Policy Research Working Paper 9945

The Impact of Internet Access on Innovation and Entrepreneurship in Africa

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WORLD BANK GROUP
International Finance Corporation
February 2022

Policy Research Working Paper 9945

Abstract

This paper investigates the effects of access to high-speed internet on innovation and entrepreneurship in Africa. The identification strategy exploits the staggered arrival of submarine internet cables to the coast of Africa and the subsequent rollout of terrestrial fiber network across the continent. The findings show a positive effect of access to high-speed internet on innovation at the firm level, with availability of digital skills within the firm playing a key role in the internet-innovation nexus. The paper also finds evidence of internet-induced entrepreneurship: the probability that a household establishes a non-farm business increases when connected to the internet. However, the increase in entrepreneurial activities is largely concentrated in the service sector.

This paper is a product of the Development Impact Department, International Finance Corporation. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at ghoungbonon@ifc.org, jmensah2@ifc.org, and ntraore3@ifc.org.

The Impact of Internet Access on Innovation and Entrepreneurship in Africa[*]

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JEL: O12, O32, L26, N77

Key words: High-speed Internet, Innovation, Entrepreneurship, Africa

[*]We thank participants at the CSAE Conference 2021, Private Sector Development Research Network (PSDRN) Conference 2020, and seminars at IFC and World Bank for their helpful comments. Comments and support from Moussa Blimpo, Mark Dutz, Albert Zeufack, Valentina Saltane, Camilo Mondragon-Velez, and Issa Faye are deeply appreciated. This paper was supported by the research program at IFC's Sector Economics and Development Impact Department. The paper is also background paper for the World Bank Flagship Report on "Digital Africa for Inclusive Growth". All errors and views expressed in this paper are those of the authors. They do not necessarily represent the views of the International Finance Corporation/World Bank Group.

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1 Introduction

Many African countries are currently grappling with high levels of youth unemployment. The slow growth of productive sectors relative to population is often cited as a major cause of unemployment in the region (Goñi and Maloney, 2014). Overcoming these challenges requires, among other things, enabling innovation and entrepreneurship. In Africa, access to high-speed Internet can support employment through increased firm entry, productivity growth and export (Hjort and Poulsen, 2019). However, the innovation and entrepreneurship channels, which are critical for long run growth and employment, are yet to be investigated.

Increased access to high-speed Internet can support innovation by enabling the uptake of information and communication technologies with the potential to offer a competitive advantage to firms in terms of reduced cost, improved quality or expanded product range. Examples of such technologies include a web portal to enable online ordering/booking by clients, a cloud computing platform to automate various business functions, or a social media platform to advertise products and services. In an oligopolistic market with fixed cost of entry, the potential competitive advantage offered by Internet access would result in a higher rate of innovation for leading firms, compared to laggards. However, in a free entry scenario, the revenue derived from such advantage is competed away by new entrants, resulting in reduced incentive to innovate. The overall impact of Internet access on innovation remains an empirical question.

Likewise, increased access to high-speed Internet can support entrepreneurