those which have adopted website technology are found to have more than doubled their direct and indirect exports (120% increase).

TABLE 8. INTERNET TECHNOLOGIES ADOPTION: MANUFACTURING VERSUS SERVICE FIRMS

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var:	Sales	Sales / w	Dir. Indir. Exports	#workers	# temp. workers	# perm. workers
Email use	0.565***	0.378***	0.374***	0.154***	0.217***	0.136***
	(0.112)	(0.097)	(0.109)	(0.0393)	(0.0309)	(0.0386)
Website use	0.574***	0.319***	0.847**	0.222***	0.0938	0.227***
	(0.0728)	(0.080)	(0.393)	(0.0394)	(0.0621)	(0.0410)
Email × Manuf.	0.280*	0.131	0.771***	0.158***	-0.0118	0.173***
	(0.144)	(0.123)	(0.160)	(0.0521)	(0.0333)	(0.0517)
Website × Manuf.	-0.140*	-0.128	1.199***	0.00508	0.103	-0.0139
	(0.0804)	(0.087)	(0.413)	(0.0429)	(0.0645)	(0.0453)
Manufacture	0.251**	0.352**	0.613	-0.111	0.0758	-0.106
	(0.120)	(0.170)	(0.381)	(0.0794)	(0.122)	(0.0752)
N	14,818	14,762	14,901	16,548	16,037	16,548
R^2	0.745	0.728	0.188	0.609	0.158	0.616

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls ($X_{i,j,,t}$, $d_{j,k,t}$; $d_{j,l,t}$) are included in the regressions but not reported in the table.

Employment outcomes among manufacturing firms

The literature on the ICT-employment nexus has stressed that technological change induced by the introduction of ICTs is biased in favour of an educated and skilled workforce in rich economies (Michaels et al., 2014; Akerman et al., 2015; Acemoglu & Restrepo, 2018). We test this "skill-biased technological change" (SBTC) hypothesis, by exploiting data reported by manufacturers on their workforce's type of occupation. Therefore, the (logarithmic) number of non-production and production workers and the (logarithmic) number of skilled and unskilled production workers in manufacturing firms are used as dependent variables ($Y_{i,j,t}$) in the next round of estimations.

Estimations of Equation (1) using these four additional dependent variables conducted on the subsample of small and medium manufacturers (SMM) are reported in Table 9. The results stress that email use is significantly and positively associated with all types of positions. First, results do not provide striking evidence in favour of the SBTC hypothesis regarding email adoption. Estimates stress that the correlation between email use and the number of non-production workers (column 2), often allocated to tasks requiring higher skills or education levels (accounting, management, marketing, etc.), and the number of production workers (column (1)) is of similar amplitude. In fact, results suggest that SMMs using email have 29% more non-production workers and 27% more production workers. However, website use seems more favourable to the SBTC hypothesis since this technology adoption is associated with a 24% increase in the number of non-production workers (column (1)), against a 16% increase in the number of production workers (column (2)).

Second, estimations also stress that the strongest correlation is between email use and the size of the unskilled production workforce. In fact, SMMs using emails are found to have a 37% larger unskilled production workforce. This result therefore challenges the SBTC hypothesis by providing evidence on the benefits of email adoption for the unskilled workforce, as also evidenced by Hjort and Poulsen (2019). By contrast, regression estimates support a significant positive relationship between website adoption and the number of skilled production workers (column (3)) but do not support any significant relationship with the unskilled production workforce (column (4)). Overall, email adoption seems to be more beneficial to the unskilled production workforce, while website adoption is more beneficial to the skilled one (non-production workers and skilled production workers).

TABLE 9. INTERNET TECHNOLOGIES AND MANUFACTURER WORKFORCE COMPOSITION

	(1)	(2)	(3)	(4)
Dep. Var (ln):	**# perm. prod. workers**	**# perm. non prod. wk**	**# perm. skilled prod. wk**	**# perm. unskilled prod. wk**
Email use	0.273***	0.292***	0.229***	0.373***
	(0.0126)	(0.0260)	(0.015)	(0.037)
Website use	0.165***	0.239***	0.156***	0.0182
	(0.0178)	(0.0165)	(0.021)	(0.022)
N	6,753	6,711	6,664	6,634
R^2	0.556	0.494	0.323	0.338

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls ($X_{i,j,t}$, $d_{j,k,t}$; $d_{j,l,t}$) are included in the regressions but not reported in the table.

In a nutshell #5: Heterogeneous effects of DTs

- Evidence of a stronger positive, consistent, and significant relationship between email technology adoption by manufacturers and their exports and workforce size compared to service firms.
- Email adoption by manufacturers is positively correlated with all types of employment positions (production/nonproduction workers, skilled/unskilled production workers), but particularly beneficial to unskilled production workers.
- Website adoption by manufacturers is positively correlated with the number of production and non-production workers, but more strongly with the latter.
- Website adoption by manufacturers is positively associated with the skilled production workforce, but not with the unskilled production workforce.
- Website adoption by manufacturers is found to be beneficial to skilled jobs, while email adoption is more beneficial to unskilled ones.

4.2.3 Spillover effects

The empirical literature on the spatial, within-industry, and cross-industry spillovers of ICT adoption is vast (Harrison et al., 1996; Röller & Waverman, 2001; Malmberg et al., 2006; Frenken et al., 2007; Paunov & Rollo, 2015, 2016). Building on this literature, we test the existence of spillover effects of Internet adoption on African firm sales, productivity, exports, and employment.

It is indeed of great interest to separate the effect of firm's individual decision to use email and website from the spillover effect of the industry and location-level diffusion of these technologies. To test the existence of industry and spatial spillovers, we build on Paunov and Rollo (2015, 2016) to construct variables of industry-level and geographic-level incidence of email and website adoption. To do this, we compute for each survey-round the average email and website adoption rate at the country-industry and location levels:

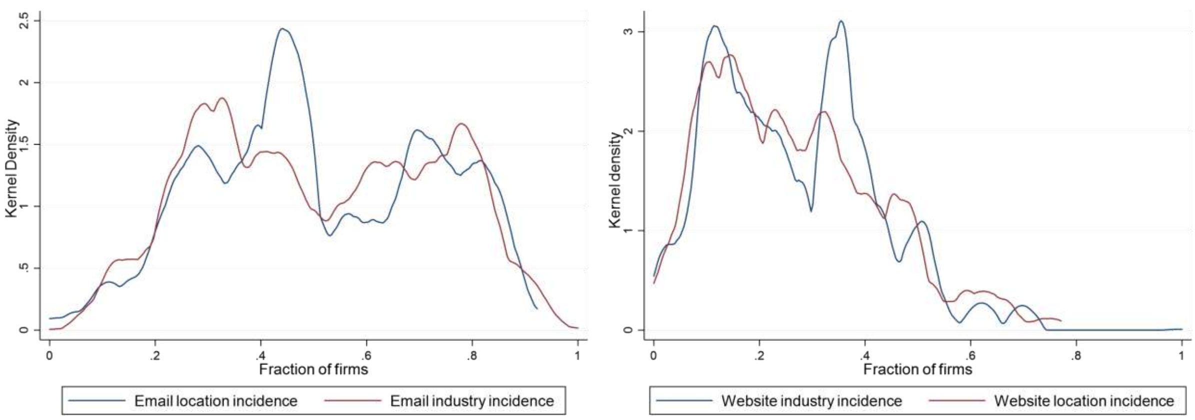
- Email industry spillovers: $\overline{Email_{i,j,k}} = \frac{1}{N_k - 1}\left(\sum_{f \in k} Email_{f,k} - Email_{i,k}\right) \forall k \in K, i \neq f$ (3a)
- Email location spillovers: $\overline{Email_{i,j,l}} = \frac{1}{N_l - 1}\left(\sum_{f \in l} Email_{f,l} - Email_{i,l}\right) \forall l \in L, i \neq f$ (3b)
- Website industry spillovers: $\overline{Website_{i,j,k}} = \frac{1}{N_k - 1}\left(\sum_{f \in k} Website_{f,k} - Website_{i,k}\right) \forall k \in K, i \neq f$ (3c)
- Website location spillovers: $\overline{Website_{i,j,l}} = \frac{1}{N_l - 1}\left(\sum_{f \in l} Website_{f,l} - Website_{i,l}\right) \forall l \in L, i \neq f$ (3d)

Where K and L respectively refer to the sets of industries and locations in the sample where firm i operates, and N_k and N_l refer to the respective number of firms in each industry k and location l. Following Paunov and Rollo (2015, 2016), these incidence variables are computed excluding firm i's own technology adoption.[28] Therefore, these spillover variables reflect the effect of a higher or lower diffusion of digital technologies, irrespective of firm *i*'s technology adoption.

Figure 23 below plots the kernel density distributions of spillover variables by technology types. It appears that the distribution of email incidence (Figure 23a), whether at the location or industry levels, is more uniform than that of website incidence (Figure 23b), suggesting a greater variability of email technology incidence compared to website technology incidence across locations and industries.

FIGURE 23. KERNEL DENSITIES OF DIGITAL TECHNOLOGY SPATIAL AND INDUSTRY INCIDENCE

a. Email incidence b. Website incidence



Source: Authors.

Email and website spillover variables are separately included in Equation (1) as described in Equations (4a) and (4b). Equation (4a) is estimated to measure the industry spillover effects:

$$Y_{i,j,k,l,t} = \alpha_0 + \alpha_1 email_{i,j,k,l,t} + \alpha_2 website_{i,j,k,l,t} + \alpha_3 \overline{Internet_{\iota,j,k,t}} + \alpha_4 X_{i,j,k,l,t} + d_{j,k} + d_{j,l,t} + \varepsilon_{i,j,k,l,t} \qquad (4a)$$

While Equation (5b) is estimated to measure the spatial spillover effects:

$$Y_{i,j,k,l,t} = \beta_0 + \beta_1 email_{i,j,k,l,t} + \beta_2 website_{i,j,k,l,t} + \beta_3 \overline{Internet_{\iota,j,l,t}} + \beta_4 X_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,k,l,t} \qquad (4b)$$

Where the term *Internet* refers the alternative inclusion of email or website spillover variables. Each equation includes the same set of controls as in Equation (1), with the exception that $d_{j,k,t}$ dummies are replaced by industry dummies, $d_{j,k}$, in Equation (4a) and that $d_{j,l,t}$ dummies are replaced by location dummies, $d_{j,l}$, in eq.(4b). This difference in the calibration of the set of dummies between eq. (4a) and (4b) is justified by the need to exploit temporal variability in spillover variables. Moreover, standard errors are clustered at the country-industry-year level when investigating the industry spillovers, while they are clustered at the location-year level when we investigate the location spillovers. We therefore adapt the econometric framework to the type of spillovers emphasized.

Following Paunov and Rollo (2015, 2016), we assume in this subsection that relationships between spillover variables and firm performance are not subject to endogeneity, contrary to individual adoption variables. First, because firm *i*'s own use of email or website technology is excluded from the industry or location averages calculations, the resulting spillover variables are assumed to be unaffected by potential reverse causality from firm *i*'s performance to technology diffusion in the industry or firm location. Second, using an aggregate measure of technology diffusion limits the risk of measurement error. And third, as mentioned before, fixed effects included in Equation (5ab) control for a wide range of unobserved determinants of firm performance, which strongly reduces the risk of omitted variable bias. This exogeneity assumption is next relaxed in section 4.3.

[28] These variables therefore exhibit firm-level variability.

Industry spillovers

Estimations of Equation (4a) using the four main dependent variables are reported in the Table 10 below. They support the existence of important industry-level spillover effects of email and website diffusion on firm sales, sales per worker, exports (only for website diffusion) and employment. Industry-level spillover effects of email and website diffusion on firm sales and sales per worker are of similar magnitude, revealing that a 10 percentage point increase in the diffusion of these technologies at the industry level leads to a 14-15 percentage point increase in the firm's annual sales, and to an approximate 9 percentage point increase in sales per worker. The incidence of website use is found to create greater job spillovers than does email use incidence, since according to our estimates, a 10 percentage point increase in this technology diffusion leads to a 6.8 percentage point increase in total firm workforce, compared to a 4.7 percentage point increase for email technology. The industry diffusion of both technologies is found to significantly increase the number of permanent workers (columns (11)-(12)). Regarding exports, website diffusion is found to have very large spillover effects on exports, as a 10 percentage point increase in an industry's website use incidence leads to a 37 percentage point increase in direct and indirect export proceeds, confirming previous evidence on the strong and positive association between website adoption and export performance.

TABLE 10. INDUSTRY SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION (1/2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var (ln):	Total sales (USD)		Total sales / worker		Exports (USD)		# of workers	
Firm use								
Email	0.708***	0.708***	0.450***	0.450***	0.740***	0.732***	0.225***	0.225***
	(0.0695)	(0.0702)	(0.051)	(0.052)	(0.123)	(0.125)	(0.0336)	(0.0337)
Website	0.492***	0.496***	0.240***	0.243***	1.513***	1.524***	0.226***	0.229***
	(0.0535)	(0.0541)	(0.047)	(0.047)	(0.363)	(0.359)	(0.0193)	(0.0194)
Industry %								
Email incidence	1.436***		0.921***		1.502		0.466***	
	(0.325)		(0.320)		(1.104)		(0.110)	
Website incidence		1.470***		0.861**		3.661***		0.676***
		(0.476)		(0.416)		(1.143)		(0.169)
N	14,776	14,776	14,720	14,720	14,858	14,858	16,505	16,505
R^2	0.735	0.735	0.725	0.725	0.173	0.173	0.596	0.596

TABLE 10. INDUSTRY SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION (2/2)

	(9)	(10)	(11)	(12)
Dep. var (ln):	# temp. workers		# perm. workers	
Firm use				
Email	0.214***	0.213***	0.215***	0.214***
	(0.0207)	(0.0207)	(0.0347)	(0.0347)
Website	0.148***	0.150***	0.221***	0.223***
	(0.0308)	(0.0306)	(0.0213)	(0.0215)
Industry %				
Email incidence	0.241		0.490***	
	(0.181)		(0.125)	
Website incidence		0.423*		0.599***
		(0.238)		(0.169)
N	15994	15994	16505	16505
R^2	0.147	0.147	0.608	0.608

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls not reported in the table.

Estimations of equation (4a) using the four previously defined manufacturer employment variables, reported in the Table 11, support industrial spillovers of digital technology adoption on the production workforce size of manufacturing firms. According to our estimates, a 10 percentage point increase in email and website use incidence leads to 4.5 and 6.4 percentage point increases in the number of production workers, respectively. These results tend to temper concerns regarding skill-biased technological change in Africa by showing that for manufacturers, production workers, who are generally associated with lower skill level than non-production workers, benefit more from digital technology diffusion than non-production workers.

TABLE 11. INDUSTRIAL SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION ON MANUFACTURER WORKFORCE

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var (ln):	# perm. prod. workers		# perm. non prod. workers		# perm. skilled prod. workers		# perm. unskilled prod. workers	
Firm use								
Email	0.271^{***}	0.270^{***}	0.292^{***}	0.292^{***}	0.226^{***}	0.226^{***}	0.372^{***}	0.371^{***}
	(0.0142)	(0.0145)	(0.0254)	(0.0256)	(0.0172)	(0.0175)	(0.0383)	(0.0387)
Website	0.164^{***}	0.165^{***}	0.237^{***}	0.237^{***}	0.154^{***}	0.154^{***}	0.0205	0.0216
	(0.0184)	(0.0181)	(0.0181)	(0.0181)	(0.0227)	(0.0225)	(0.0239)	(0.0239)
Industry %								
Email	0.452^{**}		0.0607		0.345		0.0621	
	(0.210)		(0.144)		(0.249)		(0.285)	
Website		0.639^{*}		-0.184		0.275		0.567
		(0.327)		(0.221)		(0.385)		(0.448)
N	7,737	7,737	7,706	7,706	7,640	7,640	7,611	7,611
R^2	0.621	0.621	0.580	0.580	0.428	0.427	0.386	0.386

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls not reported in the table.

Spatial spillovers

Estimations of equation (4b) using the four main outcome variables are reported in the Table 12 below, and the results stress less clear-cut evidence on the spatial spillovers of digital technology diffusion. First, they support the existence of a positive effect of email spatial diffusion on sales per workers and of website spatial diffusion on both firm sales and sales per workers. By contrast, a negative spatial spillover effect of email on exports, significant at the 10% level, is found in column (5), which can be explained by the higher competition on foreign markets from other firms located in the same place that adopted email use. Negative spatial spillovers of website diffusion on the firm's workforce size are also evidenced in column (8). This decrease in the total workforce seems to be explained by the reduction of the number of temporary workers (column (9)). These negative spillovers may result from the risk of higher competition on foreign markets as previously mentioned, but can also be explained by the decline of "old industries" made obsolete by Internet technologies or unable to take the path of digitalisation. Overall, this evidence contrasts with the evidence of positive spatial spillover effects of Internet technology diffusion among large firms reported in Appendix B, which are more geographically mobile (Dollar et al., 2006ab) and can probably better exploit agglomeration economies.

TABLE 12. SPATIAL SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION (1/2)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var (ln):	Total sales (USD)		Total sales / worker		Exports (USD)		# of workers	
Firm use								
Email	0.702^{***}	0.699^{***}	0.447^{***}	0.443^{***}	0.701^{***}	0.707^{***}	0.223^{***}	0.223^{***}
	(0.059)	(0.059)	(0.053)	(0.053)	(0.141)	(0.143)	(0.0181)	(0.0182)
Website	0.498^{***}	0.503^{***}	0.247^{***}	0.254^{***}	1.527^{***}	1.537^{***}	0.227^{***}	0.226^{***}
	(0.0496)	(0.0503)	(0.051)	(0.052)	(0.305)	(0.303)	(0.0215)	(0.0214)
Location %								
Email incidence	0.844		1.074^{*}		-2.503^{*}		-0.0529	
	(0.618)		(0.058)		(1.332)		(0.110)	
Website incidence		1.107^{**}		1.533^{***}		2.394		-0.249^{*}
		(0.499)		(0.464)		(1.938)		(0.128)
N	14,818	14,818	14,762	14,762	14,901	14,901	16,548	16,548
R^2	0.743	0.743	0.727	0.731	0.180	0.180	0.606	0.606

TABLE 12. SPATIAL SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION (2/2)

	(9)	(10)	(11)	(12)
Dep. var (ln):	# temp. workers		# perm. workers	
Firm use				
Email	0.210***	0.212***	0.213***	0.213***
	(0.0422)	(0.0427)	(0.0186)	(0.0187)
Website	0.145**	0.141**	0.222***	0.222***
	(0.0697)	(0.0708)	(0.0214)	(0.0213)
Location %				
Email	-0.430		0.0441	
	(0.321)		(0.125)	
Website		-0.865**		-0.0762
		(0.377)		(0.155)
N	16,037	16,037	16,548	16,548
R^2	0.155	0.155	0.614	0.614

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ *dummies* are replaced by location dummies, $d_{j,l}$.

This explanation might be particularly relevant for the retail industry whose digitization process, culminating in the e-commerce industry's expansion, may have outperformed brick-and-mortar retail stores, or have led to the destruction of jobs related to the management and handling of customers/suppliers relationships. To test this possible explanation, we introduce in equation (4b) an interaction term between the location website incidence variable and a dummy variable equal to one if the firm operates in the retail industry:

$$Y_{i,j,t} = \beta_0 + \beta_1 email_{i,j,t} + \beta_3 website_{i,j,t} + \beta_3 \overline{Website_{\iota,J,l,t}} + \beta_4 \overline{Website_{\iota,J,l,t}} \times retail_{j,k,t}$$

$$+\beta_5 X_{i,j,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,t} \quad (4c)$$

Estimations of equation (4c) are conducted using employment outcomes as dependent variables and are reported in Table 13 below. Results support the hypothesis of job destruction in the retail industry induced by the spatial diffusion of website, as evidenced by the negative effect of website location incidence on total, temporary and permanent jobs in the retail industry. However, operating in the retail industry cannot fully explain the loss of temporary jobs induced by website spatial diffusion, which might not be specific to one industry.

TABLE 13. SPATIAL EMPLOYMENT SPILLOVERS OF INTERNET TECHNOLOGY DIFFUSION IN THE RETAIL INDUSTRY

	(1)	(2)	(3)
Dep. Var (ln):	# of workers	# temp. workers	# perm. workers
Firm use			
Email use	0.222***	0.210***	0.212***
	(0.0186)	(0.0433)	(0.0192)
Website use	0.226***	0.141**	0.222***
	(0.0215)	(0.0705)	(0.0215)
Location %			
Website incidence	-0.206	-0.782*	-0.0343
	(0.126)	(0.406)	(0.145)
Website incidence x retail	-0.290**	-0.490*	-0.285**
	(0.147)	(0.283)	(0.128)
N	16,548	16,037	16,548
R^2	0.607	0.156	0.614

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ dummies are replaced by country-location dummies, $d_{j,l}$.

Thresholds in spillover effects

A critical mass of Internet users in a given location or industry might be necessary for network effects, knowledge spillovers, and related agglomeration economies to yield the expected dividends for SMEs (Grace et al, 2004). By contrast, below a certain rate of technology diffusion within industries, first movers on the new technology may capture the market share of less productive competitors or use their market power to impose barriers to new entrants. Within locations, the technology introduction may increase the profitability of ICT-intensive industries at the expense of less ICT-intensive industries, with possible adverse consequences on local productive capacity and on the labour market (WDR, 2019; Choi et al., 2020). Marsh et al. (2017) point to the possibility of threshold spillover effects induced by the delayed diffusion of digital technologies within industries, arguing that it takes time for a technology to be widespread and fully exploited within a given industry.

As a result, negative spillovers may prevail below a given threshold of industry or location technology use incidence, when the diffusion of digital technologies benefits a limited number of firms; while positive spillovers may prevail above this threshold when digital technologies are ubiquitous. As such, because of the large (spatial) digital divide prevailing in SSA[29], it is therefore of great interest to test the existence of possible U-shaped spillover effects in Internet technology diffusion, and to identify the threshold beyond which the positive externalities of these technologies are at play.

First, to test the presence of thresholds in digital technology spillovers, we add to Equations (4a) and (4b) the quadratic term of the industry and location spillover variables:

$$Y_{i,j,k,l,t} = \alpha_0 + \alpha_1 email_{i,j,k,l,t} + \alpha_2 website_{i,j,k,l,t} + \alpha_3 \overline{Internet_{i,j,k,t}} + \alpha_4 \left(\overline{Internet_{i,j,k,t}}\right)^2 + \alpha_5 X_{i,j,k,l,t} + d_{j,k} + d_{j,l,t} + \varepsilon_{i,j,k,l,t} \quad (5a)$$

$$Y_{i,j,k,l,t} = \beta_0 + \beta_1 email_{i,j,k,l,t} + \beta_2 website_{i,j,k,l,t} + \beta_3 \overline{Internet_{\iota,j,l,t}} + \beta_4 \left(\overline{Internet_{i,j,k,t}}\right)^2 + \beta_5 X_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,k,l,t} \quad (5b)$$

Where the term *Internet* refers the alternative inclusion of email or website spillover variables. Only significant estimates of nonlinear industry spillovers are reported in Table 14. They stress a significant U-shaped effect of email industry incidence on exports (columns (1) and (2)). In fact, an increased incidence of email users has a significant negative effect on firm-level sales below a threshold estimated to be a 48% email adoption rate for a given industry, and a positive significant and same-magnitude effect beyond this threshold.[30] A positive industrial spillover effect of website diffusion on exports is also evidenced above a threshold estimated to be a 9% website adoption rate for a given industry. This U-shaped industry spillover may result from the advantage taken by first-movers on Internet technologies over their competitors on foreign markets, at low levels of Internet use incidence in the industry. However, when digital technologies are widely disseminated within industries, positive spillovers, induced by forces such as network effects or knowledge spillovers, may prevail over the competition effect.

Regarding employment spillovers, a positive but 10%-significant effect of email incidence on permanent workers is also evidenced above an email adoption incidence rate of 12% in industries (column (3)). Looking further at employment outcomes among manufacturers, the estimates in columns (5) to (8) also support the existence of U-shaped industry spillovers on permanent production workers, particularly on the skilled production workforce. Below respective thresholds of 33% and 37%, a 10 percentage point increase in email industry incidence is found to reduce by 11-12% the production and the skilled production workforces. Above these thresholds, an increase of equal magnitude in email industry

[29] See Companion report 1, Section 2.

[30] The samples are relatively well balanced below/beyond estimated thresholds. See also Figure 22a.

incidence raises by 16-17% the size of these two workforce groups. Large positive industry spillover effects of website incidence on these specific workforce groups are also evidenced, as a 10% percent increase in website adoption rate is found to raise by 20% and 25% the size of the production and skilled production workforce above a website adoption threshold of 11% and 21%, respectively. Therefore, the positive industry spillover effects of technology adoption on the size of manufacturing industry's skilled workforces are found to be conditional on industry level diffusion of email.

Next, we proceed with the same analysis applied to spatial, i.e. location-level, spillovers. Table 15 reports significant estimates of Equation (5b) supporting the existence of threshold spillover effects of email spatial diffusion on sales and labour productivity, only. Regarding firm-level sales, a 10 percentage point increase in the location penetration of emails increases the firm's annual sales by 64% above an incidence threshold of 47%. Moreover, below the same threshold, a 10 percentage point increase in the penetration of emails reduces by 77% firm's annual sales per worker, while raising them by 81% above it. We do not find evidence of nonlinear spillover effects of email and website incidence on exports and workforces' size.

TABLE 14. INDUSTRY SPILLOVERS: NONLINEAR EFFECTS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var (ln):	Exports (USD)		# perm. workers		# perm. prod. workers		# perm. skilled prod. workers	
Email use	0.724***	0.740***	0.214***	0.214***	0.271***	0.269***	0.226***	0.225***
	(0.127)	(0.129)	(0.035)	(0.035)	(0.0149)	(0.015)	(0.0181)	(0.0177)
Website use	1.516***	1.515***	0.221***	0.223***	0.164***	0.167***	0.154***	0.156***
	(0.363)	(0.364)	(0.021)	(0.021)	(0.0183)	(0.018)	(0.0226)	(0.0225)
Industry %								
Email	-8.887***		-0.132		-1.077**		-1.225**	
	(3.039)		(0.344)		(0.418)		(0.515)	
Email^2	9.141***		0.544*		1.615***		1.664***	
	(2.223)		(0.318)		(0.440)		(0.534)	
Website		-1.778		0.138		-0.438		-1.054
		(2.797)		(0.349)		(0.552)		(0.641)
Website ^2		9.307**		0.719		2.018**		2.493**
		(4.056)		(0.542)		(0.982)		(1.154)
Threshold	48%	9%	12%	-	33%	11%	37%	21%
N	14,858	14,858	16,505	16,505	6,717	6,717	6,629	6,629
R^2	0.175	0.174	0.608	0.608	0.552	0.551	0.317	0.316

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,k,t}$ dummies are replaced by industry dummies, $d_{j,k}$.

TABLE 15. SPATIAL SPILLOVERS: NONLINEAR EFFECTS

	(1)	(2)	(3)	(4)
Dep. var (ln):	Real annual sales (USD)		Real annual sales / worker	
Email use	0.706***	0.699***	0.453***	0.443***
	(0.0583)	(0.0589)	(0.052)	(0.053)
Website use	0.499***	0.504***	0.248***	0.255***
	(0.0499)	(0.0512)	(0.052)	(0.053)
Location %				
Email	-6.082		-7.674**	
	(3.708)		(3.283)	
Email^2	6.396**		8.078***	
	(3.119)		(2.773)	
Website		0.757		1.161
		(2.709)		(2.591)
Website ^2		0.394		0.642
		(4.577)		(4.305)
Threshold	47%	-	47%	-
N	14,818	14,818	14,762	14,762
R^2	0.743	0.743	0.727	0.727

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ dummies are replaced by location dummies, $d_{j,l}$..

In a nutshell #6: Internet technologies spillovers

- Evidence of positive industry spillovers of email and website diffusion on main firm outcome variables.
- Evidence of U-shaped industry spillovers of Internet technologies diffusion on exports, and on the permanent production workforce, in particular its skilled components.
- Positive spatial spillovers of email and website use on sales and sales per worker. Evidence of U-shaped spatial spillovers of email use incidence on sales and sales per worker.
- Negative spatial spillovers of website use incidence on employment. These negative spatial are partly transmitted through the retail industry, which might be particularly challenged by the structural transformations induced by the spatial diffusion of digital technologies.
- In short, positive industry and spatial spillovers on firm-level outcomes are found to exist above a certain threshold of Internet technology diffusion, suggesting that Internet technologies must reach a critical mass of users within industries and locations in order to generate positive externalities. This evidence suggests that policies aimed at spurring Internet technology diffusion could be a powerful lever for firm development.

4.2.4 Mobile money and SME performance

In this last subsection, we analyse the specific contribution of a digital technology called upon to play a critical role in SSA private sector development: mobile money. The following analysis is conducted on a smaller sample of SMEs interviewed in recent survey rounds, which include a module on mobile money (MM) adoption by firms.

Evidence of MM adoption on SME performance

To conduct this analysis, we add to Equation (1) a binary variable indicating whether the firm reported using MM for its operations, keeping the vector of control variables unchanged and using the same dependent variables:

$$Y_{i,j,k,l,t} = \beta_0 + \beta_1 email_{i,j,k,l,t} + \beta_2 website_{i,j,k,l,t} + \beta_3 mobile\ money_{i,j,k,l,t} + \beta_4 X_{i,j,k,l,t} + d_{j,k,t} + d_{j,l,t} + \epsilon_{i,j,k,l,t} \quad (6)$$

Including this additional variable of interest results in significant sample attrition, restricting the sample to some 3,000 SMEs located in 14 countries[31], surveyed between 2013 and 2018. Results are reported in Table 16. They show that MM adoption is significantly associated with higher direct and indirect exports, positively correlated with the number of temporary workers, and negatively correlated with the number of permanent workers. To further the MM-export nexus, we report in Table 17 logit estimations of the probability of exporting using the whole sample of SMEs (column (1)), which is also split between small firms (column (2)) and medium firms (column (3)). Result stress that using MM is associated with a higher probability of exporting. In fact, firms using mobile money have a 4.8% higher probability of exporting. This relationship is found to be driven by small firms only (column (2)). In column (4), we re-estimate the relationship between MM adoption and total exports, restricting the sample to exporters only, and find that the resulting estimated relationship is significant but negative, suggesting that MM is instrumental to small firms involved in small export transactions.

[31] Côte d'Ivoire, Cameroon, Ghana, Guinea, Kenya, Liberia, Mali, Niger, Sierra Leone, Chad, Togo, Tanzania, Uganda, Zambia. See Appendix A.3.

TABLE 16. MOBILE MONEY ADOPTION AND FIRM PERFORMANCE

Dep. Var (ln):	(1) Sales (USD)	(2) Sales / worker	(3) Dir. & indir. exports	(4) # workers	(5) # temp. workers	(6) # perm. workers
Email use	1.006***	0.695***	0.026	0.185***	0.163**	0.179***
	(0.233)	(0.165)	(0.280)	(0.0542)	(0.0677)	(0.0616)
Website use	0.802***	0.484***	2.102***	0.261***	0.138**	0.266***
	(0.221)	(0.164)	(0.670)	(0.0644)	(0.0627)	(0.0633)
Mobile money use	-0.270	-0.130	0.629**	-0.114	0.238**	-0.126**
	(0.220)	(0.139)	(0.249)	(0.0726)	(0.101)	(0.0580)
Control variables						
% of state ownership	0.972	0.738	2.198	0.261	-0.903**	0.342
	(0.814)	(0.505)	(2.330)	(0.276)	(0.340)	(0.280)
% of foreign ownership	0.763**	0.581**	2.426***	0.0844	-0.182	0.0974
	(0.343)	(0.276)	(0.768)	(0.0626)	(0.121)	(0.0651)
% dir. & indir. Exports in sales	0.0104	0.009	-	0.00117	0.00243	0.00103
	(0.0087)	(0.007)	-	(0.0008)	(0.00181)	(0.0008)
Firm's age (ln, years)	-0.0767	-0.136	-0.162	0.0477	-0.0471	0.0537
	(0.253)	(0.223)	(0.509)	(0.050)	(0.0344)	(0.0476)
Initial # perm. FT employees (ln)	0.252**	0.0145	0.242	0.261***	0.148***	0.252***
	(0.108)	(0.057)	(0.152)	(0.057)	(0.0405)	(0.056)
Manager experience (ln, years)	0.353	0.289*	0.265	0.0910**	0.0722	0.0863**
	(0.257)	(0.170)	(0.393)	(0.043)	(0.0593)	(0.0400)
Bank loan dummy	0.615***	0.357***	0.691**	0.197***	0.131*	0.194***
	(0.168)	(0.106)	(0.335)	(0.047)	(0.0764)	(0.0465)
Elec. outages losses (% annual sales)	-0.0206***	-0.0165***	-0.001	-0.0028**	0.000247	-0.00334**
	(0.003)	(0.0031)	(0.010)	(0.001)	(0.00261)	(0.00134)
Insecurity losses (% annual sales)	-0.0187***	-0.0211***	-	0.0024	0.00857*	0.00117
	(0.007)	(0.006)	-	(0.002)	(0.00490)	(0.0020)
Obstacle informal competitor	-	-	-0.377	-	-	-
	-	-	(0.262)	-	-	-
N	2,879	2,854	2,920	3,390	3,221	3,390
R^2	0.774	0.783	0.208	0.339	0.178	0.345

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

TABLE 17. MOBILE MONEY ADOPTION AND FIRM EXPORTS, BY FIRM SIZE.

Dep var.	(1)	(2) Exporter (0/1)	(3)	(4) Dir. & indir. Exports among exporters
	SMEs	Small firms	Medium firms	
Email use	0.019	0.001	0.058	0.531
	(0.023)	(0.029)	(0.043)	(0.498)
Website use	0.121***	0.113***	0.115***	0.797
	(0.036)	(0.038)	(0.039)	(0.482)
Mobile money use	0.048**	0.051**	0.037	-0.569*
	(0.021)	(0.020)	(0.047)	(0.284)
N	3,500	2,330	1,079	548
(Pseudo)R^2	(0.205)	(0.210)	(0.306)	0.695

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The exporter variable equals 1 if the firm has exported directly or indirectly at least 10% of its total sales. In columns (1) to (3), Logit estimations of Equation (6) are conducted and marginal effects are reported. Controls ($X_{i,j,t}$, $d_{j,k,t}$; $d_{j,l,t}$) are included in the regressions but not reported in the table.

Spillover effects of mobile money

Next, we proceed with an analysis of spillover effects of MM adoption on firm-level performance, using the same methodolo gy as described in subsection 4.2.3. We first compute the variable of MM incidence at the industry and location levels as follows:

- MM industry spillovers: $\overline{MM_{\iota,J,k}} = \frac{1}{N_k - 1}\left(\sum_{f \in k} MM_{f,k} - MM_{i,k}\right) \forall k \in K, i \neq f$ (7a)

- MM spatial spillovers: $\overline{MM_{i,j,l}} = \frac{1}{N_l - 1}\left(\sum_{f \in l} MM_{f,l} - MM_{i,l}\right) \forall l \in L, i \neq f$ (7b)

Where *K* and *L* respectively refer to the sets of industries and locations in the sample where firm *i* operates, and N_k and N_l the respective number of firms in each industry *k* and location *l* at the survey time *t*. We then include separately each incidence variable in Equation (6) to estimate the industry and spatial spillover effects of MM adoption, respectively:

$$Y_{i,j,t} = \alpha_0 + \alpha_1 email_{i,j,k,l,t} + \alpha_2 website_{i,jk,l,t} + \alpha_3 MM_{i,j,k,l,t} + \alpha_4 \overline{MM_{i,j,k,t}} + \alpha_5 X_{i,j,k,l,t} + d_k + d_{j,l,k,l,t} + \varepsilon_{i,j,k,l,t} \quad (8a)$$

$$Y_{i,j,t} = \beta_0 + \beta_1 email_{i,j,k,l,t} + \beta_3 website_{i,j,k,l,t} + \alpha_3 MM_{i,j,k,l,t} + \beta_4 \overline{MM_{i,j,l,t}} + \beta_5 X_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,k,l,t} \quad (8b)$$

Tables 18 and 19 report estimates of Equations (9a) and (9b), respectively. Results in Table 18 support the existence of negative industry spillovers of MM adoption on total sales and sales per worker. In Table 18, estimates in column (4) point to a negative spatial spillover on the total workforce and the permanent workforce. One explanation for this result is that the digitization of financial transactions could have led to increased competition between SMEs, permanent job destruction (column (6)), by for instance spurring the development of e-commerce (Kabanda & Brown, 2017) at the expense of the traditional retail sector (Choi et al, 2020).

To check this hypothesis, we include in equation (9b), an interaction term between the spatial spillover variable and a dummy variable equal to one if the firm operates in the retail industry ($Retail_{i,j,t}$):

$$Y_{i,j,t} = \beta_0 + \beta_1 email_{i,j,t} + \beta_3 website_{i,j,t} + \alpha_3 MM_{i,j,t} + \beta_4 \overline{MM_{i,j,l,t}} + \beta_6 \overline{MM_{i,j,l,t}} \times Retail_{j,k,t} + \beta_6 X_{i,j,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,t} \quad (8c)$$

Results are reported in Table 20 and tend to support this hypothesis since the interaction term is found to drive the former negative spatial spillovers on permanent jobs. Therefore, in the same way as with the diffusion of website (Table 13), the negative spatial spillovers of MM on employment are specific to the retail industry, and could possibly be explained by the expansion of digital marketplaces induced by the diffusion of digital payment facilities (Kabanda & Brown, 2017).

TABLE 18. INDUSTRY SPILLOVERS OF MOBILE MONEY DIFFUSION

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var (ln):	**Sales (USD)**	**Sales / worker**	**Dir. & indir. exports**	**# workers**	**# temp. work.**	**# perm. work.**
Email use	1.020***	0.713***	0.0331	0.185***	0.179**	0.178***
	(0.216)	(0.165)	(0.275)	(0.0551)	(0.0667)	(0.0619)
Website use	0.809***	0.490***	2.053***	0.264***	0.121*	0.269***
	(0.221)	(0.159)	(0.653)	(0.0636)	(0.0625)	(0.0623)
Mobile money use	-0.325*	-0.171	0.495*	-0.118*	0.275**	-0.133**
	(0.189)	(0.136)	(0.259)	(0.0704)	(0.106)	(0.0562)
Industry %						
Mobile money	-3.410*	-3.076*	-0.623	-0.0177	1.663	-0.158
	(1.807)	(1.649)	(4.854)	(0.429)	(1.410)	(0.411)
N	2873	2848	2914	3384	3215	3384
R^2	0.769	0.780	0.201	0.323	0.139	0.330

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-industry. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,k,t}$ dummies are replaced by industry dummies, $d_{j,k}$.

TABLE 19. SPATIAL SPILLOVERS OF MOBILE MONEY DIFFUSION

Dep. Var (ln):	(1) Sales (USD)	(2) Sales / worker	(3) Dir. & indir. exports	(4) # workers	(5) # temp. work.	(6) # perm. work.
Email use	1.002***	0.692***	0.0361	0.186***	0.164**	0.179***
	(0.230)	(0.190)	(0.220)	(0.0530)	(0.0620)	(0.0515)
Website use	0.807***	0.487***	2.096***	0.261***	0.137*	0.266***
	(0.221)	(0.163)	(0.744)	(0.0470)	(0.0761)	(0.0465)
Mobile money use	-0.451	-0.218	0.905*	-0.175***	0.163*	-0.167***
	(0.307)	(0.233)	(0.455)	(0.0578)	(0.0948)	(0.0476)
Location %						
Mobile money	-28.38	-13.65	43.20	-9.906*	-12.06	-6.538*
	(20.62)	(15.30)	(29.45)	(5.135)	(12.92)	(3.888)
N	2879	2854	2920	3390	3221	3390
R^2	0.774	0.783	0.231	0.340	0.179	0.345

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ dummies are replaced by location dummies, $d_{j,l}$.

TABLE 20. SPATIAL SPILLOVERS OF MOBILE MONEY DIFFUSION IN THE RETAIL INDUSTRY

Dep. Var (ln):	(1) Sales (USD)	(2) Sales / worker	(3) Dir. & indir. exports	(4) # workers	(5) # temp. work.	(6) # perm. work.
Email use	1.002***	0.715***	0.0372	0.189***	0.163**	0.182***
	(0.230)	(0.195)	(0.219)	(0.0534)	(0.0623)	(0.0519)
Website use	0.807***	0.478***	2.100***	0.262***	0.137*	0.268***
	(0.222)	(0.162)	(0.745)	(0.0453)	(0.0761)	(0.0446)
Mobile money use	-0.451	-0.208	0.913*	-0.171***	0.162*	-0.162***
	(0.306)	(0.240)	(0.453)	(0.0576)	(0.0940)	(0.0471)
Location %						
Mobile money	-28.08	-16.35	47.09	-7.761	-12.41	-4.248
	(20.48)	(15.90)	(29.48)	(5.310)	(12.98)	(3.967)
MM incidence x retail	-0.248	1.088*	-3.317	-1.641**	0.272	-1.751***
	(0.562)	(0.562)	(2.372)	(0.605)	(0.610)	(0.602)
N	2879	2854	2920	3390	3221	3390
R^2	0.774	0.789	0.231	0.347	0.179	0.354

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ dummies are replaced by country-location dummies, $d_{j,l}$.

In a nutshell #7: Mobile money and SME performance

- MM adoption is associated with higher exports in general and with a higher probability of exporting. However, exporters using MM are generally involved in smaller-size export transactions.
- MM adoption is positively correlated with a firm's temporary workforce size and negatively with the permanent workforce size. MM adoption could therefore favour precarious job positions.
- Evidence of negative industry spillovers of MM diffusion on firm-level sales and sales per worker.
- Evidence of negative spatial spillovers of MM diffusion on a firm's workforce size, explained by a decrease in the number of permanent workers.
- This negative spatial spillovers on employment seems to be explained by the deterrent effect of this technology on permanent jobs in the retail industry.

4.3 The causal effects of email use on SME performance

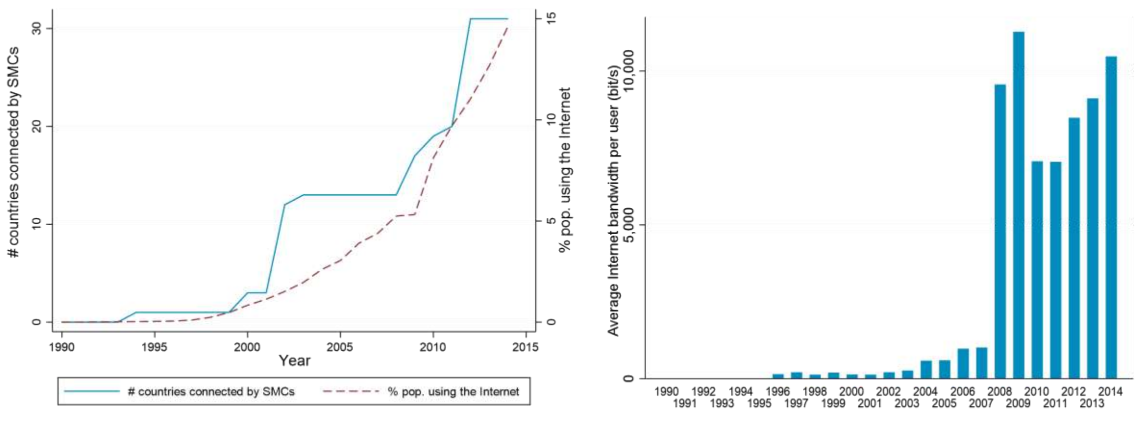
The relationship between Internet adoption and firm-level outcomes is bidirectional, so the decision to adopt and use Internet during operations may be both the consequence and the cause of firm performance. These simultaneous relationships hold at the firm level, but probably also exist at more aggregated level of economic activity, such as the industry or the location where firms operate. In fact, a firm's decision to adopt a new technology is cross-correlated, so that the industry or spatial incidence of email or website adoption may be caused by individual behaviours of leading firms or first-movers, which could exert influence on other firms' decisions with whom they interact (Galliano & Roux, 2008). As a result, previous estimates could be biased by this reverse causality mechanism.

The identification strategy implemented in this subsection follows the instrumental variable (IV) approach similar to IMF (2020) and Cariolle et al. (2019). It exploits exogenous variations in international Internet connectivity, induced by the staggered laying of submarine telecommunications cables (SMCs) and their exposure to external shocks, and amplified by the firm's distance to terrestrial connectivity infrastructures (Grubesic & Murray, 2006; Grubesic et al., 2003).

4.3.1 Identification strategy

ICTs are network goods (Katz & Shapiro, 1985; Crémer et al., 2000; Bjorkegren, 2019) whose economic impacts grow stronger with increasing size and capacity of the worldwide telecommunications network. Submarine telecommunications cables (SMCs) are the central element of the worldwide telecommunications network, and exponential laying of cables over time increased the worldwide network's size, capacity, and redundancy[32]. This process has not excluded Sub-Saharan Africa (Cariolle, 2020b), as highlighted in Figure 24, which plots the coevolution of key connectivity indicators: the region's Internet penetration rate, the cumulative number of deployed SMCs, and the average international Internet bandwidth per user. These variables give a striking idea of the dramatic increase in African Internet connectivity that followed the laying of SMCs along African coasts (Cariolle, 2020b).

FIGURE 24. INTERNATIONAL CONNECTIVITY AND INTERNET PENETRATION IN SSA.



Source: Cariolle (2020b), data from ITU (2019) Telegeography's submarine cable map. Sample: 49 African countries.

The SMC network, the world connectivity's cornerstone, has considerably densified during recent decades, facilitating Internet communications and spurring related digital technologies. International connectivity can therefore be expressed as a positive function of the SMC **network** size, its **capacity** to carry telecommunications traffic, and its **stability**.

[32] Redundancy refers to the ability to maintain a capacity for telecommunications when a shock affects the infrastructure by rerouting telecommunications traffic toward alternative paths.

SMCs can affect Internet connectivity for firms in two ways. First, their laying along the coastlines of African countries increases their aggregate telecommunications capacity and network size. This laying can be considered as exogenous to firm performance inasmuch we control for the aggregate determinants of SMC laying. Second, the exposure to SMC outages, caused by humans (sabotage), maritime activities (anchors and fishing nets) or natural hazards (seaquakes, turbidity currents), is also an exogenous source of variation in Internet connectivity for firms, by reducing the telecommunications network capacity and stability (Carter et al., 2009; Carter, 2014; Pope et al., 2017). In addition to the economic and welfare costs related to telecommunication shutdowns, SMC outages induce expensive repairs, higher insurance costs, and costs to related to the rerouting of Internet traffic towards more expensive and lower-capacity cable paths, which affects Internet access tariffs and services quality (Carter et al., 2009; Carter, 2014; OECD, 2014).[33]

Table 21 below reports the number of SMC faults experienced by several SSA countries over the last six years, as reported on the Internet. This table stresses that some 10 countries have been hit by SMC outages during the last two decades. To complete this shock variable, which might not be fully exhaustive of the stresses experienced by the African SMC network[34], we also computed a shock exposure variable, reflecting the risk for the SMC network of being hit by maritime seismic events. Some African coasts are exposed to seaquakes, which may cause multiple cable breaks, cable erosion, and destabilize the seabed, which in turn increases the likelihood of future cable faults (Carter et al., 2009; Carter, 2014; Pope et al., 2017). Table 22 reports African SMC network exposure to maritime seismic risk (Cariolle et al., 2019), measured by a variable equal to the number of seaquakes located in the vicinity of SMC landing stations over the current and last five years. Central and Eastern Africa's SMC network has been exposed to such shocks over the last two decades.

TABLE 21. CUMULATIVE SUM OF SMC FAULTS OVER THE CURRENT AND LAST FIVE YEARS

Country iso code	WBES survey year	# cable faults over [t ;t-5]
Burundi	2014	1
Benin	2009	1
Kenya	2013	2
	2018	1
Madagascar	2013	1
Mozambique	2018	1
Niger	2009	1
Nigeria	2014	3
Togo	2009	1
	2016	1
Tanzania	2013	2
Zimbabwe	2013	1

Source: Author' calculation.

[33] These costs are amplified by delays necessary for cable repairs (Palmer-Felgate et al., 2013).

[34] Data gathered from the SubTel Forum https://subtelforum.com/category/cable-faults-maintenance/, completed and cross-checked with Internet searches on Google and Twitter using keywords such as "undersea/submarine cable outage/break/fault"

TABLE 22. CUMULATIVE SUM OF SEAQUAKES LOCATED WITHIN 500 KM OF SMCS OVER THE LAST SIX YEARS

Country iso code	WBES survey year	Freq. seaquakes within 500 km rad from SMC landing station over [t;t-5]
AGO	2006	1
COD	2006	1
KEN	2007	1
MDG	2013	1
SDN	2014	4
TZA	2006	3
TZA	2013	4

Source: Cariolle et al. (2019). Data on seismic events is gathered from The Northern California Earthquake Data Center of the University of Berkeley. http://www.ncedc.org/ Only seaquakes above 5 on the Richter scale are considered.

Instrumental variables

An analysis of Internet impacts on firm performance using SMC-related instrumental variables (IV) requires the weighting of these aggregate connectivity shocks by a factor reflecting treatment intensity for observational units. Interestingly, studies have shown that populations remote from the backbone infrastructure often suffer from slow and unstable telecommunications, are the last to benefit from an increase in aggregate telecommunications capacity, and are the first to experience telecommunications disruptions when infrastructural outages occur (Grubesic & Murray, 2006; Buys et al., 2009). Since the WBES dataset includes information on the location of observational units (city or province), we follow an approach similar to Hjort and Pouslen (2019) and Cariolle et al. (2019), and use the firm's location distance to important connectivity infrastructures, i.e. SMC landing stations or Internet Exchange Points[35], as a shock weighting factor.

Combining this distance variable with the three aggregate connectivity shocks identified above provides us with three separate IVs, reflecting local exogenous variations in connectivity. The first IV (IV1), denoted $SMC\_proximity_{l,j,t}$, consists of calculating the ratio of the number of SMCs laid in country j at time t ($SMCnum_{j,t}$) over the firm's location distance to terrestrial connectivity infrastructures ($Distance_{l,j,t}$)[36]:

- **IV1:** $SMC\_proximity_{l,j,t} = SMCnum_{j,t} \times \frac{1}{(1+\ln(1+Distance_{l,j,t}))}$ (9a)

The second IV (IV2) reflects the firm's exposure to SMC faults, denoted $SMC\_faults_{j,l,t}$, consisting of multiplying the same distance variable, $Distance_{l,j,t}$, by the number of SMC outages ($Outages_{j,t}$) experienced by countries over a chosen time window [t; t-k]:

- **IV2:** $SMCfaults_{l,j,t} = Outages_{j,t} \times \left(1 + \ln(1 + Distance_{l,j,t})\right)$ (9b)

The third IV (IV3) reflects the firm's exposure to maritime seismic shocks upon the SMC network, denoted $SMC\_seaquakes_{j,l,t}$, consisting of multiplying the same distance variable, $Distance_{l,j,t}$, by the number of SMC outages ($Seaquakes_{j,t}$) experienced by countries:

[35] IXPs represent key elements of the international connectivity infrastructure and an important source of network efficiency and Internet bandwidth (Weller & Woodcock, 2013; OECD, 2014; Towela & Tesfaye, 2015). IXPs are indeed physical telecommunications hubs favouring direct interconnections between countries and enhancing the telecommunications network efficiency and capacity (Weller & Woodcock, 2013; OECD, 2014).

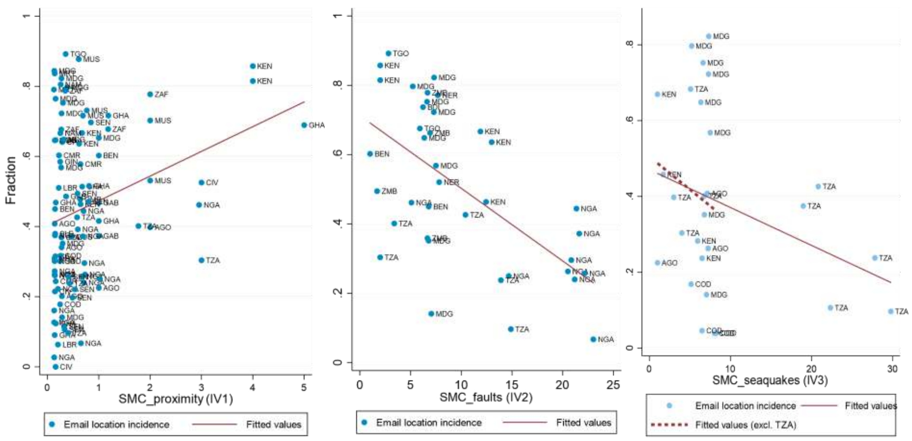
[36] The distance variable is subject to a small transformation to avoid that firms located in place hosting connectivity infrastructures are not associated with a null IV's value but equal to the unweighted aggregate connectivity variables.

- **IV3:** $SMCseaquakes_{l,j,t} = Seaquakes_{j,t} \times \left(1 + \ln(1 + Distance_{l,j,t})\right)$ (9c)

The variable *Seaquakes*$_{j,t}$ is the sum of individual seaquakes that occurred within a 500 km radius from a country's SMC landing station(s) calculated over a chosen time-window [t; t-k].[37]

In Figure 25, we plot the graphical correlation between our three IVs and the incidence of email use at the location level. Moreover, because current and past shocks can have a lagging effect on Internet penetration through a decrease in Internet service quality and an increase in Internet tariffs, shock-based IVs (IV2 and IV3) are calculated using a time window set to [t; t-5]. The figure below highlights, as expected, a strong and positive graphical correlation between IV1 and the incidence of email at the location level, and a strong negative correlation between shock IVs (IV2 or IV3) and email use incidence.

FIGURE 25. GRAPHICAL CORRELATION BETWEEN IVS AND EMAIL DIFFUSION AT THE LOCATION LEVEL



Sources: Author. Notes: email use incidence variable is an average calculated using the country-year-location level using sample stratification weights. Observations that did not experienced aggregate connectivity shocks are not reported. The number of cable faults (IV2) and seaquakes (IV3) are summed over [t;t-5].

4.3.2 IV estimations

Baseline estimations

This causal analysis focuses on email use incidence rather than website use incidence because the former reflects an active and daily use of the Internet, while the latter implies higher fixed costs and a more strategic use of the Internet (Sadowski et al., 2002; Kabanda & Brown, 2017). In fact, websites allow firms that adopt them to maintain at high fixed costs a permanent digital presence with customers and suppliers, a feature particularly helpful in environments prone to telecommunications disruptions. Moreover, most African websites are hosted in European or American data centres, which makes them less vulnerable to shocks on African SMCs. By contrast, email is a digital technology that is used to communicate within the firm, and between its clients or suppliers. Its potential impacts on firm performance might be higher due to its internal and external usages, and to possibly stronger network effects than websites.

In a first step, our IV approach therefore consists in estimating the following first-stage (Equation 10a) and second-stage equation (Equation 10b):

[37] Seaquakes with an epicentre located less than 100km from SMC landing stations are not counted because of a potential direct effect on firm performance and a conflicting effect on the firm's ICT use when seaquakes occur (e.g. communicating with clients/suppliers to ensure everything is fine).

$$Y_{i,j,k,l,t} = \alpha_0 + \alpha_1 Email_{i,j,k,l,t} + \alpha_2 W_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \varepsilon_{i,j,k,l,t} \quad (10a)$$

$$Email_{i,j,k,l,t} = \gamma_0 + \gamma_1 Z_{j,l,t} + \gamma_2 W_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \epsilon_{i,j,k,l,t} \quad (10b)$$

Where $Email_{i,j,k,l,t}$ is the dichotomous variable of email adoption by firm i. $W_{j,l,t}$ is the set of instrument (IV1; IV2; IV3) and $W_{i,j,k,l,t}$ is a set of controls, which includes the previous control variables in X_{it}, to which we add the logarithm of the firm's location distance to connectivity infrastructures, used as an interaction term in IV construction (Equations 10a, b, and c), and the website use variable. First, it is important to include the distance variable alone in order to control for the possible effect of proximity to capital cities or major urban centres, since connectivity infrastructures – SMC landing stations and IXPs – are often constructed in such locations. Second, it is also important to additionally control for website adoption since this technology use may reflect a more strategic and intense use of the Internet by the firm. Last, the concern for omitted variable bias is lowered by the inclusion of a country-year-industry dummy, $d_{j,k,t}$, controlling for country and industry-level time-invariant and time-varying determinants of email use and firm performance, and a location dummy, $d_{j,l}$, controlling for location time-invariant determinants of email use and firm performance. $\varepsilon_{i,j,k,l,t}$ and $\epsilon_{i,j,k,l,t}$ are error terms.

Two-Stage Least-Square estimations (2SLS) of Equations (10a) and (10b), with two-stage GMM standard errors clustered by location-year, are conducted. Results are reported in Table 23, using the set of three IVs whose computation time-windows are calibrated to optimize identification statistics.[38] First-stage estimates are significant and with the expected sign, and identification statistics suggest that our set of IVs respects identification restrictions in the usual confidence levels. Second-stage estimations point to a 10%-significant positive effect of email use during operations on firm-level total annual sales. According to this estimate, adoption of email technology by firms increases their sales by 80% on average, which is slightly stronger than OLS estimates in Table 7 (column 3). This relationship seems driven by the increase in labour productivity (column (2)) but mitigated by the strong negative effect of email use on firm-level exports (column (3)). Lastly, our results highlight a positive effect of email use on the firm's number of permanent and temporary workers (column (4)), suggesting that adoption of email technology leads to an average 28% increase in the size of the total workforce. Looking at the effect of email use on the size of the permanent and temporary workforce, estimates in columns (5) and (6) suggest that email adoption has a positive 10%-significant effect on the number of permanent workers, but apparently no effect on temporary workers.[39]

[38] Appendix C reports the various IV estimations conducted in this section, using the firm's total sales as the dependent variable and restricting the IV set to shock-based instruments: SMC_{fault} and $SMC_{seaqsuakes}$.
[39] Estimates using the employment variables previously defined for manufacturers are not reported because our instrument set is not valid using a sample restricted to manufacturing firms.

TABLE 23. 2SLS ESTIMATIONS OF EQUATIONS (11A) AND (11B).

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var. (Ln):	**Total sales**	**Sales / worker**	**Exports**	**# workers**	**# temp. workers**	**# perm. workers**
			1st stage estimates			
IV1: SMC_proximity	0.075^{**}	0.077^{**}	0.077^{***}	0.094^{***}	0.098^{***}	0.094^{***}
	(0.036)	(0.038)	(0.025)	(0.023)	(0.026)	(0.023)
IV2: SMC_faults[1]	-4.424^{***}	-4.431^{***}	-3.963^{***}	-4.106^{***}	-4.016^{***}	-4.016^{***}
	(0.255)	(0.255)	(0.203)	(0.210)	(0.220)	(0.220)
IV3: SMC_seaquakes[2]	-2.226^{***}	-2.228^{***}	-2.000^{***}	-2.072^{***}	-2.027^{***}	-2.071^{***}
	(0.126)	(0.126)	(0.101)	(0.104)	(0.109)	(0.104)
			2nd stage estimates			
$Email_{i,j,t}$	**0.799^{*}**	**0.606^{***}**	**-10.00^{***}**	**0.282^{**}**	**0.876**	**0.171^{*}**
	(0.445)	**(0.214)**	**(2.754)**	**(0.140)**	**(0.741)**	**(0.103)**
Dummies			Country-year-industry Location			
Hansen test P-value	0.54	0.71	0.11	0.52	0.31	0.32
Kleibergen-Paap Wald rk F statistic	115.33	113.44	135.74	154.96	119.47	154.96
Redundancy LM test (pval)[a]	0.02	0.02	0.04	0.02	0.07	0.02
N	14,779	14,722	14,859	16,508	15,998	16,508

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. a. Redundancy LM test of the null that IV2 and IV3 are redundant.

1. IV2's time-window is [t;t-2].

2. IV3's time-window is [t;t-3].

Spatial spillover effects

These results point to strong benefits of email adoption for African SMEs, but also to negative effects of this technology on exports. This strong negative effect of email use on exports could be explained by the higher competition on foreign markets resulting from the pressure exerted by domestic competitors also using this technology. To investigate the possibility of spatial email spillover effects, we add to the equation system an additional first-stage equation relating the location incidence of email use to our set of IVs:

$$Y_{i,j,k,l,t} = \beta_0 + \beta_1 Email_{i,j,k,l,t} + \beta_2 \overline{Email\_location}_{j,l,t} + \beta_3 W_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \varepsilon_{i,j,tk,l,} \quad (11a)$$

$$Email_{i,j,k,l,t} = \gamma_0 + \gamma_1 Z_{j,l,t} + \gamma_2 W_{i,j,t} + d_{j,k,t} + d_{j,l} + \epsilon_{i,j,t} \quad (11b)$$

$$\overline{Email\_location}_{j,l,t} = \delta_0 + \delta_1 Z_{j,l,t} + \delta_2 W_{i,j,k,l,t} + d_{j,k,t} + d_{j,l} + \omega_{i,j,k,l,t} \quad (11c)$$

Where $\overline{Email\_location}_{j,l,t}$ is the email location incidence variable described in equation (4b), and $\omega_{i,j,k,l,t}$ is the error term. In other words, in our IVs displaying location-level variability, we are able to instrument the spatial spillover effects of email diffusion and separate these spillover effects from the effect of individual email adoption on firm performance. Moreover, including this additional variable of interest in the equation system is instrumental to identification by allowing us to neutralize a potential indirect effect of our instrument set on email adoption through other firms' adoption rates.

Therefore, 2SLS estimations of Equations (11a), (11b) and (11c), with standard errors robust to heteroscedasticity and clustered by location-year, are conducted. Results are reported in Table 24. They suggest that previous estimates were measuring the global effect of email adoption on firm's sales, which results from conflicting individual and spatial spillover effects. IV estimates indeed stress that the diffusion of email at the location-level has a negative effect on total firm-level sales (column (1)), possibly induced by increased competition on foreign markets, as suggested by the strong negative spatial spillover effect on firm exports.

Once this spatial spillover effect of email diffusion has been estimated, the estimated effect of individual email adoption is much stronger, since using email is found to increase firm sales by 251% and a firm's (permanent) workforce by more than 80%. However, estimated spatial spillovers suggest that a 10 percentage point increase in email location incidence reduces firm's total sales by 26% and exports by 150%. This estimated negative spatial spillover effect on sales contrasts with the corresponding spatial spillover estimates reported in Table 12 (column (1)), but the negative spatial spillovers of email diffusion on exports (Table 12, column (3)) is confirmed and found to be much stronger after instrumentation.

TABLE 22. 2SLS ESTIMATIONS OF EQUATION (12A), (12B), AND (12C).

	(1)	(2)	(3)	(4)	(5	(6)
Var dep (ln):	Total sales	Sales per worker	Indirect and direct exports	# workers	# temp. workers	# perm. workers
			1st stage est: $Email_{i,j,t}$			
IV1	0.075^{**}	0.077^{**}	0.077^{***}	0.094^{***}	0.098^{***}	0.094^{***}
	(0.036)	(0.038)	(0.025)	(0.023)	(0.026)	(0.023)
IV2	-4.424^{***}	-4.431^{***}	-3.963^{***}	-4.106^{***}	-4.016^{***}	-4.016^{***}
	(0.255)	(0.255)	(0.203)	(0.210)	(0.220)	(0.210)
IV3	-2.226^{***}	-2.229^{***}	-2.000^{***}	-2.072^{***}	-2.027^{***}	-2.071^{***}
	(0.126)	(0.126)	(0.101)	(0.104)	(0.109)	(0.104)
SW multivariate F-test	53.03^{***}	42.81^{***}	55.96^{***}	29.14^{***}	19.03^{***}	29.14^{***}
			1st stage est: $Email\_location_{j,t}$			
IV1	0.088^{***}	0.088^{***}	0.085^{***}	0.090^{***}	0.098^{***}	0.090^{***}
	(0.034)	(0.034)	(0.032)	(0.033)	(0.026)	(0.033)
IV2	-2.859^{***}	-2.859^{***}	-2.875^{***}	-3.103^{***}	-4.016^{***}	-3.103^{***}
	(0.072)	(0.072)	(0.072)	(0.039)	(0.220)	(0.038)
IV3	-1.440^{***}	-1.440^{***}	-1.447^{***}	-1.562^{***}	-2.027^{***}	-1.562^{***}
	(0.036)	(0.036)	(0.036)	(0.019)	(0.109)	(0.019)
SW multivariate F-test	50.87^{***}	40.58^{***}	39.28^{***}	20.43^{***}	14.22^{***}	20.43^{***}
			2nd stage estimates			
$Email_{i,j,t}$	**2.511^{***}**	**1.960**	**3.037**	**0.812^{*}**	**1.718**	**0.827^{*}**
	(0.986)	**(1.577)**	**(3.236)**	**(2.416)**	**(1.308)**	**(0.472)**
$Email\_location_{j,t}$	**-2.672^{***}**	**-2.095**	**-14.88^{***}**	**-0.717**	**-0.760**	**-0.922**
	(1.576)	**(2.400)**	**(2.222)**	**(0.602)**	**(1.506)**	**(.616)**
Dummies			Country-year-industry Location			
Hansen test P-value	0.74	0.57	0.11	0.25	0.16	0.71
KP Rk Wald F stat.	29.10	21.99	32.82	8.670	9.35	8.67
N	14,779	14,723	14,859	16,508	15,998	16,508

Two-stage GMM standard errors in parentheses, robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV2's time-window is [t;t-2]. IV3's time-window is [t;t-3]. Controls are included in the regressions but not reported in the table.

Localization diseconomies

Next, we attempt to further the comprehension of the mechanisms underlying evidence of the negative spillover effects of email spatial diffusion on the performance of SMEs. To test the hypothesis of increased competition from other domestic firms, we posit that this competition mechanism is a source of localization diseconomies, i.e. only has an effect in the industry where the firms operates. To test this hypothesis, we decompose the variable of email spatial spillovers (Equation (4b)) into i) a variable of email diffusion at the location-industry level ($\overline{Email\_loc\_indus_{i,j,l}}$), reflecting the spatial diffusion of email among firms from the industry where the surveyed firm operates[40], and ii) a variable of email spatial diffusion among the remaining universe of firms operating in the same location ($\overline{Email\_loc\_other_{i,j,l}}$).

[40] And therefore relates to localization (dis)economies mentioned in subsection 2.2.1.

Let K be the set of industries k. For all firms $i \neq f$, located in location l, and operating in industry k, we compute:

$$\overline{Email\_loc\_indus}_{i,j,l} = \frac{1}{N_{k,l}}\left(\sum_{f\in k,l}^{=k} Email_f \; - Email_i \;\right) \forall\, i \neq f, f \in K \quad (12a)$$

$$\overline{Email\_loc\_other}_{i,j,l} = \frac{1}{N_{-k,l}}\left(\sum_{f\in -k,l} Email_f \;\right) \forall\, i \neq f, f \in K \quad (12b)$$

With $N_{k,l}$ referring to the number of firms operating in industry k from location l, and $N_{-k,l}$ representing the number of firms operating in other industries from location l. We therefore conduct 2SLS estimations of the following system of equations, with two-stage GMM standard errors clustered by location-year, including location and industry fixed effects:

- $Y_{i,j,k,l,t} = \beta_0 + \beta_1 Email_{i,j,k,l,t} + \beta_{2a}\overline{Email\_loc\_indus}_{j,l,t} + \beta_{2a}\overline{Email\_loc\_other}_{j,l,t} + \beta_3 W_{i,j,k,l,t} + d_{j,l} + d_k + \varepsilon_{i,j,k,l,t}$ (13a)
- $Email_{i,j,k,l,t} = \gamma_0 + \gamma_1 Z_{j,l,t} + \gamma_2 W_{i,j,k,l,t} + d_{j,l} + d_k + \epsilon_{i,j,k,l,t}$ (13b)
- $\overline{Email\_loc\_indus}_{i,j,l,t} = \delta_0 + \delta_1 Z_{j,l,t} + \delta_2 W_{i,j,k,l,t} + d_{j,l} + d_k + \omega_{i,j,l,t}$ (13c)
- $\overline{Email\_loc\_other}_{i,j,l,t} = \rho_0 + \rho_1 Z_{j,l,t} + \rho_2 W_{i,j,k,l,t} + d_{j,l} + d_k + \xi_{i,j,k,l,t}$ (13d)

Estimates are reported in Table 25 below. Estimates strongly support the existence of localization diseconomies, i.e. possibly induced by increased competition from firms operating in the same industries.[41] According to these estimates, a 10% increase in email incidence at the location-industry level reduces firm total sales by 130%, firm labour productivity by 120%, firm's workforce size by 29%, and the firm's number of permanent workers by 33%. However, the negative email spatial spillovers on exports previously evidenced in Tables 23 and 24 do not seem to be related to increased competition from firms in the same industry.

Robustness

In a last step, we conduct robustness checks to ensure that our estimates do not suffer from potential location selection bias, induced by the most performing firms choosing to locate in urban centres where connectivity infrastructures are deployed. Such a mechanism would invalidate our identification strategy. As a result, it would induce an upward bias in IV estimates by inflating the digital divide and the revenue/employment gap between performing firms, located at the core, and less performing firms, located at the periphery. To address this source of endogeneity, we first exclude from the sample foreign and medium-sized firms, and rerun IV-2SLS estimations of Equations (11a, b, and c) on a sample of domestic small enterprises, which are less likely to be mobile in choosing their location (Dollar et al., 2006ab). Estimates, reported in Table 26, confirm the relevance of our identification strategy applied to this restricted sample of firms, and highlight a larger impact of email firm-level adoption on small firm's sales, and total/permanent workforce size. Moreover, estimates in column (1) show that the negative spillover effect of email spatial diffusion on firms' sales is not anymore significant after this sample restriction, suggesting that previous evidence of negative spillovers were driven by medium firms. Still, large negative spillovers on exports and the (permanent) workforce size remain strong and significant, but the firm-level adoption of email by small firms is found to have a strong and 1%-significant effect on their exports, which was not the case when medium firms were in the sample.

Therefore, this first robustness additionally lowers the concern for a location selection bias that would have inflated previous IV estimates. However, it is worth noting that identification statistics in columns

[41] This evidence also corroborates the findings of Marsh et al. (2017), who find evidence of within-industry explained by limited absorptive capacity of US firms.

(4) and (6) suggest a risk of weak instrument bias, so that the resulting estimated employment equations, despite being consistent with previous IV estimations, should be taken with due caution.

As second robustness test, for the same concern of location selection bias, we additionally exclude exporting SMEs that, disregarding of their size or ownership structure, could be more inclined to locate in large urban centres or close to the coast, where international connectivity infrastructures are often located, to facilitate their access to foreign markets. IV estimations of Equations (11 a, b, and c) are hence rerun on a sample of non-exporting firms, and results, presented in Table 27, confirm the existence of large impacts of email adoption on sales, sales per worker and temporary employment in non-exporting firms. Interestingly, the negative email spillover effects on firms' total sales, and on the number of (permanent) workers are not significant, which suggests that evidence of negative spillovers on the permanent workforce size were possibly driven by the negative spillovers on exports. Still, negative spillovers email spatial diffusion on the temporary workforce remain significant in a 10% confidence level.

TABLE 25. 2SLS ESTIMATIONS OF EQUATIONS (12A), (12B), AND (12C).

	(1)	(2)	(3)	(4)	(5	(6)
Var dep (ln):	Total sales	Sales per worker	Indirect and direct exports	# workers	# temp. workers	# perm. workers
			1st stage est: $Email_{i,j,t}$			
IV1	0.043***	0.043***	0.030***	0.044***	0.044***	0.044***
	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.006)
IV2	0.028**	0.028**	0.024**	0.025**	0.025**	0.025**
	(0.013)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)
IV3	0.113***	0.106***	0.117***	0.118***	0.118***	0.118***
	(0.012)	(0.012)	(0.011)	(0.010)	(0.010)	(0.010)
SW multivariate F-test	273.88***	105.98***	282.32***	52.06***	24.34***	52.06***
			1st stage est: $Email\_loc\_indus_{j,t}$			
IV1	0.069***	0.068***	0.067***	0.075***	0.075***	0.075***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
IV2	0.019*	0.019*	0.019*	0.019*	0.019*	0.019*
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
IV3	0.091***	0.090***	0.091***	0.107***	0.107***	0.107***
	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)
SW multivariate F-test	120.88***	214.20***	57.89***	31.92***	15.68***	31.92***
			1st stage est: $Email\_loc\_other_{j,t}$			
IV1	0.062***	0.062***	0.063***	0.058***	0.058***	0.058***
	(0.018)	(0.018)	(0.018)	(0.012)	(0.012)	(0.012)
IV2	0.006	0.006	0.005	0.008	0.008	0.008
	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)
IV3	0.105***	0.105***	0.110***	0.099***	0.099***	0.099***
	(0.025)	(0.024)	(0.025)	(0.017)	(0.017)	(0.017)
SW multivariate F-test	25.22***	28.49***	21.80***	13.64***	7.60***	13.64***
			2nd stage estimates			
$Email_{i,j,t}$	**17.75***	**18.13**	**1.685**	**1.772*** **	**0.572**	**1.853*** **
	(10.43)	**(11.28)**	**(1.977)**	**(0.629)**	**(0.209)**	**(0.694)**
$Email\_loc\_indus_{j,t}$	**-13.00** **	**-11.98** **	**2.109**	**-2.916*** **	**0.553**	**-3.260*** **
	(5.718)	**(6.172)**	**(3.209)**	**(1.009)**	**(0.860)**	**(1.110)**
$Email\_loc\_other_{j,t}$	**-17.34**	**-19.61**	**-4.991**	**2.066**	**0.237**	**2.197**
	(23.73)	**(21.99)**	**(4.210)**	**(1.607)**	**(1.648)**	**(1.776)**
Dummies			Location, industry			
KP Rk Wald F stat.	10.01	12.07	6.28	2.83	1.435	2.83
N	13,830	13,830	13,642	15,547	15,074	15,547

Two-stage GMM standard errors in parentheses, robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV2's time-window is [t;t-2]. IV3's time-window is [t;t-3]. Controls are not reported in the table.

TABLE 26. 2SLS ESTIMATIONS OF EQUATIONS (12A), (12B), AND (12C), SAMPLE OF SMALL DOMESTIC FIRMS

	(1)	(2)	(3)	(4)	(5	(6)
Var dep (ln):	Total sales	Sales / worker	Exports	# workers	# temp. workers	# perm. workers
			1st stage est: $Email_{i,j,t}$			
IV1	0.048**	0.049**	0.051***	0.089***	0.101***	0.089***
	(0.022)	(0.023)	(0.016)	(0.020)	(0.030)	(0.020)
IV2	-3.502***	-3.507***	-2.981***	-2.805***	-2.773***	-2.805***
	(0.314)	(0.314)	(0.210)	(0.280)	(0.286)	(0.280)
IV3	-1.759***	-1.761***	-1.505***	-1.419***	-1.403***	-1.419***
	(0.155)	(0.155)	(0.104)	(0.138)	(0.141)	(0.138)
SW F-test	28.97***	27.09***	92.47***	3.61**	13.06***	3.61**
			1st stage est: $Email\_location_{j,t}$			
IV1	0.077***	0.077***	0.075***	0.081***	0.079***	0.081***
	(0.026)	(0.026)	(0.025)	(0.029)	(0.027)	(0.029)
IV2	-2.890***	-2.889***	-2.903***	-3.071***	-3.081***	-3.071***
	(0.085)	(0.085)	(0.084)	(0.105)	(0.096)	(0.105)
IV3	-1.453***	-1.453***	-1.459***	-1.544***	-1.548***	-1.544***
	(0.042)	(0.042)	(0.041)	(0.515)	(0.047)	(0.515)
SW F-test	26.71***	25.04***	24.26***	2.94**	9.15***	2.94**
			2nd stage estimates			
$Email_{i,j,t}$	**3.678*** **	**1.920**	**6.990*** **	**2.379*** **	**-2.935**	**3.024*** **
	(1.520)	**(1.442)**	**(2.389)**	**(0.881)**	**(2.837)**	**(1.162)**
$Email\_location_{j,t}$	**-1.992**	**-0.302**	**-11.91*** **	**-1.822*** **	**2.508**	**-2.523** **
	(1.956)	**(1.676)**	**(1.287)**	**(0.875)**	**(3.245)**	**(1.176)**
Dummies			Country-year-industryLocation			
Hansen test P-value	0.78	0.64	0.13	0.37	0.18	0.52
KP Rk Wald F stat.	15.05	13.51	22.10	2.00	6.879	2.00
N	9,373	9,341	9,406	10,477	10,169	10,477

Two-stage GMM standard errors in parentheses, robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV2's time-window is [t;t-2]. IV3's time-window is [t;t-3]. Controls are not reported in the table.

TABLE 27. 2SLS ESTIMATIONS OF EQUATIONS (12A), (12B), AND (12C), SAMPLE OF NON-EXPORTING SMES

	(1)	(2)	(3)	(4)	(5)
Var dep (ln):	Total sales	Sales / worker	# workers	# temp. workers	# perm. workers
			1st stage est: $Email_{i,j,t}$		
IV1	0.024*	0.024*	0.067***	0.078***	0.067***
	(0.014)	(0.014)	(0.017)	(0.033)	(0.017)
IV2	-5.327***	-5.327***	-4.855***	-4.809***	-4.855***
	(0.199)	(0.199)	(0.143)	(0.157)	(0.143)
IV3	-2.665***	-2.665***	-2.439***	-2.417***	-2.439***
	(0.099)	(0.099)	(0.071)	(0.079)	(0.071)
SW multivariate F-test	253.48***	238.1***	199.12***	87.51***	199.12***
			1st stage est: $Email\_location_{j,t}$		
IV1	0.081***	0.081***	0.087***	0.086***	0.087***
	(0.029)	(0.029)	(0.031)	(0.030)	(0.031)
IV2	-2.688***	-2.688***	-2.914***	-2.925***	-2.914***
	(0.072)	(0.072)	(0.061)	(0.058)	(0.062)
IV3	-1.353***	-1.353***	-1.467***	-1.471***	-1.467***
	(0.036)	(0.036)	(0.030)	(0.029)	(0.030)
SW multivariate F-test	91.33***	92.87***	137.87***	66.47***	137.87***
			2nd stage estimates		
Email use	**2.345*** **	**2.199*** **	**0.141**	**4.160*** **	**0.141**
	(0.507)	**(0.549)**	**(0.324)**	**(1.246)**	**(0.432)**
Email location incidence	**-1.672**	**-1.296**	**0.122**	**-3.457* **	**0.026**
	(1.159)	**(1.120)**	**(0.453)**	**(1.961)**	**(0.517)**
Dummies			Country-year-industry. Location		
Hansen test P-value	0.92	0.73	0.35	0.80	0.14

KP Rk Wald F stat.	67.32	66.39	25.05	28.81	25.04
N	13,366	13,317	14,947	14,526	14,947

Two-stage GMM standard errors in parentheses, robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV2's time-window is [t;t-2]. IV3's time-window is [t;t-3]. Controls are included in the regressions but not reported in the table.

In a nutshell #8: Impacts of email adoption and diffusion on firm performance

- We implement an IV approach to estimate the impact of email adoption on firm performance, by exploiting exogenous sources of variation in international Internet connectivity – the deployment of submarine cables and their exposure to shocks – and weighting them by the firm's distance to connectivity infrastructures.
- We estimate simultaneously the impact of email adoption by firms and the spatial spillovers resulting from email diffusion at the location level.
- Results point to a strong positive impact of individual use of email by firms on their total sales and (permanent) workforce size, but to negative spillover effects of email location diffusion on sales, exports, and employment.
- The positive impact of email adoption by firms on the size of the total and permanent workforce disappears once controlling for labour productivity, which suggests that the positive effect of email technology on permanent job creation is explained by changes in labour productivity.
- Negative spatial spillovers on firm-level sales and employment seem to be explained by localization diseconomies, i.e. by the spatial diffusion of email among firms working in the same industry, which supports the hypothesis of increased local pressure from competitors adopting Internet technologies.
- Estimated effects do not seem to be affected by location selection bias.

4.4 Main lessons

The purpose of this section was to provide an empirical overview of the contribution of digital technologies commonly used in the conduct of business by SMEs: email, websites, and mobile money. An important empirical novelty of this section is the separation between the individual effect of digital technology adoption by firms from the spillover effects resulting from its diffusion at the industry or local levels. It turns out from this analysis that the adoption of digital technologies by firms is likely to yield subsequent benefits in terms of revenue, productivity, exports, and employment. Our analysis of digital technology adoption spillovers also stressed the existence of threshold effects of email industry-level and spatial diffusion on firm outcomes. In fact, U-shaped relationships were evidenced, stressing that below (above) a certain threshold of digital technology incidence in a given industry and location, a larger diffusion of that technology may be detrimental (beneficial) to firms, whether they have adopted this technology or not. This evidence is however not exempt from estimation bias resulting from possible reverse causality from firm performance to email adoption and diffusion across sectors and locations.

Another empirical novelty is the IV approach, which exploits exogenous sources of variation in international Internet connectivity resulting from the staggered laying of telecommunications submarine cables and from their exposure to random shocks to estimate the causal effects of digital technologies on SME operations. This causal analysis supports the existence of a strong positive effect of email use on sales, productivity and employment, and a negative effect on firm-level exports. Separating the impact of individual use of email by SMEs from the spatial spillover effects of their diffusion within a location, we find evidence of positive impacts of email adoption on firm-level sales and workforce size, concomitant to negative location spillovers on sales, sales per worker, exports, and employment. This evidence therefore suggests that digital technologies, especially email technology, may have not yet reached the critical mass of users required to yield positive spillovers. Moreover, a decomposition of these spatial spillovers into those prevailing between firms from the same industry and those within the remaining universe of firms, supports that previous negative spillovers of email diffusion were driven by firms operating in the same location and industry. These results therefore give credit to the hypothesis that the spatial diffusion of email increases competition between firms operating within the same sector, and primarily benefits the most performing firms, as already evidenced in other studies (Bustos, 2011; Paunov & Rollo, 2016).

5 Advancing digital frontiers in West African economies: an in-depth look at African and international firms bringing digital solutions to key market sectors

This last section presents a deeper dive on several promising key players currently pushing frontiers in the digitalization landscape in Sub-Saharan Africa in general and West Africa in particular, using cutting-edge technologies and digital innovations to improve small and medium enterprise (SME) development and job creation throughout the region. This section takes the format of seven case studies, each presenting one or more firms in various business and service provision sectors. Although the list of sectors and technologies described in the case studies is by no means exhaustive, in their ensemble, the section provides an in-depth picture of both domestic and international firms leveraging a diverse set of technologies, serving a diverse communities, and offering a wide array of products and services destined for SMEs as well as consumers.

Major sectors addressed in this section include: 1) eCommerce platforms serving both consumers as well as SMEs and other vendors looking to increase their customer bases; 2) Job search and gig economy platforms, including aspects such as formalization of informal workers, job training programs, and linking SMEs with potential employees; 3) Insurtech, with a specific focus on provision of weather-indexed crop insurance to smallholder farmers and agricultural firms; 4) Logistics and supply chain services, with a focus on domestic and international terrestrial transport of goods and products for SMEs and other firms; 5) Drone ventures using unmanned aerial vehicle (UAVs) for applications in precision agriculture (increasing access to inputs and optimization of input use) and healthcare logistics (delivery of blood, medications, and other medical supplies to clinics and hospitals); 6) Energy access, production, and consumption monitoring, with a focus on off-grid solar energy provision to both households and SMEs and including a discussion of the impact of solar electricity access on SME creation and development; and 7) Tax and bill payment platforms, facilitating rapid, low-cost tax and bill payments by SMEs and households while increasing access to microcredit and other beneficial financial services as well as essential public utilities such as water.

Each case study begins with a discussion of the market failures and inefficiencies that have traditionally affected the abovementioned sectors in West African countries, preventing inefficient market outcomes for both SMEs and their clients. This is followed by an introduction of the firm or firms being studied, with a description of the innovative digital technologies they are leveraging to rectify the market failures described in the first section and improve outcomes for firms, customers, service providers, and the general public. The third section describes deployment and development of the firms, many of which are still in the start-up phase, including information on founding, fundraising and investments, and awards. The fourth section describes preliminary impacts, including any information on completed or ongoing econometric impact evaluations where applicable. If no impact evaluations have been conducted, this section presents general results relating to numbers of customers and SMEs served or results of questionnaires on customer experience and satisfaction. The fifth section describes obstacles encountered by the firms in developing and deploying their products, complying with regulatory frameworks, and encouraging take-up of digital platforms and services. The sixth section discusses perspectives and future directions, with a focus on plans for further development and expansion into new geographic areas, sectors, products, and technologies. The seventh and final section consists of key takeaway lessons gleaned from the firms' experiences leveraging digital technologies in an attempt to overcome market failures and leapfrog missing infrastructures.

The severe economic upheaval caused by the Covid-19 pandemic in 2020 has presented both new challenges and opportunities to many of the firms discussed in this section. Where information is available, a discussion of the firms' response to the pandemic is included in the case studies, including obstacles faced due to restrictions on freedom of movement and business operations during lockdowns and opportunities to meet previously unforeseen needs, such as delivery of Covid-19 diagnostic tests to health centres in remote locations via drone. Although many of the firms, products, and technologies discussed in the case studies are intended to serve and benefit diverse sectors of society, including individuals, households, farmers, informal sector workers, and government agencies, the case studies have a particular focus on opportunities presented to SMEs for development and job creation.

5.1 Overcoming logistics and payment modality barriers to bring eCommerce to Africa: the case of Jumia in West Africa

5.1.1 Context & Market Failures

In developing country settings, including many areas of Sub-Saharan Africa, poor communications infrastructure can lead to market failures such as high transaction costs (including information search, transportation, and verification costs) and imperfect or asymmetric access to information across various market agents. This can lead to high levels of price dispersion in product markets between communities and across regions. With rising levels of internet penetration in Sub-Saharan Africa, many eCommerce start-ups have attempted to fill in gaps in markets through the creation of online product markets that bridge information gaps between producers, wholesalers, middlemen, and consumers. One such company, Jumia, has experienced both encouraging successes and challenging setbacks since its founding in 2012, illustrating both the seemingly boundless opportunities for eCommerce platforms in SSA as well as impeding factors that have prevented eCommerce initiatives from enjoying wider success on the continent.

5.1.2 Technology

Jumia is a three-pronged platform consisting of an online marketplace chiefly dominated by third-party sellers connecting vendors to consumers, a logistics arm responsible for shipments and deliveries, and an online payments platform, recently developed into a formal fintech service. One of these payment platforms, Jumia One, is a mobile application that enables purchase of airtime for prepaid mobile phone services. The principal fintech service, Jumia Pay, facilitates online payment for all Jumia transactions for products and services, including electronics, fashion, travel, and other markets. The company also instituted a Jumia lending program that enables its third-party vendors to access business loans. Jumia has partnered with banks and other financial services providers in countries throughout SSA to offer mobile money-based payment solutions to both customers and vendors, such as its deal with Equity Bank of Kenya in 2016 enabling customers to use the bank's EazzyPay platform on the Jumia market (James, 2016).

5.1.3 Deployment & impacts

Jumia is one of the largest eCommerce companies operating on the African continent, with over 22,000 listings on its platform as of 2018 (Olagunju, Oyebode, & Orji, 2020). The company was founded in 2012 in Lagos, Nigeria, and later expanded its network to include Egypt, Morocco, Côte d'Ivoire, Kenya, and South Africa. In 2014, the company further widened its reach, launching country offices in Tunisia, Tanzania, Ghana, Cameroon, Algeria, and Uganda, with a presence in 18 African countries by 2018. In 2016, Jumia was the first African tech start-up to receive unicorn status, which is a valuation of over 1 billion USD. Additionally, in April of 2019, the company became the first African tech start-up to be listed on the New York Stock Exchange (NYSE). Jumia shares initially listed at $14.50, with the firm's stocks rising to $49.77 a share just four days later. The main shareholder is the mobile phone company MTN, based in South Africa.

Jumia has a large potential market in Sub-Saharan Africa, with 1.2 billion potential consumers and 17 million potential small and medium enterprises (SMEs) across the continent as a whole. The company reported 700 million visits to its online marketplace for the 2018 year, with one transaction or lead every two seconds, 81,000 active sellers on its platform, and over 29 million products, hotels, restaurants, and other service listings (Jumia, 2020). Additionally, Jumia Pay reported 2.1 million mobile money transactions during the third quarter of 2019 alone (Jumia, 2020). In terms of sales, job creation, and SME growth, Jumia has reported anecdotal evidence of positive impacts on businesses throughout the continent, as SMEs and other merchants take advantage of Jumia's online platform to widen their customer bases domestically and regionally. This can be a safer alternative to foraying into risky and expensive export markets. Last but not least, selling products through Jumia's online platform has also proven to provide informal firms a strong incentive to formalize, through a smooth process towards formalization requirements compliance.

To evaluate Jumia's impact on reducing barriers to growth for SMEs in Sub-Saharan Africa, Private Enterprise Development in Low-Income Countries, coordinated by the Centre for Economic Policy Research and in partnership with UK Aid, is conducting two randomized controlled studies on SMEs. The first trial will include subjecting treatment firms to a targeted Jumia recruitment campaign, comparing outcomes with those of a control group which does not receive the campaign. The second trial involves offering various monetary and other benefits to SMEs already using the Jumia platform, including loans, sales guarantees, and product shipping and delivery training (PEDL, 2020).

5.1.4 Obstacles

Despite Jumia's initial successes after being listed on the NYSE in 2019, the company's stocks quickly plummeted from a high of $14.50 to under $3.00 in a matter of weeks, and they have remained at comparable levels since that time. The potential reasons for this downfall are multiple, but a more fundamental, economically based set of underlying factors may also be at play. Throughout the late 2010s, Jumia's business strategy was characterized by series of rapid changes, including increase in the size of the company's operations, diversification in ownership, capitalization, and expansion into multiple markets across the African continent. It is possible that these rapid developments and changes in the company's business operations may have introduced new risks and rendered attainment of regulations compliance, cost effectiveness and profitability more difficult. As a result of these difficulties, the company closed its operations in three countries in 2019, namely Tanzania, Rwanda, and Cameroon, due to lack of profitability.

5.1.5 Perspectives & Future Directions

With the onset of the Covid-19 pandemic in 2020, Jumia recently announced that its logistics service will be open to external clients, including individuals and businesses; this represents a transformation from the service's original objective of simply handling internal deliveries for its e-commerce platform (Henry, 2020). This expanded service, which began in June of 2020, is currently only available in Kenya. Customers have the option of dropping off their packages at Jumia drop-off centres in Nairobi, or Jumia will collect them on-site through a business-to-customer (B2C) or business-to-business (B2B) transaction setup. Jumia Nigeria CEO and Executive Vice President Marketplace at Jumia Group, Massimiliano Spalazzi, explained that during 2019, Jumia processed 20 million packages and achieved 25 percent deliveries in rural areas through its network made up of more than 6,500 direct agents and 3,000 warehouse operators (Henry, 2020). Spalazzi emphasized that opening the e-logistics service to the public will allow Jumia to make an even greater impact, with its access to dozens of logistics entrepreneurs through its network in Kenya. This network includes both small Kenyan companies and larger enterprises such as POSTA and Wells Fargo, giving Jumia access to thousands of bikes and vans and hundreds of pickup locations, according to Sam Chappatte, Jumia Kenya CEO (Henry, 2020). This expansion of its e-logistics service is one strategy for diversifying the company's revenue streams and reaching its goal of becoming profitable by 2022, ten years after launching.

In recent months, Jumia has refocused its strategy from its initial rapid growth as a multiservice vendor to a focus on achieving cost efficiency and profitability, scaling back on unprofitable ventures and focusing on activities that have greater promise for long-term sustainability. For example, Jumia closed its e-commerce markets in Tanzania and Cameroon in November 2019 and its Jumia Food market in Rwanda one month after that, concluding that operations in these countries could not be made profitable due to current economic conditions (Betti, 2020). Also, in December 2019, Jumia made an agreement with Travelsafe in which Travelsafe would white-label Jumia Travel, taking control of sales, fulfilment, and customer service for Jumia. In addition to expansion of its logistics service as described above, the company is also investing in and marketing the JumiaPay mobile money payment service as a strategic tool to provide a lock-in mechanism, build a base of loyal, returning customers, and create more profitability in the face of thin margins in its e-commerce activities (Betti, 2020).

Investors have suggested that although Jumia has suffered a considerable downfall over the last year, the company has nevertheless developed a sound strategy for rebounding and achieving profitability, including closing markets in several countries as mentioned above and focusing on larger markets where consumers have greater purchasing power and internet access, such as Nigeria, Egypt, and South Africa. Since internet access is an important factor in e-commerce, Jumia stands to benefit greatly from recent developments that have the potential to drastically increase internet penetration in the continent. One of these projects is the 2Africa subsea internet cable, which will link 16 African countries with Europe and the Middle East after implementation by Facebook and several large telecom companies (Ebiefung, 2020). Jumia's 1st quarter earnings for 2020 show positive signs, even amid the ravages of the Covid-19 pandemic, with annual active customers growing by 51% to 6.4 million and marketplace revenue growing by 22% to 19.1 million euros (Ebiefung, 2020).

5.1.6 Main lessons

This case study on Jumia reveals several important takeaways in relation to the developmental potential of SMEs through digitalization processes in Sub-Saharan Africa (SSA). First and foremost, the rise of international e-commerce champions working in SSA is good news overall for SME ecosystems and for job creation. Results from ongoing studies on the specific impacts of e-commerce platforms on reducing barriers to growth for SMEs will help to further contextualize these benefits. Second, despite the overall positive influence of e-commerce platforms on SMEs, the digital divide still remains the greatest obstacle to further expansion of Jumia and other e-commerce platforms in SSA. With many SMEs across the region still operating without access to mobile phones, internet, or email, e-commerce platforms may actually widen the gap by allowing firms with digital access (including importers of products from industrialized countries) capture more of the markets in SSA countries. Third, logistics infrastructure is critical to the success of e-commerce. Logistical challenges such as underdeveloped transportation and communications infrastructures and the dearth of existing pick-up and delivery services with which to partner have prevented transnational e-commerce giants such as Amazon and Alibaba from gaining traction in SSA, and have challenged companies such as Jumia in their attempts to build this infrastructure from the ground up. Fourth, e-commerce platforms need to have a long-term vision for sustainable development and resist the temptation towards rapid over-expansion and capitalization on the stock market.

5.2 Connecting informal economy workers and clients through mobile technology: the case of Lynk in Kenya and implications for West Africa

5.2.1 Context & Market Failures

Many countries in Sub-Saharan Africa (SSA) are characterized by low rates of participation in formal sector employment, with over eighty percent of the region's labour force working in the informal sector (Grunewald, 2020). Despite their lack of formalization, informal sector workers are key players in most SSA markets; for example, in Nairobi, Kenya, households and businesses, including SMEs, purchase more than 80 million USD worth of products and services from informal sector workers every month (Grunewald, 2020), and the informal sector accounts for 45% of the country's total economic activity (PROPARCO, 2020). Due to market failures such as informational asymmetries, informal workers may be unable or otherwise fail to use formal job application channels, such as submitting paper or electronic CVs and job applications to potential employers. As a result, informal sector workers usually must resort to finding work through informal connections or pure luck, leading to lower wages, irregular work, and limited opportunities for professional advancement, job training, and skills acquisition.

The reasons for these inefficiencies are numerous; for example, low internet penetration and access to smart electronic devices are two factors that prevent informal sector workers from applying for formal jobs. Another factor consists of low levels of literacy, numeracy, and digital skills, which are additional obstacles preventing informal workers from searching for and applying for job opportunities (Grunewald, 2020). This results in decreased supply and demand, reduced market efficiency, and increased price dispersion for products and services due to high transaction costs (Dupoux et al., 2019). However, despite the commonly held belief that informal workers are completely disconnected from digital job platforms, qualitative research conducted in Senegal has shown that many informal sector workers, including those with few years of formal schooling, report using the internet to search for jobs, often using mobile devices due to lack of computer access (Shemin & Wallach, 2020). This shows the potential for digital job platforms to rectify market failures by bringing workers and employers together and filling in gaps in supply and demand.

5.2.2 Technology

Several digital job platforms in SSA have adapted traditional job platform models used in developed countries to meet the needs of both informal and formal sector workers in emerging markets. One example of such a platform is Lynk, a digital job platform launched in Kenya in 2015. The platform is available both via a website and a customer-facing mobile application, and workers can participate via internet connection, SMS, or phone, which increases the accessibility of the platform to those with limited or no internet access (Grunewald, 2020; Shemin & Wallach, 2020). Lynk partners with Safaricom, a leading mobile network operator (MNO) in Kenya with a large involvement in the informal sector, to facilitate payments between customers and professionals and for marketing purposes. Lynk also partners with vocational training schools throughout the country to recruit and onboard skilled informal sector workers (Grunewald, 2020).

Customers, including households or businesses seeking specific services, access the platform by searching and selecting from among available service packages on the mobile application or the website, customize their request (specifying a timeframe and other details), and pay for the service using M-PESA, a Kenyan mobile money platform integrated with the Lynk app, or with a credit or debit card. Next, the job is matched with a professional service provider in the Lynk network, which usually takes between two and six hours. After the service provider confirms the request, the customer receives an initial notification, several reminder messages before the date and time of the job, and a request to rate the quality of the job once it is completed, all through the mobile app (GSMA, 2019).

For informal sector workers, accessing the platform first involves setting up a profile, including name, qualifications, location, and price, after which they are vetted by the Lynk team and given an in-person interview. After being approved, the professional receives job notifications and has fifteen minutes to approve or decline them, with further details being given after approval of a job. The professional receives reminder messages before and during the job, and then marks the job as finished on the application or website once it has been completed. The professional then completes a quality checklist and receives a request to rate the customer, after which payment is disbursed through the integrated M-PESA mobile money platform within 24 hours of job completion (GSMA, 2019).

One of the key features of the Lynk platform is its integration with M-PESA, which is a transfer service owned by the Kenyan mobile network operator (MNO) Safaricom. In addition to enabling customers to submit payments and professionals to receive payments for services through M-PESA, Safaricom and Lynk have also collaborated to integrate Safaricom's e-commerce service, Masoko, with the Lynk platform. Customers can buy beauty services from Lynk professionals on the Masoko platform and add on installation services from Lynk professionals when buying appliances through Masoko (GSMA, 2019).

5.2.3 Deployment & impacts

Lynk was launched in 2015 and is financed and accompanied by the Novastar East Africa Fund, an investment fund that backs entrepreneurs in East Africa providing basic services in fields such as education, health, food, water, and employment for disadvantaged populations and groups in countries throughout the region (PROPARCO, 2020). Novastar also plays an advisory role by participating in Lynk's governing body and advising on strategic decisions. In addition to 1.7 million USD raised from Novastar, Lynk also brought Safaricom, Mercy Corps, and Steel Africa on board in 2017, and all three have been significant investors in the company (TechNews Report, 2018). As mentioned in the technology section above, the partnership with Safaricom has also been instrumental in integrating Lynk services with the M-PESA mobile money payment platform and the Masoko e-commerce platform.

According to Solve MIT, between 2016 and 2018, Lynk connected Kenyan workers to over 25,500 jobs completed via its platform, with a customer retention of 80 percent and an average of 28 jobs completed per customer (2020). PROPARCO reports that Lynk already has over 1,000 professionals and 3,000 customers (made up of both individuals and businesses) using the platform (2020). As of 2019, more than 2 million USD had already been transferred to workers through the platform, and the number of customers had grown to over 3,500 (Global Innovation Exchange, 2019). The company currently has over 100 employees and over 1,300 workers specializing in over 72 different fields (PROPARCO, 2020). The global humanitarian aid organization Mercy Corps, a Lynk partner, has also announced that it is integrating Lynk into its youth empowerment program, meaning that Lynk professionals using the platform will have access to training, jobs, and entrepreneurial opportunities through the Mercy Corps program (Mercy Corps, 2020).

5.2.4 Obstacles

Lynk founder Adam Grunewald explains that in the firm's early days, Lynk overcommitted to projects that it did not necessarily have the logistical capacity or technical know-how to complete, causing the company to lose out on other jobs it could have completed in the meantime (Maritz, 2019). Grunewald also explained that the company approached its mission at a sprinting pace in its early stages, hastily working to fix technical bugs and operational issues. The company now has a philosophy that is more based on long-term sustainability, focusing on growing incrementally and smartly (Maritz, 2019). In other SSA countries, including francophone West African countries such as Senegal and Côte d'Ivoire, attempts have been made at replicating the Lynk model on some level to link gig economy or informal economy workers with businesses and individuals seeking services. However, most of these ventures seem to have garnered limited investment to date, have few service providers and customers using their platforms, and have not progressed past the pilot phase. More information on these and other ventures is provided in the perspectives section below.

5.2.5 Perspectives & Future Directions

Lynk has enjoyed remarkable success since its founding and hopes to expand into additional fields and geographical locations, moving beyond Nairobi into other regions of Kenya. Digitalization of the informal economy has not progressed nearly as far in other countries of SSA. However, the possibilities for platform development and growth are large in some countries, including Senegal. In 2016, 47% of the Senegalese workforce was in the informal sector, suggesting that there is a large gap in the market that could be filled by a digital jobs platform similar to Lynk. Additionally, broadband internet access is very strong in Senegal's major cities, and smartphone penetration is among the highest in SSA at 35.6% (Shemin & Wallach, 2020). There is also a high degree of coverage from reliable digital payment providers such as Wari and Joni-Joni, and 32% of the population held a mobile money accounts with a provider such as Orange Money and Tigo Cash as of 2017 (Shemin & Wallach, 2020).

To date, there no comprehensive digital jobs platform such as Lynk has been rolled out in Senegal. Nevertheless, several Senegalese start-ups that serve informal and gig economy workers in specific sectors have been launched. For example, Noflaay, launched in 2015, brings on-demand home cleaning and babysitting services to customers across Dakar, with plans to expand into other services such as laundry collection/drop-off and home repairs. Clients request services online, and service providers also sign up online (Jackson, 2016). Noflaay pairs professionals with clients, provides job training, insures the clients against damages, and follows up on customer satisfaction through online questionnaires (Nouvelles Dakar, 2017). However, Noflaay has not yet had any significant outside investment, has suffered high client turnover due to its clientele base being mostly expats and wealthy households who frequently emigrate out of the country, and the platform has not yet progressed past its pilot phase (Jackson, 2016).

Other attempts at digital jobs platforms for informal and gig economy workers have been undertaken in francophone West Africa. For example, the Agatha platform in Côte d'Ivoire was launched in 2015 with a similar mission as Lynk – namely, linking informal economy workers to clients seeking their services.

Another such venture, Djazi, was also launched in Côte d'Ivoire in 2016 with similar goals. However, there is little information on the internet about these ventures, with few details on investment, technical development, and impacts to date. Additionally, based on a cursory search of their websites, the number of subscribers for each platform is relatively low, suggesting that neither has progressed past the pilot phase.

On a related note, there are several traditional job platforms with an online presence in francophone West Africa. For example, sites such as Senjob.com, Emploi Dakar, AtooJob, Talent2Africa, Wutiko, and AMNAJob all serve seekers of formal jobs with businesses and organizations in Senegal. Some of these services use innovative digital technology to provide services to job seekers and employers alike. For example, Talent2Africa is an executive search firm that uses a combination of algorithms and human resources to match candidates with potential jobs that fit their expertise and professional objectives. Emploi Dakar allows candidates to upload their CV and apply for jobs with a simple click of their mouse. AtooJob offers online job training seminars in addition to job postings. Wutiko offers users the opportunity to network with other professionals, and SME owners can search for funding and partnership opportunities. AMNAJob provides information about university programs, scholarships, job training, and internships in addition to formal job postings. However, all of these platforms could benefit from further technical development to provide better mobile functionality and user interfaces, and none of the platforms seem to satisfactorily meet the needs of informal economy workers and SME owners looking for gig services or employees in the informal sector.

5.2.6 Main lessons

Several key takeaways can be gleaned from the development and success of Lynk in Kenya and the relative lack of success of similar initiatives in other SSA countries to date. First, the informal sector is very important to the economic livelihood of millions of individuals throughout SSA as well as to the provision of goods and services for individuals and businesses, including formal SMEs. Second, market failures such as informational asymmetries and poorly developed market structure have led to inefficiencies such as reduced supply and demand for products and services in SSA countries. There are real opportunities to fill this need using digital platforms to connect skilled professionals with customers, such as Lynk has successfully done in Kenya. Third, development of digital platforms such as Lynk requires both technical expertise and significant outside investment, including funds from socially oriented impact investors willing to invest in the informal sector. This is important because the informal sector has traditionally been regarded as risky by many investors due to problems of informational asymmetry, including adverse selection and lack of information on creditworthiness. With the right blend of technical know-how and social impact investment, job platforms similar to Lynk can fill gaps in the market and help connect informal workers with individual and business clients in countries throughout SSA.

5.3 Insurtech companies: Using mobile technology and weather data to insure farmers against drought in Sub-Saharan Africa – the case of WorldCover

5.3.1 Context & Market Failures

Numerous climate risk indices have identified West Africa as one of the most vulnerable regions of the world to the effects of climate change, and the region has a relatively weak adaptive capacity compared to other areas (IPCC, 2014). For example, the Physical Vulnerability to Climate Change Index (PVCCI), which captures vulnerability to risks from geophysical conditions, reveals that many countries in Sub-Saharan Africa are at the highest level of risk from shocks related to temperature, rainfall, storms, sea level rise, and desertification, including several Sahelian West African countries (Feindouno et al., 2020). Approximately 60% of the region's population is dependent on small-scale agriculture for economic sustenance, with agricultural systems characterized by lack of modern inputs and techniques, extensive versus intensive farming, marginal and degraded soils, and reliance on rainfall for cultivation (Fonta et al., 2018; Kurukulasuriva & Mendelsohn, 2008). Faced with a growing population and increasingly severe climate change effects, agricultural systems in West Africa are predicted to meet only 13% of the region's food needs by 2050 in the absence of adaptation measures to increase productivity (Montpellier Panel, 2013). Other problems, including undeveloped market structure, missing road and other infrastructures, and weakly developed input provision mechanisms exacerbate welfare losses in West African agricultural markets.

Many smallholder farmers in West Africa face challenging conditions, including poverty traps and subsistence consumption restraints, severely reducing their resilience to droughts and other weather-related shocks that can decimate crops. As such, climate shocks and resulting crop failures can render farm households unable to pay for basic necessities such as school fees and food (Oliver Wyman, 2019). Although crop insurance could mitigate some of these problems through transfer of agricultural production risks, numerous market failures limit mechanisms for effective risk transfer under traditional credit and insurance schemes (Tadesse et al., 2015). For example, the problem of adverse selection prevents insurers from determining the level of risk aversion, agricultural knowledge and competency, or work ethic of farmers, and the related problem of moral hazard makes it logistically difficult to observe farmer effort and crop production in the field. Other forms of informational asymmetry between insurers and producers also exist, resulting in overall welfare reductions to society and stunted supply and demand in agricultural insurance markets (Tadesse et al., 2015).

5.3.2 Technology

Provision of weather index insurance to smallholder farmers and agribusinesses through digital technology, a form of digital insurance provision or "Insurtech", is a potential solution to the market failures described above that negatively affect traditional agriculture and insurance markets in West Africa. Under this form of insurance, weather insurance payments are initiated automatically when measurable rainfall at a representative weather station falls below a predefined threshold level during a given growing season. This simplified structure for triggering insurance payments reduces moral hazard and monitoring costs for insurers, eliminates incentives to misreport crop production among farmers, and increases efficiency and timeliness of payments by eliminating the need to directly observe crop losses at the farm level (Tadesse et al., 2015).

A leader in leveraging Insurtech for provision of weather index insurance in West African agricultural markets is WorldCover, an Insurtech company founded in 2015 and based in Accra, Ghana and New York City. WorldCover uses satellite data, on-ground sensors, mobile phone technology, and data analytics, including innovation risk modelling, as the backbone for creating and delivering its weather index insurance products to both commercial producers and agribusinesses (Bright, 2019; Oliver Wyman, 2019).

Farmers in countries where WorldCover operates are able to access insurance services through simple mobile phone technology. Its insurance policies, which it refers to as "smart contracts", are based on blockchain, a distributed ledger technology used to underpin cryptocurrencies such as bitcoin (Bird, 2018; Socialfintech.org, 2017; Weld, 2018). Using blockchain simplifies the insurance underwriting process by automating policies once they are already in place and reducing operations costs (Bird, 2018). A parametric or index-based insurance scheme such as rainfall-based crop insurance is a prime candidate for use of blockchain, because it requires only on-ground or remotely sensed rainfall data obtained from satellites for pay-outs, bypassing tedious manual assessments of losses and decision-making that characterize traditional crop insurance schemes. Once the rainfall amount has been assessed, payments are sent instantly to farmers through mobile money providers used widely in the countries where WorldCover operates, including MTN Mobile Money in Ghana and M-Pesa in Kenya (Bird, 2018). Farmers also use mobile money to make their insurance premium payments and interface with WorldCover through an app that can be used by the simplest mobile phones.

WorldCover highlights the numerous features of public blockchain enabled products that make blockchain technology a good fit for its business model. Namely, blockchain products are trustless (all contracts receive pay-outs as promised), time-stamped (policyholders can obtain proof that they hold a contract and stakeholders have the ability to view transaction information), and protective of digital identities (policyholders own their digital data and can thus leave a network and control their financial transactions histories as they please) (Weld, 2018). Each time a pay-out is made to a policyholder, it is logged to the blockchain, where the transaction will be publicly viewable while still keeping personal identifying information confidential. The first transaction appears as a simulation of an actual insurance contract, while all subsequent transactions represent automatic pay-outs to clients once rainfall falls below a certain threshold (Weld, 2018).

Blockchain allows government regulators and other stakeholders to view and confirm payment information in a more efficient and timely manner, without WorldCover having to disclose more information than is necessary about its clients or its company (Weld, 2018). Indeed, blockchain technology is regarded as highly secure in its potential for guarding personally identifiable information, with many blockchain technologies using asymmetric cryptography for authentication, integrity verification, and permission enforcement. This involves using both a public and a private key to encrypt and decrypt information, with use of one key cancelling out the other key (Lee & Mueller, 2019).

5.3.3 Deployment & impacts

WorldCover was launched in 2015 in Ghana by graduates of Massachusetts Institute of Technology (MIT) and has since expanded to Kenya and Uganda. The start-up initially raised 120,000 USD in seed funding, followed by a 6 million USD series A round in 2019 led by MS&AD Ventures in partnership with Y Combinator, Western Technology Investment, and EchoVC (a series A round is a name commonly given to a firm's first significant round of venture capital financing). After receiving these additional investment funds, WorldCover’s CEO, Chris Sheehan, announced that the company was planning to expand to other emerging economy markets, including India, Mexico, Brazil, and Indonesia (Bright, 2019). In May of 2019, WorldCover announced a new partnership with Nephilia Capital, the world’s largest insurance-linked securities (ILS) fund manager, with a focus on creating natural catastrophe and weather risk exposure portfolios. WorldCover currently uses a person-to-person (P2P) lending platform to connect social investors with farmers and agribusiness owners through a marketplace, enabling investors to add diversified returns and social impact to their investment portfolios (Oliver Wyman, 2019). The company is currently headquartered in New York City, where it is registered as a for-profit Public Benefit Corporation.

As of May 2019, WorldCover has insured over 30,000 farmers in Ghana, Uganda, and Kenya. Common crops grown by farmers insured by WorldCover include maize, rice, and peanuts. As mentioned above, WorldCover has secured funding from a variety of investors, which has made it possible for the firm to offer its insurance products to farmers in the three pilot countries to date. For the time being, WorldCover only provides insurance against drought or low rainfall events and only works in the major crop value chains mentioned above, but there are plans to expand the geographic extent of its services, the types of crops insured, and the types of insurance offered, contingent on future growth and investment. To date, no econometric impact evaluations have been conducted on WorldCover or its weather-indexed insurance programs.

5.3.4 Obstacles

Despite its successes in securing significant investment and clients during its start-up and pilot phases, WorldCover faces some of the same challenges faced by other companies attempting to sell insurance to rural farmers in Sub-Saharan Africa (SSA). For example, there are significant logistical and marketing challenges inherent in selling small insurance policies to resource-poor farmers who are often spread out over remote, sparsely populated regions characterized by high linguistic diversity and low literacy and numeracy rates (Hight, 2019). Additionally, some smallholder farmers in SSA may be unfamiliar with the concept of insurance, and there is evidence that farmers who do not understand insurance are less likely to take it up (Patt et al., 2010). Furthermore, given that insurance plans are an abstract product with which many farmers are unfamiliar, it can be difficult to build loyalty among clients who may be expecting a service or product quite different from the insurance pay-outs they actually receive (Hight, 2019).

Another challenge faced by many insurers in the field is basis risk, which is the gap between actual revenue losses from failed crops and the insurance pay-outs farmers receive for those losses. When actual losses are greater in magnitude than weather-indexed pay-outs, farmers may be unsatisfied with the product (Hight, 2019); however, it is also theoretically possible for actual losses to be smaller than pay-outs. Some weather-indexed insurance providers are using technology in an attempt to mitigate basis risk, pursuing verification of satellite precipitation data using unmanned aerial vehicles (UAVs) and measurement of crop yields at key reference points (Hight, 2019). Melanie Bacou, WorldCover Head of Research, explains that instead of basis risk, the main challenge faced by the company involves reducing its high marketing costs. She explains that after finding its 40-person in-field sales team was too costly, the firm has reduced its Ghana sales team to 10 and shifted its focus to forming partnerships with organizations that already have relationships with farmers, including agriculture extension providers, microfinance organizations, and agricultural input provisioners (Hight, 2019).

There are additional potential issues that have not specifically been reported by publications on WorldCover to date but that are faced by many weather-indexed insurance providers in developing country settings. One such issue lies in potential interactions between insurance products and collateral and limited liability loan default rules that could affect adoption of improved agricultural technologies (Carter et al., 2016). Additionally, standalone insurance has been shown to be ineffective in low-collateral environments, which are characteristic of many communities in SSA. Potential solutions to these problems include finding collateral substitutes and offering insurance in tandem with credit to internalize the positive externality insurance exerts on the stability of the lender’s portfolio (Carter et al., 2016). Another issue lies in the fact that farmers in SSA often belong to producer associations or other groups with common interests; this may lead to low take-up if positive externalities from one farmer purchasing insurance lead to free riding by other farmers (De Janvry et al., 2014). Additionally, coordination failure may prevent risk-averse farmers from taking up insurance if other group members do not purchase insurance. To overcome these group-based problems, it has been suggested that insurance policies be sold to groups of farmers instead of individual farmers (De Janvry et al., 2014).

5.3.5 Perspectives & Future Directions

As mentioned above, WorldCover is currently planning to expand into additional markets in Latin America and Asia, including India, Mexico, Brazil, and Indonesia, with expansion to India likely coming first (Bright, 2019). The firm is also planning to expand the list of crops it covers with its insurance products from maize, rice, and peanuts to also include cashews, coffee, and cocoa (Towett, 2019). Additionally, the firm is planning to expand beyond drought insurance to cover crop diseases as well, as many diseases are highly correlated with poor weather conditions (Socialfintech.org, 2017). Another initiative currently being pursued by WorldCover involves using blockchain to develop a premium sharing scheme wherein smallholder farmers can spread insurance costs to include other actors in the value chain, including larger commercial-scale producers and multinational corporations (Bird, 2018; Scoialfintech.org, 2017).

5.3.6 Main lessons

Several key takeaway lessons can be gleaned from WorldCover's experiences in developing and rolling out provision of weather-indexed crop insurance to resource-poor farmers in Sub-Saharan Africa. First, despite the proliferation of microfinance services, agro-tech products, and agricultural extension programs in the region, high levels of weather and natural catastrophe risks inherent in SSA's agricultural production systems prevent many smallholders from successfully utilizing these services to improve their yields and revenue streams. This underlines the need for risk transfer mechanisms such as crop insurance for smallholder farmers in SSA. Second, problems of adverse selection and moral hazard that affect traditional insurance platforms can be circumvented through blockchain-supported, parametric or weather-indexed insurance plans delivered through simple mobile phone technology, with pay-outs triggered by measured rainfall at a representative site passing below an established drought threshold. Blockchain is especially beneficial in creating seamless, efficient insurance delivery packages that provide digital records of transactions while still protecting the confidentiality and autonomy of end users. Third, insurance providers looking to create sustainable operations in low-resource settings can achieve profitability by building marketplaces where social impact investors can connect with farmers. Fourth, to reduce high marketing and logistical costs, insurance providers may consider seeking partnerships with organizations in the agricultural sector that have established relationships with existing farmer networks.

5.4 Linking truck drivers and owners to cargo in Nigeria: the experience of Kobo360

5.4.1 Context & Market Failures

Poor infrastructure is currently one of the biggest impediments to the development of logistics markets in Sub-Saharan Africa (Russon, 2019). Roads and related land transportation infrastructure, which are a public good, are underprovided in most countries in the region, leading to inefficiencies in transport of both goods and people. In some cases, unpaved roads in poor condition slow down travel significantly during the dry season and become impassable during the rainy season, cutting off entire communities or regions for days or weeks at a time (Hervey, 2020; Njoh, 2012). Indeed, a telling statistic from a recent OECD report reveals that only 19% of Sub-Saharan Africa's roads are currently paved (Julius, 2016). Additionally, many rural communities are not connected to road networks at all and have no vehicle access. Where road infrastructure does exist, including in many urban centres of SSA, this infrastructure is often poorly equipped and too meagre to handle daily traffic volumes, leading to traffic jams, accidents, and persistent slowdowns (Akorede, 2019). In addition to missing physical road infrastructure, the region is also lacking in infrastructure and mechanisms that help to ensure transparent and efficient movement of goods. This includes mechanisms for optimizing customs and cross-border trade, institutions to regulate drivers and road safety, and verification mechanisms and regulations to reduce transport price volatility (Giuliana & With, 2019).

This dearth of infrastructure and regulatory frameworks has created multiple market failures that reduce the efficiency of logistics markets throughout SSA. Transportation costs are often significantly higher in SSA than in other regions of the world due to high price volatility and a lack of regulation and transparency in transport markets. This makes it very difficult for African firms to compete effectively in international export markets (Giuliana & With, 2019). Undersupplied public goods infrastructure, lengthy transport times, dangerous road conditions, and lack of supporting institutional frameworks have resulted in underdeveloped logistics markets throughout the region, leading to reduced supply of goods and services in many areas (Giuliana & With, 2019). Additionally, informational asymmetries between transportation service providers and their potential customers lead to underutilization of existing truck and cargo space, creating further inefficiencies in the market. In fact, over 70% of the countries in the bottom three deciles of the World Bank's Logistics Performance Index are located on the African continent, due to poor reliability of supply chains and low a low level of resilience in the face of disruptions (Giuliana & With, 2019).

5.4.2 Technology

Despite the numerous and persistent challenges described above, recent years have seen a proliferation of African start-ups leveraging digital technologies to leapfrog missing infrastructures and transform Sub-Saharan Africa's logistics markets. Significant increases in mobile penetration throughout the region have led to a rapid expansion in the number of companies offering digital marketplaces where carriers and shippers can interact, digital platforms for courier services, and supply chain management platforms taking advantage of more widely available rapid communication and cloud services (Giuliana & With, 2019).

One start-up that has had particular success is the Nigerian firm Kobo360, which became the most funded logistics start-up in SSA after raising 20 million USD in a Series A investment round led by Goldman Sachs in August 2019 and 10 million USD in working capital financing from several Nigerian commercial banks (Bright, 2019; Nsehe, 2019; Giuliana & With, 2019). Kobo360 began by marketing itself as an "Uber for trucks" of sorts, developing and launching a mobile application where truck drivers, truck owners, cargo owners, cargo recipients, and other key players in logistics supply chains can interact, effectively formalizing and optimizing services throughout the supply chain and reducing inefficiencies (Giuliana & With, 2019; Russon, 2019). The firm's mobile application is available in English, Hausa, and Pidgin in order to facilitate use by drivers who commonly speak these languages (Bright, 2018). The company also has a call centre manned by staff able to monitor deliveries in real time and communicate with drivers, manufacturers, and distributors with the assistance of GPS satellite positioning (Russon, 2019). The firm's setup ensures a greater level of safety for cargo in transit and increased accountability and transparency in the logistics process.

Kobo360's forthcoming Global Logistics Operating System (GLOS), is a blockchain-enabled platform that will enable the firm to continue expanding the supply chain services it offers to customers (Bright, 2019). When a user creates a request via the mobile app, the digital platform gathers information about the customer, including geolocation of origin and the destination address and selects a truck type and other necessary parameters to make the shipment possible. Then, the request is matched with an available driver. The app aggregates reliable transport providers, provides customers with real-time updates about their shipments, creates a mechanism for faster and more reliable feedback, and improves efficiency and cost-effectiveness of supply chain activities for all involved actors, including truck drivers, truck owners, cargo owners, and cargo recipients (Kobo360, 2019).

5.4.3 Deployment & impacts

Kobo360 was founded in 2017 by Obi Ozor and Ife Oyedele II. Soon after, the firm was accepted into Y Combinator's 2018 cohort, and that same year it received 1.2 million USD in pre-seed funding led by

Western Technology Investment and supported by the Lagos-based angel investment fund Africa Future Limited (Bright, 2018). Additionally, as mentioned above, the company announced in 2019 that it had raised 20 million USD in a Series A round and 10 million USD in working capital financing from several Nigerian commercial banks. The firm also won “Disruptor of the Year” at the 2019 Africa CEO forum, and co-founder Obi Ozor was named both Young Business Leader of the Year and Innovator of the Year at the All Africa Business Leaders Awards (AABLA) in 2019 (Iyanda, 2019). With its success in securing significant investment funds, the company was able to expand from its home base in Nigeria to launch operations in Togo, Ghana, Kenya, and Uganda during the 2019 year (Nsehe, 2019). By the end of that year, Kobo360 had secured a total of 37.3 million USD in investments since its launch date from global institutional venture capital firms (Iyanda, 2019). The list of the firm’s investors includes the International Finance Corporation (IFC), Y Combinator, TLcom, and Goldman Sachs, among others (Iyanda, 2019).

In the two years between its launching in 2017 and 2020, Kobo360 moved over 760 million kilograms of goods worth an estimated 200 billion USD, aggregated a fleet of over 17,000 vehicles and drivers, and served thousands of small and medium enterprises (SMEs) and more than 80 global logistics companies with over 700 total formal clienteles, including Dangote Group, DHL, Unilever, OLAM, African Industries, Flour Mills of Nigeria, and Lafarge (Gerretsen, 2020; Iyanda, 2019; Nsehe, 2019).

5.4.4 Obstacles

In addition to traditional issues of sparse road networks, poor road conditions, and lingering inefficiencies in cross-border transport, the Covid-19 pandemic has presented a new series of challenges to Kobo360. The travel restrictions that have been put in place in Nigeria and other countries throughout SSA in response to the pandemic have resulted in the volume of goods moved by the firm dropping by a third, with drivers facing significant delays at ports and borders (Gerretsen, 2020). As of April 2020, the firm reported that 3,000 of its trucks had been grounded, shipping turnaround times had increased significantly, and millions of dollars in revenue were being lost, citing legal restrictions to movement as impediments to truckers seeking to make deliveries (Onaleye, 2020). The company has been providing its drivers with identification documents and urging the Nigerian government to clarify its cargo movement restrictions to ensure that logistics services transporting food and other vital goods are declared to be essential services (Onaleye, 2020).

5.4.5 Perspectives & Future Directions

Kobo360 is looking to benefit from Africa’s Continental Free Trade Area (AFCTFA), which was signed by all 54 of the continent’s countries in 2019 with a goal of reducing barriers and impediments to pan-African international trade. The company has announced a goal to expand into ten new countries by the end of 2020 (Bright, 2019), with its reach from its hub countries of Nigeria, Ghana, Togo, and Kenya already extending to include other countries such as Côte d’Ivoire, Burkina Faso, Niger, Uganda, Ethiopia, Tanzania, Rwanda, Burundi, Malawi, Democratic Republic of the Congo, South Sudan, Mozambique, Zimbabwe, and Zambia (Kobo360, 2019). Kobo360 has also announced its plans to expand beyond SSA to areas such as Egypt and Middle Eastern countries, with a goal of 1.2 million drivers using its platform within 3 years (Gerretsen, 2020).

As mentioned above, the firm is working on developing its blockchain-enabled platform, the Global Logistics Operating System (GLOS), which will enable the company to further increase the efficiency and security of the value chain services it offers to its customers. Additionally, Kobo360 is working on launching the Kobo Wealth Investment Network, or KoboWIN, which is a crowd-invest vehicle financing platform. Through this platform, truck drivers can finance trucks through citizen investors and pay them back over a 60-month period with interest (Bright, 2018). The firm is offering this service because there are currently limited options for vehicle financing in SSA markets, and the venture has the potential to increase the firm's fleet by up to 20,000 vehicles (Bright, 2018). The company has also recently launched the driver working capital finance program KoPay, an insurance product called KoboSafe, and KoboCare, a suite of packages offered to drivers including HMO packages and family tuition assistance (Bright, 2019).

5.4.6 Main lessons

There are several key takeaways from this case study on Kobo360. First of all, missing infrastructure and sparse regulations have led to significant inefficiencies in logistics and transportation networks throughout Sub-Saharan Africa, leading to market inefficiencies, high transaction costs, and low competitivity of SSA firms in international export markets. Second, digital platforms that harness mobile and blockchain technology to connect cargo owners and receivers with truck owners and drivers have the potential to leapfrog these missing physical and institutional infrastructures and optimize transport and logistics processes. Third, significant investment funds such as those obtained by Kobo360 are helpful and possibly necessary to achieving profitability and expansion into other markets. Fourth, governments can support e-logistics firms by reducing red tape in customs and cross-border transport and by including logistics and shipping in the list of essential services during public health emergencies such as the current Covid-19 pandemic.

5.5 Using drones to boost harvests and improve healthcare access: Investiv Group and Zipline

5.5.1 Context & Market Failures

Deficiencies in public infrastructure such as roads, electricity, potable water, sanitation, and telecommunications have created barriers to the efficient movement of goods, ideas, and people in many Sub-Saharan African countries, leading to market failures and stunted economic development (Signé, 2017). Roads and related land transportation infrastructure, which are a public good, are underprovided in most countries in the region, with public infrastructure projects often affected by incomplete information, lack of regulatory frameworks, poor implementation, inadequate causal analysis, lack of clearly defined and politically acceptable priorities, and other issues (Signé, 2017). This dearth of infrastructure and regulatory frameworks has created multiple market failures that result in reduced demand and supply of certain essential products (Giuliana & With, 2019).

One vital supply chain affected by poor infrastructure in many regions of SSA is healthcare logistics, including distribution of blood and medications which are often vital to save the lives of patients experiencing medical emergencies or chronic health conditions (Bulage et al., 2015). Other factors also combine to create an undersupply of medical supplies, including poorly developed procurement systems for imported drugs, lack of storage facilities, and weak manufacturing capacity (Pheage, 2017). Additionally, unreliable energy supply and cold chain facilities lead to frequent spoiling of blood (Pothering, 2019). These conditions have resulted in only 2% of drugs consumed on the African continent being produced there, with high prices for imported drugs due to logistical inefficiencies in the supply chain (Pheage, 2017). This renders residents of SSA significantly more susceptible to diseases including malaria, tuberculosis, and HIV/AIDS, that can be effectively treated with sufficient access to life-saving medications (Pheage, 2017).

Another sector affected by market inefficiencies is agriculture, where problems of access to inputs are compounded by inefficient input applications due to lack of farmer knowledge on how to optimize input use. A World Bank study of 22,000 farm households in six SSA countries shows that while access to inputs is more nuanced than commonly believed, input use often varies drastically across and within countries (World Bank, 2020). In many cases, input applications often do not take farmer perceptions of soil quality or other sources of environmental variation into account, leading to inefficient applications as mentioned above (World Bank, 2020). This suggests that in addition to logistical difficulties creating problems of access, market failures such as informational asymmetries often lead to under or overapplications, reducing profitability for farmers and often creating negative production externalities such as nutrient and chemical pollution. There are also important gender gaps in input provision and use in many SSA countries (Ali et al., 2016).

5.5.2 Technology

Drones are a powerful digital solution to many of the logistical supply chain and crop management problems mentioned above. Numerous development initiatives and private sector start-ups are using unmanned aerial vehicles (UAVs) or drones to leapfrog missing road and logistics infrastructures and improve inefficient crop management methods, delivering vital agricultural inputs and medical supplies to isolated rural areas and urban centres and increasing precision of crop management.

In the medical field, the start-up Zipline is harnessing UAV technology to deliver blood, medications, and other supplies to medical centres throughout the countries of Rwanda and Ghana, with plans to expand to other countries. Zipline manufactures its own UAVs, launching and landing systems, and logistics software in San Francisco, California, where the company is based (Bright, 2019; Giuliana & With, 2019). The company uses a fixed-wing style drone with a top speed of 128 km/h, a round trip range of 160 km, and capacity to carry up to 1.75 kg of cargo (McCall, 2019). Drone delivery of medical products occurs as the drone drops off a parachuted package from a height of approximately 80 meters which then lands in a designated area, often a small quadrangle in the courtyard or campus of a medical centre. Drones do not have to stop moving at any time between leaving the base warehouse, making a delivery, and returning to the base (Asiedu, 2019). In one instance, yellow fever vaccines were delivered to the New Tafo Government Hospital in the Eastern Region of Ghana in 21 minutes, a process that would have normally taken two hours at the very least if delivered by road (Asiedu, 2019). Drones can travel to any medical centres within an 80-kilometer radius of Zipline's distribution centres stocked with vaccines, medications, blood, and blood products (Asiedu, 2019).

In the agriculture sector, one company successfully using drone technology to increase access and precision of input usage for better crop management is the Ivorian start-up Investiv Group. Precision agriculture involves coordinated use of multiple technologies, including UAVs, cameras, sensors, and GPS devices that allow farmers to monitor their crops, optimize their use of inputs, conserve water, and reduce environmental impacts of input use (Commodity Port, 2019). For example, a UAV equipped with a camera and GPS device can take aerial images of a crop field, identifying specific areas of the field affected by nutrient deficiencies, drought stress, crop diseases, or pest and weather damage (Commodity Port, 2019). This information can then be used to optimize applications of fertilizer, irrigation water, and pest or disease management inputs, targeting areas of the field in specific need of these inputs and avoiding wasteful overapplications. Drones can also be used for aerial mapping of farmer plots which is often required in certification programs (Karim, 2020). Additionally, drones can be used for aerial spraying for disease, weed, and pest control, fertilizer applications, and even for spreading beneficial insects and replanting forests through aerial seeding (Hill, 2018). Application time is also greatly reduced through use of drones, with Investiv Group reporting that fertilizer can be applied by drone over a two-hectare field in just fifteen minutes (Okafor, 2019).

5.5.3 Deployment

Zipline was founded in 2014 in San Francisco, California. The company began operations in Rwanda in 2016 after a testing period with the Rwandan government, first delivering only blood and blood products during emergencies and later expanding to cover routine medications and vaccines (Asiedu, 2019; Bright, 2019). In 2019, Zipline launched operations in a second country, namely Ghana, after negotiating a partnership with the country's national government (Bright, 2019). Its operations commenced with delivery of medical products from a distribution centre in Omenako, located 70 kilometres north of the capital of Accra, with plans to build three more distribution centres before the end of 2019 (Asiedu, 2019). Zipline has procured funding through a partnership with UPS's non-profit foundation which will enable construction of necessary infrastructure and provision of logistical support; the company has also received additional funding through the Bill and Melinda Gates Foundation and Pfizer (Bright, 2019). The company has raised a total of 225 million USD over the last two years, achieving unicorn status in 2019 with a value of $1.2 billion (Pothering, 2019).

Investiv Group was co-founded in 2016 by Aboubacar Karim, an Ivorian entrepreneur who had recently completed graduate studies at Laval University in Quebec, Canada (Okafor, 2019). The company was recognized as one of the most promising start-ups in Côte d'Ivoire by the Ivorian Business Federation in 2017 (Flying Labs, 2020). In 2019, the firm announced that it had raised the equivalent of 400,000 USD in funds from an Ivorian holding company specializing in agriculture input provision after nine months of negotiation (Okafor, 2019). As of 2019, the company had received six different business awards, including first place in the start-up category at the German-African Business Summit in Ghana, Africa (Okafor, 2019).

5.5.4 Impacts

Since its founding, Zipline has been able to provide national distribution of medical products throughout Rwanda through its partnership with the Rwandan government. With the launch of the Zipline distribution centre in Omenako, Ghana, the firm is now able to deliver supplies to 500 medical centres within an 80-kilometer radius of that centre. With construction of its four distribution centres in Ghana scheduled to be finished by late 2019, the company should now be able to deliver 150 different medical products to 2,000 medical centres, servicing 12 million Ghanaians (Bright, 2019). Under its contract with the Ghanaian government, Zipline is obligated to make 600 on-demand flights per day from its four distribution centres (Pothering, 2019). In Rwanda, Zipline claims to cover 65% of the country's blood supply deliveries outside of Kigali, cutting medical supply waste in the areas it services by 95%. The company has already made over 13,000 deliveries in Rwanda and has expanded to cover 170 different medical products in that country (Pothering, 2019).

In terms of Investiv Group, as of 2019, the firm reported having already mapped and diagnosed approximately 8,000 hectares of farms and plantations and set up over 30 off-ground farms with capacity for aerial mapping, diagnosis, and application of inputs (Okafor, 2019). The firm is also partnering with KINEDEN, an organization that works in the cocoa bean exporting industry in Côte d'Ivoire, on certifying 9,467 farmers in 9 different cooperatives to help them access the cocoa bean export market. This involves collection of GPS data and aerial flyover mapping of a total of 28,744 hectares of cocoa farms (Karim, 2020).

5.5.5 Obstacles

Zipline has faced obstacles in convincing governments and public health ministries that its drone-based model is the optimal solution to existing healthcare logistics challenges. For example, before obtaining its contract with the Ghanaian government, the firm initially faced political pushback, with critics questioning whether it would not be more effective to invest in more basic infrastructure such as medical supplies and ambulances (Pothering, 2019). This suggests that in addition to pursuing profitability, entrepreneurs using novel, often unproven technologies must also face the burden of convincing potential partners that their technologies will work and be more efficient than alternative solutions.

For Investiv Group, while not an unforeseen setback, the firm must comply with Ivorian governmental regulations related to operation of privately owned drones in the Ivorian airspace, such as the *Règlement Aéronautique de Côte d'Ivoire relatif aux aéronefs télépilotés numéro 3009* (RACI 3009) which requires purchasing a license for drone operation from the Ivorian government (Suy, 2019). In fact, many SSA nations have enacted strict rules regulating drone usage, potentially wary of the potential surveillance issue inherent with allowing drones in their countries. Use of drones in agriculture also requires high manufacturing, operating, and maintenance costs, making them prohibitively expensive for many smallholder farmers. Additionally, with limited technical knowledge in many rural agricultural communities of SSA, the time and monetary costs of training farmers to use drones can be high (Odunowo, 2018).

5.5.6 Perspectives & Future Directions

Since the outbreak of the Covid-19 pandemic in 2020, Zipline has been delivering Covid-19 tests in Ghana and Rwanda in addition to its gamut of traditional medical supplies (Baker, 2020; De León, 2020). Additionally, since 2018, the firm has been planning to expand to other countries, participating in talks with governments of multiple countries in developing regions of Sub-Saharan Africa, South America, and Southeast Asia (Glauser, 2018). And although Zipline's services have the unique potential to leapfrog missing infrastructure in developing countries of SSA, the company is not only focused on emerging markets. For example, Canadian doctors approached Zipline cofounder Keenan Wyrobek after a presentation at the TEDMED 2018 conference asking him to consider bringing the firm's drone delivery services to Canada (Glauser, 2018). Zipline is also partnering with the state of North Carolina in the United States to start a pilot medical supplies delivery program there (Pothering, 2019).

Investiv Group has recently launched a partnership with SECO, a subsidiary of the Ivorian cotton agribusiness OLAM, testing drone-based plant health diagnostics and aerial fertilizer applications on cotton at an experimental site near Ferkessédougou in June of 2019 (Investiv Group, 2019). The goal of the tests was to quantitatively evaluate the effects of these technologies on cotton growth, with a long-term objective of progressively rolling out drone technology to all producers in OLAM's cotton supply chain (Investiv Group, 2019). The company is also partnering with the sugarcane agribusiness Sucrivoire to provide drone-based aerial fertilizer application services on 2,690 hectares of the company's sugarcane production lands, with a goal of further expanding in the sugarcane value chain as well (Investiv Group, 2019).

5.5.7 Main Lessons

This case study on the use of drone technology to leapfrog missing infrastructures and overcome market failures in the healthcare logistics and agricultural supply chains reveals several key points. First, drones have the capacity to reduce travel time and avoid waste or spoilage of goods in regions with poor road, electricity, and logistics infrastructures. Second, drones integrated with GPS devices, sensors, and cameras can revolutionize crop management, enabling farmers to practice precision agriculture and optimize their use of inputs to save money and protect the environment. Third, in order to be successful, firms using drones for healthcare logistics may need to build their own infrastructure where this is missing, including warehouses or distribution centres with cold storage capacity. Fourth, in the agriculture industry, there may be greater barriers to take-up where end users are often resource-constrained smallholder farmers with limited funds to invest in drones. Solving these issues requires sufficient funding, which may be procured through impact or social investment.

5.6 Unlocking green digital technologies to increase energy access in West Africa: the case of Lumos Global and off-grid solar home systems

5.6.1 Context & Market Failures

Despite positive trends in electricity access around the world, over 940 million people in 2017 still had no electricity access, representing 13% of the world's population; of this total, 591 million live in Sub-Saharan Africa (SSA) (Ritchie & Roser, 2019). Even this statistic fails to capture the difficult realities of energy access in remote, rural communities, where often less than 10% of a given community has access to electricity (USAID, 2016). For example, in Nigeria, only half of the country's households are connected to the electrical grid and only one quarter have regular access to electricity (Lumos Global, 2016). Most households and businesses without electricity have to rely on traditional methods of lighting such as candles, kerosene lamps, and diesel generators, which can be costly and hazardous (Orpaz, 2013), are time-consuming to set up, and can create negative externalities such as excess noise and indoor air pollution (USAID, 2016).

Lack of electricity access can cut workdays short for businesses and households alike, leading to lost revenues, lower educational achievement, and inflated household energy costs for tasks such as accessing light and charging phones (Tobias & Castro, 2020). Additionally, research has shown that unreliable electricity supply decreases firm sales, profits, and total factor productivity in SSA, with stronger effects for firms that do not own a generator (Cole et al., 2018). An econometric analysis of firm-level data from the World Bank Enterprise Surveys showed that decreasing power outage frequency in less-developed SSA countries to the average power outage frequency in South Africa would increase firm sales across the region by 85.1%, with increases of 117.4% for firms without a generator (Cole et al., 2018).

In addition to the economic impacts described above, insufficient energy access creates potential environmental problems as well. Faced with underdeveloped infrastructures and persistent electricity shortages, governments of countries in Sub-Saharan Africa and other developing regions often see little other choice pursuing exploitation of traditional, carbon-intensive energy resources to expand their countries' grids, producing negative externalities in the form of pollution and greenhouse gas emissions as a result. For these reasons, pursuing innovative, environmentally sustainable technologies that focus on renewable energy sources is tantamount to lifting populations out of poverty while ensuring continued mitigation of climate change impacts and reducing negative production externalities (Dagnachew et al., 2018; Suberu et al., 2013).

5.6.2 Technology

One firm that has been harnessing renewable sources of energy to solve problems of energy access in West Africa is Lumos Global. The company provides off-grid electricity services to households and small and medium enterprises (SMEs) in multiple Sub-Saharan African countries through solar energy technology. The firm's model combines solar energy with mobile payments and financing provided through existing cellular network providers, taking advantage of the relatively high rates of mobile penetration in many rural, off-grid communities where demand for electricity services is high. The firm's solar home system (SHS) is small enough to fit in a box, making it easy to transport on foot or by bicycle, and includes a solar panel activated by text message with sufficient capacity to charge small appliances such as mobile phones, laptop computers, electric fans, radios, and lights for a household or a business (Orpaz, 2013; USAID, 2016).

Customers are required to make an initial down payment, which was valued at approximately 20 to 30 USD in 2013, after which they make incremental payments of 0.50 USD per day or 3 USD per week over a period of five years until they have completely paid off the package and the SHS is unlocked (Orpaz, 2013). By 2019, the joining fee had increased to 40 USD; there is also a one-time 12 USD installation fee (Clowes, 2019). In this sense, Lumos offers a pay-as-you-go (PAYG), lease-to-own financial model through provision of an SHS to a household or business (Roach & Cohen, 2016). The capacity of the SHS is sufficient to power homes, small businesses, hospitals, schools, mosques, and churches (Roach & Cohen, 2016).

Lumos has opted to use airtime credit payments instead of traditional mobile money payments to increase its penetration into markets and communities where mobile money access is limited. This is a simple, easy-to-use payment mechanism for customers, but it requires a much more complex technology integration on the back end than does mobile money (Roach & Cohen, 2016). The service is enabled by machine-to-machine (M2M) connectivity and billing integration between the cellular carrier's billing platform and the Lumos back-end system. All SHS's are equipped with an embedded SIM card that facilitates two-way communication through the GSM network, enabling Lumos to remotely monitor energy use and control the system (Roach & Cohen, 2016).

Customers top up their phones with sufficient funds to pay for the service bundle of their choosing (3, 7, or 30 days of electricity access), after which they send an SMS indicating their chosen service package. At this point, the mobile provider deducts the customer's airtime account and notifies Lumos' back-end system, and Lumos then sends a command to the customer's SHS to unlock the system. This command is then received and executed by the SIM card embedded in the customer's SHS. Once the system is unlocked, customers receive power for the duration of their chosen package, and the SHS shuts down automatically once the package expires. At this point, the customer must top up with more airtime and request another service package via SMS as described above. While a service package is active, the SHS's embedded M2M SIM card regularly sends information on system usage and performance to the Lumos back-end system (Roach & Cohen, 2016).

5.6.3 Deployment

The company was co-founded as Nova Lumos in 2012 by Israeli entrepreneurs Nir Marom and Davidi Vortman, with pilot programs initially planned in Nigeria and Guinea through the mobile providers MTN Nigeria and Cellcom Guinea (Orpaz, 2013). With the outbreak of the Ebola epidemic in Guinea in 2014, Lumos decided to focus its pilot program entirely on Nigeria (Roach & Cohen, 2016). This program, which created an MTN Nigeria and Lumos co-branded service called MTN Mobile Electricity, was facilitated by a seed grant awarded to the firm in December 2013 by GSMA's Mobile for Development Utilities Programme (Roach & Cohen, 2016). In 2016, Lumos became a USAID Power Africa Partner, securing 15 million USD in financing from the U.S. government's development finance institution, the Overseas Private Investment Corporation (OPIC), to help the firm scale its business in Nigeria (USAID, 2016). Additionally, in 2016, the firm raised 50 million USD in debt funding from OPIC and 40 million USD in equity from a consortium led by Pembani Remgro Infrastructure Fund (PRIF), VLTCM, and ICV (Lumos Global, 2016).

In late 2017, Lumos Global announced its launch in Côte d'Ivoire, with plans to make its services available to the 10.5 million MTN Côte d'Ivoire subscribers in the country (Lumos Global, 2017). In 2019, the Nigerian government announced that it would be awarding part of a 75 million USD grant funded by the World Bank to Lumos; under the agreement, the firm receives a fee for each new SHS instalment from Nigeria's Rural Electrification Agency (REA) (Clowes, 2019).

5.6.4 Impacts

As of 2019, Lumos had already fitted over 100,000 solar home systems in Nigeria (Clowes, 2019), provided electricity to over 250,000 people, and created over 1,100 jobs in the country (Lumos Global, 2017). A CDC Group report published in 2020 investigating the impacts of Lumos' solar home systems on client quality of life and related outcomes in Nigeria found positive results, with 63% of respondents stating that Lumos' services were a "very good" or "good" value for their money (Lumos Global, 2020b; Tobias & Castro, 2020). Additional results revealed that 88% percent of customers reported the quality of their daily lives and their emotional well-being had improved as a result of using Lumos' solar energy package (Tobias & Castro, 2020). The study baseline showed that before using Lumos' services, 78 percent of customers had been connected to the government electricity grid but experienced unreliable electricity access, with 69 percent using generators to supplement electricity delivered by the grid; at endline, both of these figures had declined slightly, likely due to customers accessing Lumos as an alternative energy service. The report also revealed that 91 percent of Lumos customers were first-time users of solar energy services, and that the majority relied on these services to meet their daily needs while also continuing to use other energy sources (Tobias & Castro, 2020).

Additional findings from the study illustrate the potential of solar energy for increasing productivity and raising incomes. Nineteen percent of Lumos customers reported using electricity provided by their SHS for income-generating activities, with 80 percent of this group reporting increased incomes through improved electricity access (Tobias & Castro, 2020). Sixteen percent of Lumos customers reported using the SHS at their place of work; 60 percent of this group were shop owners and 25 percent owned a barbershop or a salon. The majority of these individuals were small business owners with an average of only two employees. Two thirds of business owners reported using a generator and were spending on average 42% more than home-use customers on electricity costs before adopting the Lumos SHS system (Tobias & Castro, 2020). Eight percent of business customers reported launching a new business as a result of subscribing to the Lumos SHS service.

Six months after purchase, 96 percent of Lumos' business customers reported that the business where they were using the SHS was their main source of income, an increase of 9 percentage points from baseline (Tobias & Castro, 2020). Follow-up surveys with business customers also revealed that 77 percent of clients reported their business had progressed as a result of using the Lumos SHS, with 14 percent reporting that their opening hours had increased as a result. Additionally, one third of business owners reported that the Lumos product had improved their daily lives outside of their business, and many had purchased a second system for home use (Tobias & Castro, 2020). These figures show the potential of off-grid solar energy systems to leapfrog missing electricity infrastructures, overcoming market failures caused by low energy access and raising productivity and revenues for SMEs and entrepreneurs.

5.6.5 Obstacles

The CDC Group customer survey included a question on customer satisfaction and loyalty, which researchers used to calculate a Net Promoter Score® (NPS) of 16 for Lumos Global, which is considered a fair score. Detractors, or those unlikely to recommend the service to a family member or friend, cited the expense of the payment plan, the challenges of using the SHS product, and dissatisfaction with customer service as reasons for giving a low rating (Tobias & Castro, 2020). Two thirds of customers also expressed a desire for a larger system with greater battery power and capacity, while 19 percent expressed a desire for lower prices. Additionally, males reported much higher rates of purchasing and relying on the SHS and had a higher NPS than female users, suggesting that the firm should make an effort to improve gender inclusivity in the design and delivery of its products (Tobias & Castro, 2020).

5.6.6 Perspectives & Future Directions

In 2020, Lumos announced that it had received additional funding from FMO, the Dutch entrepreneurial bank, to greatly expand its operations in Côte d'Ivoire. The company plans to provide energy to tens of thousands of households and small businesses throughout the country, providing approximately 200,000 people with reliable solar energy services (Lumos Global, 2020a). In describing its motivation for supporting Lumos, PMO cited the firm's commitment to leapfrogging technologies, enabling developing countries to bypass expensive, less efficient, and higher carbon-intensive energy systems and instead focusing on harnessing sustainable energy to lift vulnerable populations out of poverty.

In response to results obtained from the CDC Group customer satisfaction survey and other channels, Lumos has made several key adaptations to better serve its customers. For example, the firm has expanded its line of products to include both higher and lower-capacity packages, thus giving customers a wider range of options and achieving better customer-product fit. Lumos has also made improvements to its call centre technology and reinforced the reliability of its products. These changes have enabled 85% of customer issues to be addressed by the call centre staff directly, avoiding the need for a costly direct visit by a technician. To help the company better understand how to serve a diverse clientele base covering a wide swath of the socioeconomic spectrum, the CDC Group recommends that Lumos compare its results in serving its Nigerian customers with an analysis of the impact of its more recently launched operations in Côte d'Ivoire, as its Ivorian customer base is more rural and off-grid than its Nigerian clientele (Tobias & Castro, 2020).

5.6.7 Main Lessons

There are multiple key lessons that can be learned from this case study. First, there is a large potential for leapfrogging technologies such as off-grid solar to increase energy access in Sub-Saharan Africa while avoiding traditional carbon-intensive technologies. However, one literature review of decentralized electrification projects concluded that the effectiveness of the SHS is limited due to its small size, suggesting that larger mini-grids which combine benefits of both sustainability and flexibility, often through hybrid renewable energy models, can be more effective (Berthélemy et al., 2018; Berthélemy & Millien, 2018). Second, given the proven potential of electricity access to improve productivity and raise incomes, there is a great deal of interest among private sector investors, national governments, and international organizations in supporting innovative, sustainable energy solutions. Third, integrating with mobile network providers is an effective way for off-grid energy providers to gain customers, market their products, and facilitate take-up of services in Sub-Saharan Africa, where mobile penetration is often more widespread than the extent of electrical grids. Although airtime payments may be more technically complex in terms of the provider's back-end system development, they can nevertheless improve ease of use and access for clients in areas where mobile money penetration is low but mobile phone penetration is high. Fourth, pay-as-you-go is an effective mechanism for providing solar power at an affordable cost to clients, with many clients choosing shorter, lower-cost bundles – for example, 3-day bundles were significantly more popular than 7- and 30-day bundles in Lumos' Nigerian market (Roach & Cohen, 2016). Finally, although the majority of Lumos' systems are used in residential households, its off-grid solar systems have also been used by SMEs and entrepreneurs, with reported revenues, productivity, and opening hours improving as a result.

5.7 Streamlining municipal tax payments and water utility access for households and businesses: the experience of Sudpay in Senegal and CityTaps in Niger

5.7.1 Context & Market Failures

In many Sub-Saharan African (SSA) countries, municipal governments are faced with a shortage of funds for investing in delivery of basic public services such as educational and healthcare systems, road and other infrastructures, streetlights, and waste collection. Research has shown that these cash shortages are often exacerbated by high rates of tax fraud and evasion (Thibault, 2020). For example, some municipalities in Senegal have reported tax fraud rates of up to 40 percent, most jurisdictions collecting less than 70 percent of the funds they are due (Jackson, 2018b). It is estimated that corporate tax avoidance represents losses of up to 2 percent of GDP throughout SSA (Thibault, 2020). Informational asymmetries are at the heart of the tax evasion problem, with tax inspector hiring subject to issues of adverse selection and attempts to identify concrete evidence of tax evasion plagued by moral hazard problems. Additionally, traditional methods of tax enforcement and tax payment often involve high transaction costs.

Similar problems affect the provision of water and other utilities. Many SSA residents are not connected to utilities at all, or they become disconnected after being unable to pay for unexpectedly large bills over a period of several months (Gridley, 2020). Outstanding unpaid bills and large numbers of disconnected subscribers affect the ability of many SSA utilities to provide reliable services to communities. Additionally, sending personnel to issue and write off bills, collect payments, and disconnect subscribers adds to transaction costs (Gridley, 2020). In water markets, wasteful usage, high water losses, billing inaccuracies, and inefficient monitoring of water use due to informational asymmetries and high transaction costs further exacerbate financial difficulties for water utilities across the region (Andres, 2016; Kore, 2020). This leads to significant costs for both utilities and consumers, with an estimated 20 billion USD lost by utilities companies globally each year and an estimated 830 million people worldwide lacking access to household water (Gridley, 2020). Marginalized urban communities throughout SSA pay high monetary, time, and health costs as a result of inefficient household water prevision, and these costs stand to increase with high rates of urban population growth in many SSA countries (Kore, 2020).

5.7.2 Technology

With a growing number of fintech ventures cropping up across SSA, fintech is increasingly being proposed as an innovative means to leverage mobile and digital technologies to digitalize municipal tax collection (Sy et al., 2019). Among the fintech start-ups proposing innovative tax collection solutions is the Senegalese firm Sudpay. Its digital tax payments platform, TownPay, enables local governments to track and collect taxes from micro, small, and medium enterprises (MSMEs) through a B2G payments platform. The platform enables municipal governments to geolocate tax payment activities for all MSMEs registered in their jurisdictions (Shi, 2018). MSMEs are provided with proprietary mobile terminals and municipalities are given digital dashboards to use for tax collection (Bayen, 2019). Businesses are able to pay their taxes through simple cash payment, the Senegalese mobile money platform Tigo Cash, or the *Société Générale*'s electronic wallet platform, Yup (Gorwitz, 2018). To facilitate mobile money (MM) payments, Sudpay provides MSME taxpayers with SIM cards linked to their MM accounts to facilitate direct payment (Sudpay, 2019). For clients without MM accounts opting to pay their taxes in cash, the TownPay platform is principally used to confirm and geolocate tax payments. To finance the service, Sudpay deducts a 2% commission from all tax payments received by tax authorities, which it shares with its mobile operator and financial services partners (Gorwitz, 2018; Shi, 2018), and it collects additional commissions on digital credit and retirement savings products provided by its partners (Jackson, 2018b). This system allows municipalities to increase tax collection rates, reduce fraud, and increase their budgets for provision of basic public services including healthcare, education, infrastructure, waste collection, public lighting, and more (Bayen, 2019).

In the utilities field, GSMA states that aside from solar lighting, pay-as-you-go (PAYG) business models have shown the most promise with pre-paid clean water access (Sharma, 2017). One example of this is the start-up CityTaps, which is harnessing digital technologies to create innovative solutions to inefficiencies in water utilities markets in SSA through its CTSuite platform. This technology consists of a prepaid smart water meter installed at subscriber households and an integrated cloud-based software (CTCloud) that provides financial and operational data to utilities companies and consumers (Gridley, 2020; Kore, 2020). The smart water meters, called CTMeters, ensure that customers do not receive unexpectedly high water bills by providing a transparent, simple mechanism for water services provision and the ability to make micropayments on a PAYG basis (Haushofer, 2019).

The PAYG model lowers costs and increases transparency for customers, with payments made upfront through mobile money platforms such as Orange Money. Customers can top up their water balance at any time over phone, and water access is unlocked automatically via LoRA connectivity (Kore, 2020). New customers can subscribe at lower risk to the utility due to the prepaid payment model, and previously disconnected users can reconnect to the service while paying off their debts via small, daily micropayments (Kore, 2020). Utilities enjoy better financial health through real-time transfer of digital payments, and they pay a per-meter monthly subscription to CityTaps for the service (Gridley, 2020; Kore, 2020). Another advantage of the model lies in the cloud-based data gathered through the CTSuite system, which provides transparency for potential investors (Gridley, 2020). Functionality for the CTSuite system is provided through Internet of Things technology by means of an integrated management software and billing platform (Haushofer, 2019).

5.7.3 Deployment

Sudpay was cofounded in 2014 by Samba Sow and Pathé Faye in Dakar, Senegal. Sudpay's first project consisted of a P2G mobile payments app for bus fares called TTS-Trans, initially developed for the *Association des financements de transports urbains* (AFTU) of Dakar, available on fifty bus lines throughout the city as of 2018. Additional Sudpay clients include private schools processing tuition payments, the Baux-Maraîchers bus station in Dakar managing parking fee payments (also through the TTS-Trans app), and the *Championnat populaire* handling ticket sales through the P2B mobile payments app, TTS-Event (Gorwitz, 2018; Shi, 2018). The company has also developed a merchant-to-merchant B2B bill settlement app called TTS-Market (Shi, 2018). As of 2018, Sudpay claimed to be operating in eight Francophone Sub-Saharan African countries, including Senegal, Gabon, Côte d'Ivoire, Guinea, Burkina Faso, the Democratic Republic of the Congo (DRC), the Republic of the Congo, and Cameroon (VentureBurn, 2018), with plans to expand to a total of sixteen countries (Shi, 2018). TownPay was only available in Senegal as of 2018, but the firm plans to expand the platform's reach to include Côte d'Ivoire and Guinea as well (Shi, 2018). In 2018, the company received a grant from the GSMA Ecosystem Accelerator Innovation Fund worth 280,000 euros (approximately 328,800 USD), to further develop its TownPay product and roll it out in seven municipalities throughout Senegal (Bayen, 2019; Gorwitz, 2018). Sudpay also won the Senegal round of the Seedstars World global start-up competition in 2018 (Jackson, 2018a).

CityTaps was founded by Grégoire Landel and first deployed in Niamey, Niger in 2016 in partnership with the local water utility, *Société d'Exploitation des Eaux du Niger* (SEEN), a subsidiary of the French firm Veolia, and the French mobile network provider Orange. Initially, funds were raised from friends, family, and other individual donors, with several grants and prizes obtained in subsequent years. For example, the initial pilot system in Niamey, tested on 20 water meters, was funded by the GSMA Mobile for Development Utilities Innovation Fund (Gridley, 2020). CityTaps was later awarded 500,000 USD from US telecommunications company Verizon, 500,000 USD in convertible notes from the Global Innovation Fund (GIF) in 2018, and 1 million euros in non-dilutive funding from the French government in 2019 (Gridley, 2020). The firm has also raised 2.2 million euros from several impact investors (Kore, 2020). Following reception of funding from the French government, CityTaps signed a contract with Veolia Africa to scale its operations in Niger and Senegal (Haushofer, 2019).

5.7.4 Impacts

By June of 2019, when the GSMA Ecosystem Accelerator grant funding was drawing to a close, Sudpay had already enrolled 18,000 Senegalese MSMEs on the TownPay platform and was collecting approximately 40,000 USD in taxes per month (Bayen, 2019). The Sudpay platform is currently being used by nine different municipalities throughout the country of Senegal, with plans to expand to more municipalities in Senegal, Côte d'Ivoire, and Guinea (Bayen, 2019).

During its pilot phase in Niamey, CityTaps installed 1,325 CTMeters in households throughout the city, reaching over 10,500 beneficiaries (Kore, 2020). An evaluation of the firm's pilot phase found that the service had helped households save 94 percent on water costs per cubic meter consumed, with the SEEN water price of 0.21 USD per cubic meter 16 times cheaper than water sourced from traditional pushcart vendors (Kore, 2020). Customers also reported time savings of 1.5 hours per day, taking only 7 minutes to top up their mobile water account and leaving 86 more minutes per day for other activities (Kore, 2020). Survey respondents also reported perceived health improvements as a result of using the service (Gridley, 2020). There were also significant benefits for the utility, as the evaluation revealed bill payments were received on average 18 days in advance when using the CTSuite system, a significant improvement over the traditional system in which payments would sometimes be collected over 6 months after service delivery. SEEN also reported a revenue collection efficiency of 125 percent during the pilot phase (Kore, 2020).

The SEEN evaluation endline survey also found significant effects on mobile money take-up, with 43 percent of customers becoming new mobile money users, 15 percent becoming new Orange Money users, and 95.5 percent of previous mobile money users reporting using mobile money more frequently since subscribing to the CTSuite system (Kore, 2020). CityTaps was also able to negotiate a reduced transaction fee of 50 CFA francs for water balance top-ups of 500-1,000 CFA francs, a reduction from the typical 100 CFA franc transaction fee for other Orange Niger transactions (Kore, 2020). After successful installation of the first 1,325 meters, SEEN has recently ordered 10,000 additional CTMeters, with a goal of providing clean water to 100,000 urban residents by 2020 (Haushofer, 2019).

5.7.5 Obstacles

One obstacle faced by Sudpay early on in the pilot phase of its TownPay program was the refusal of municipal taxpayers to sign up for the platform. The firm has attempted to remedy this issue by linking MSME taxpayers and other public service users with desirable services such as microcredit through Senegalese microfinance institutions. This has proven to be an effective incentive for MSMEs to subscribe to the TownPay system and pay their municipal taxes (Jackson, 2018b).

On the side of utilities provision, one obstacle is that utilities poor in capital expenditures (CAPEX) cannot afford new digital and smart technologies on their own. This leads to lower demand and take-up of smart utilities services such as those offered by CityTaps in the absence of more innovative financing models. To overcome this obstacle, CityTaps is offering the PAYG service through a leasing model to utilities (Kore, 2020). The utility makes lease payments over time, and upfront capital costs are paid by investors, with the PAYG smart technology rendering investments low risk (Kore, 2020). In this model, there is a direct link between subscriber payments to the utility and utility lease repayments through CityTaps to investors, ensuring immediate and transparent payments and reducing defaults (Kore, 2020). In this manner, utilities can access the smart meter hardware and software upfront, leveraging cash flows to invest in expanding their service delivery (Kore, 2020).

5.7.6 Perspectives and Future Directions

Sudpay is currently working on rolling out financial services to its SME municipal taxpayer clients via TownPay, including loans, insurance, and microcredit (Gorwitz, 2018). The firm is also currently discussing partnership opportunities with Fintech, a Senegalese firm specializing in development of banking information systems, with a goal of integrating banks into the Sudpay platform (Gorwitz, 2018). The company is also currently in talks with the *Institution de prévoyance et de retraite* (IPRES) with a goal of developing and offering savings and retirement products to independent informal sector workers (Gorwitz, 2018). The company is currently seeking 1.5 billion CFA francs (approximately 2.5 million USD) to develop and deploy its two proposed subsidiaries in Côte d'Ivoire and Guinea (Gorwitz, 2018), and is also looking to expand into Mali (Bayen, 2019).

CityTaps announced plans to expand its services into Kenya in early 2020, partnering with the Malindi Water & Sewerage Company (MAWASCO), initially covering 30,000 customers in Malindi with plans to expand to the entire country in 2021 (Kore, 2020). Additionally, Orange Burkina Faso has purchased CTMeters for lease to the national Burkinabe water utility, the *Office National de l'Eau et de l'Assainissement* (ONEA) (Gridley, 2020; Kore, 2020). Besides Kenya and Burkina Faso, the firm has also announced plans to expand into Mali in partnership with the *Société Malienne de Gestion de l'Eau Potable* (SOMAGEP) and into Senegal (Kore, 2020). The firm hopes to raise a debt instrument of 2-5 million euros during the 2020 year, which would enable CityTaps to expand its leasing terms to utility clients and grow its customer base (Gridley, 2020). The firm is also in discussions with water utilities in several countries in Africa, Asia, and Latin America to launch new pilot programs, with a goal of contributing to the Sustainable Development Goals (SDG) and enabling the approximately one billion urban residents without access to potable household water to access these services at low cost (Haushofer, 2019).

5.7.7 Main Lessons

There are several key takeaways from this case study of Sudpay and CityTaps. First, tax collection and utilities service delivery and payments are negatively affected by numerous market failures and inefficiencies, including information asymmetries and missing infrastructure. Second, high rates of mobile phone penetration and mobile money use in Sub-Saharan Africa can be used to provide digital solutions to problems related to tax collection and utilities payments. Third, smart technology can make transactions both more transparent and more efficient, reducing fraud and waste. Fourth, SMEs may need incentives in the form of other financial services to encourage take-up and use of digital tax payment platforms. Fifth, pay-as-you-go utilities services can overcome CAPEX barriers by providing smart meter hardware and software on a lease-to-own basis to cash-strapped utilities, with fixed costs covered by investors and paid off over time.

6 Concluding remarks

Digital technologies are called upon to play a critical role where individuals and firms are strongly constrained in their daily interactions by large transactions costs, informational asymmetries, missing infrastructures and high levels of uncertainty. These market imperfections, endemic in many regions of Sub-Saharan Africa, have been accentuated by the Covid-19 crisis. In the current context of a global health and economic crisis, and in light of long-lasting handicaps to African development, the digitisation of African economies opens the door to new possibilities for removing obstacles to private sector expansion and job creation, in particular for Small and Medium Enterprises (SMEs).

The potential of basic digital technologies such as email, websites, and mobile money has not been fully exploited by African SMEs to date. While the uptake of mobile phone technology has facilitated the multiplication of Internet-based innovations throughout the region, this trend is hampered by the large Internet divide and low levels of Internet penetration among firms. In 2015, Internet penetration rates in SSA did not exceed 60 percent of the population, with some countries like Niger, Sierra Leone, or Guinea-Bissau displaying penetration rates lower than five percent of the population. According to World Bank Enterprise Surveys conducted between 2013 and 2018, less than 60% of SMEs were using email for their operations, and less than 30% used a website for business-related purposes. By comparison, 90% of large firms surveyed over the same period declared using email and/or a website during their activities. The development potential of digital technologies is therefore strongly constrained by their low diffusion and use by SMEs, which are as of yet the greatest job providers and wealth creators in the region.

Empirical evidence suggests that beyond the direct dividends of digital technologies adoption by SMEs, their diffusion across space and industries may have not yet reached the critical mass of users to unleash their expected positive network effects, knowledge spillovers, or economies of scale. However, there is a subsequent risk that their burgeoning diffusion only benefits first-movers, large and productive firms with sufficient absorptive capacity, at the expense of more fragile ecosystems, thereby concomitantly provoking revenue losses, job destruction, or firm exits. We indeed find evidence of negative spatial spillovers on firm-level sales and employment, explained by localisation diseconomies, that is, by the negative spillovers of email diffusion among firms working in the same location and industry. These results therefore lend credibility to the hypothesis that email diffusion increases competition between firms, and primarily benefits the most performing ones, as already evidenced in other studies (Bustos, 2011; Paunov & Rollo, 2016).

However, our empirical analysis, in line with recent findings on digitisation and job creation in Africa (Hjort & Poulsen, 2019), supports that the net dividends of digital technologies on SMEs are positive. Analyses of the relationship between digital technology usage (i.e. e-mail, websites, and mobile money) on firm-level performance indicators suggest that firms adopting digital technologies have more workers, higher sales and higher exports, are more productive, and potentially generate positive spillovers on other firms. On the other hand, when the diffusion of these technologies remains limited, there is a risk that they benefit only the most highly performing or innovative companies, and they can generate negative spillover effects on the rest of the entrepreneurial ecosystem. Such evidence of thresholds in digital spillover effects suggests that the impact of digital technologies diffusion could be much larger if the digital divide within industries and locations is lower, and if the technology absorption capacity of firms is greater. Therefore, our analysis gives additional support to legitimize key areas of intervention identified by development institutions and agencies: ensuring that the regulatory framework in the telecommunications and banking sectors is conducive to sustained investments in digital infrastructure and to the expansion of digital technologies and related services at affordable prices, developing digital skills and promoting digital entrepreneurship, and extending social protection coverage to protect the potential "losers" of the digitalisation process (Banga & Te Velde, 2018; World Bank, 2019; Choi et al, 2020; IMF, 2020;).

The case studies on first movers and innovators harnessing digital technologies to overcome market failures affecting multiple sectors in SSA economies reveal key information on firm deployment, use of digital technologies, preliminary impacts, and challenges and obstacles to operations. The digital solutions concocted by these firms are often multifaceted and innovative in nature, combining such diverse technologies as cloud computing, blockchain, mobile money and airtime payments, mobile applications, drones, and digital platforms where service providers and clients can transact with one another. These firms have provided solutions to overcome barriers created by imperfect information, high transaction costs, underdeveloped market structure, and missing infrastructures, increasing market efficiency for both consumers and producers. The firms detailed in the report are operating in diverse sectors, including e-commerce, Insurtech, precision agriculture, medical logistics, transportation logistics, provision of electricity and municipal water services, job and gig economy platforms, and payment of municipal taxes. Many firms have won prestigious awards and secured significant investment funding, and several have shown significant positive impacts on both client and producer welfare as measured by econometric impact evaluations. In contrast, many firms have also been faced with challenging setbacks, including unforeseen issues with digital technology, bureaucracy and red tape, low take-up of services, and access to finance. Despite these challenges, the preliminary successes of these firms suggest that opportunities for leveraging innovative digital technologies to overcome market failures in SSA economies are significant.

Acknowledgement

We are thankful to Florian Leon (Ferdi) who has carefully reviewed and commented this manuscript, and for the insightful discussions with Chloé Duvivier (Irstea), Luc Jacolin (banque de France), Maëlan LeGoff (Banque de France), Jules Armand Tapsoba (IMF), and Martha Tesfaye Woldemichael (IMF), which nurtured this report. We are also grateful to Olivier Santoni (Ferdi) who contributed to the calculation and calibration of instrumental variables. Some empirical estimations conducted within this report have been used as inputs for the IMF's *Sub-Saharan Africa Regional Economic Outlook*, Chapter 3, 2020.

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Appendixes

Appendix A. Enterprise Surveys summary statistics

A.1. Standard Enterprise Survey Composition, SMEs, by country & year.

Country	2006	2007	2009	2010	2011	2013	2014	2015	2016	2017	2018	Total
AGO	419	0	0	315	0	0	0	0	0	0	0	734
BDI	261	0	0	0	0	0	145	0	0	0	0	406
BEN	0	0	139	0	0	0	0	0	0	0	0	139
BFA	0	0	334	0	0	0	0	0	0	0	0	334
BWA	301	0	0	223	0	0	0	0	0	0	0	524
CAF	0	0	0	0	145	0	0	0	0	0	0	145
CIV	0	0	493	0	0	0	0	0	226	0	0	719
CMR	0	0	292	0	0	0	0	0	202	0	0	494
COD	329	0	0	317	0	504	0	0	0	0	0	1,15
COG	0	0	135	0	0	0	0	0	0	0	0	135
CPV	0	0	131	0	0	0	0	0	0	0	0	131
ERI	0	0	175	0	0	0	0	0	0	0	0	175
ETH	0	0	0	0	505	0	0	607	0	0	0	1,112
GAB	0	0	160	0	0	0	0	0	0	0	0	160
GHA	0	462	0	0	0	659	0	0	0	0	0	1,121
GIN	216	0	0	0	0	0	0	0	137	0	0	353
GMB	167	0	0	0	0	0	0	0	0	0	0	167
GNB	157	0	0	0	0	0	0	0	0	0	0	157
KEN	0	510	0	0	0	622	0	0	0	0	446	1,578
LBR	0	0	145	0	0	0	0	0	0	124	0	269
LSO	0	0	120	0	0	0	0	0	0	0	0	120
MDG	0	0	369	0	0	449	0	0	0	0	0	818
MLI	0	483	0	348	0	0	0	0	150	0	0	981
MOZ	0	448	0	0	0	0	0	0	0	0	273	721
MRT	232	0	0	0	0	0	125	0	0	0	0	357
MUS	0	0	340	0	0	0	0	0	0	0	0	340
MWI	0	0	99	0	0	0	439	0	0	0	0	538
NAM	311	0	0	0	0	0	552	0	0	0	0	863
NER	0	0	139	0	0	0	0	0	0	136	0	275
NGA	0	1,845	0	0	0	0	2,487	0	0	0	0	4,332
RWA	196	0	0	0	204	0	0	0	0	0	0	400
SDN	0	0	0	0	0	0	614	0	0	0	0	614
SEN	0	484	0	0	0	0	554	0	0	0	0	1,038
SLE	0	0	138	0	0	0	0	0	0	20	0	158
SWZ	272	0	0	0	0	0	0	0	0	0	0	272
TCD	0	0	131	0	0	0	0	0	0	0	139	270
TGO	0	0	136	0	0	0	0	0	94	0	0	230
TZA	374	0	0	0	0	733	0	0	0	0	0	1,107
UGA	526	0	0	0	0	696	0	0	0	0	0	1,222
ZAF	0	737	0	0	0	0	0	0	0	0	0	737

ZMB	0	420	0	0	0	662	0	0	0	0	0	1,082
ZWE	0	0	0	0	453	0	0	0	505	0	0	958
Total	**3,761**	**5,389**	**3,476**	**1,203**	**1,307**	**4,325**	**4,916**	**607**	**1,314**	**280**	**858**	**27,436**

A.2. Standard Enterprise Survey Composition, SMEs, by industry.

Industry	Freq.	Percent
Other Manufacturing	7291	26.57
Retail	5233	19.07
Food	2234	8.14
Textiles & Garments	1467	5.35
Other Services	856	31.20
Other	720	2.62
Hospitality & Tourism	465	1.69
Wholesale	369	1.34
Metals and machinery	343	1.25
Furniture	329	1.20
Services of Motor Vehicles	161	0.59
Transport	150	0.55
Chemicals & Chemical Products	114	0.42
Total	**27,436**	**100.00**

A.3. SME sample composition: mobile money variable

Country ISO_code	2013	2016	2017	2018	Total	No mobile money use	Mobile money use
CIV	0	226	0	0	226	166	60
CMR	0	202	0	0	202	180	22
GHA	659	0	0	0	659	624	35
GIN	0	137	0	0	137	131	6
KEN	622	0	0	446	1,068	430	638
LBR	0	0	124	0	124	89	35
MLI	0	150	0	0	150	127	23
NER	0	0	136	0	136	119	17
SLE	0	0	20	0	20	11	9
TCD	0	0	0	139	139	123	16
TGO	0	94	0	0	94	82	12
TZA	733	0	0	0	733	426	307
UGA	696	0	0	0	696	380	316
ZMB	662	0	0	0	662	639	23
Total	**3,372**	**809**	**280**	**585**	**5,046**	**3,527**	**1,519**

A.4 Pairwise correlation matrix, standard ES variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1. Real annual sales (ln, USD)	1.00																						
2. Real annual sales / worker (ln, USD)	0.93	1.00																					
3. Direct & indirect exports (ln, USD)	0.28	0.15	1.00																				
4. # of (perm. & temp.) workers (ln)	0.48	0.14	0.37	1.00																			
5. # of temp. workers (ln)	0.20	0.08	0.24	0.45	1.00																		
6. # of perm. workers (ln)	0.48	0.14	0.36	0.99	0.35	1.00																	
7. # perm. prod. workers (ln)	0.51	0.18	0.43	0.95	0.35	0.96	1.00																
8. # perm. non prod. workers (ln)	0.49	0.22	0.41	0.82	0.36	0.82	0.70	1.00															
9. # perm. skilled prod. workers (ln)	0.41	0.13	0.37	0.79	0.30	0.80	0.84	0.58	1.00														
10. # perm. unskilled prod. workers (ln)	0.38	0.16	0.29	0.62	0.27	0.63	0.64	0.52	0.26	1.00													
11. Email use	0.35	0.21	0.24	0.41	0.20	0.40	0.47	0.49	0.40	0.32	1.00												
12. Website use	0.26	0.12	0.24	0.38	0.17	0.38	0.42	0.43	0.39	0.25	0.49	1.00											
13. Mobile money use	-0.16	-0.18	0.01	0.00	0.10	-0.02	-0.04	0.00	-0.04	0.00	-0.04	0.07	1.00										
14. % of state ownership	0.02	0.01	0.03	0.02	0.00	0.02	0.03	0.04	0.03	0.01	0.02	0.02	-0.02	1.00									
15. % of foreign ownership	0.21	0.14	0.18	0.21	0.10	0.21	0.26	0.25	0.21	0.16	0.17	0.15	-0.11	0.00	1.00								
16. % dir. & indir. Exports in sales	0.09	0.00	0.76	0.22	0.17	0.21	0.25	0.22	0.22	0.15	0.13	0.13	-0.02	0.02	0.14	1.00							
17. Firm’s age (ln, years)	0.18	0.07	0.20	0.32	0.14	0.31	0.30	0.31	0.26	0.19	0.17	0.18	0.04	0.02	0.04	0.09	1.00						
18. Initial # perm. FT employees (ln)	0.33	0.09	0.28	0.67	0.25	0.67	0.67	0.59	0.57	0.43	0.28	0.28	-0.04	0.04	0.20	0.19	0.19	1.00					
19. Manager experience (ln, years)	0.13	0.06	0.13	0.20	0.09	0.20	0.15	0.13	0.15	0.08	0.15	0.10	0.02	0.02	0.03	0.06	0.53	0.11	1.00				
20. Bank loan	0.21	0.11	0.16	0.25	0.20	0.24	0.28	0.31	0.22	0.21	0.22	0.15	0.09	0.01	0.04	0.07	0.12	0.12	0.10	1.00			
21. Elec. outages losses (% annual sales)	-0.10	-0.10	-0.02	-0.02	0.03	-0.02	-0.05	-0.05	-0.04	-0.05	-0.04	-0.02	0.01	-0.01	-0.03	0.01	0.03	0.01	0.00	-0.01	1.00		
22. Insecurity losses (% annual sales)	-0.06	-0.06	0.00	-0.03	0.03	-0.03	-0.04	-0.02	-0.04	-0.01	-0.03	-0.01	0.03	0.00	-0.01	0.02	0.01	-0.01	0.00	0.03	0.13	1.00	
23. Greatest obstacle: informal compet.	-0.02	0.01	-0.04	-0.05	0.01	-0.05	-0.08	-0.05	-0.07	-0.04	-0.01	-0.04	0.01	-0.01	-0.02	-0.05	0.05	-0.03	0.07	0.02	0.03	0.03	1.00

Appendix B. Spatial spillovers: large firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Real annual sales (USD)		Real annual sales / worker		Direct & indirect exports (USD)		# of workers	
Firm use								
email	0.962***	0.948***	0.868***	0.861***	0.152	0.128	0.132**	0.131**
	(0.291)	(0.292)	(0.308)	(0.308)	(1.083)	(1.088)	(0.0523)	(0.0522)
website	0.245	0.261*	0.00885	0.0209	1.884***	1.914***	0.145	0.148
	(0.152)	(0.149)	(0.153)	(0.154)	(0.515)	(0.512)	(0.113)	(0.112)
Location %								
Email	2.582***		1.690***		4.496		0.333**	
	(0.942)		(0.630)		(3.958)		(0.133)	
Website		3.785**		2.967***		7.008		0.823**
		(1.508)		(0.853)		(5.663)		(0.402)
N	1,593	1,593	1,406	1,406	1,593	1,593	1,615	1,615
R^2	0.731	0.731	0.712	0.712	0.282	0.282	0.276	0.276

Standard errors in parentheses are robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Controls are included in the regressions but not reported in the table. $d_{j,l,t}$ dummies are replaced by location dummies, $d_{j,l}$. In columns (5) and (6), the share of direct and indirect exports is excluded from the set of control variables because this control variable was used to construct the dependent variable.

Appendix C. IV estimations using SMC shock-based IVs (IV2 and IV3).

	(1)	(2)
Var dep (ln):	Total sales (USD)	
	1st stage est: $\text{Email}_{i,j,t}$	
IV2	-4.034***	-4.034***
	(0.168)	(0.169)
IV3	-2.021***	-2.021***
	(0.084)	(0.084)
SW multivariate F-test	293.52***	208.57***
	1st stage est: $\text{Email\_location}_{j,t}$	
IV2	-	-3.142***
	-	(0.041)
IV3	-	-1.563***
	-	(0.021)
SW multivariate F-test	-	136.49***
	2nd stage estimates	
$\text{Email}_{i,j,t}$	**0.851****	**2.678*****
	(0.401)	**(0.675)**
$\text{Email\_location}_{j,t}$	-	**-2.520****
	-	**(0.998)**
Dummies	Country-year-industry; Location	
Hansen test P-value	0.19	-
KP Rk Wald F stat.	293.52	52.18
N	14,953	14,953

Two-stage GMM standard errors in parentheses, robust to heteroscedasticity and clustered by country-year-location. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IV2's time-window is [t;t-2]. IV3's time-window is [t;t-3]. Controls are included in the regressions but not reported in the table.

"Sur quoi la fondera-t-il l'économie du monde qu'il veut gouverner? Sera-ce sur le caprice de chaque particulier? Quelle confusion! Sera-ce sur la justice? Il l'ignore."

Pascal

Créée en 2003, la **Fondation pour les études et recherches sur le développement international** vise à favoriser la compréhension du développement économique international et des politiques qui l'influencent.

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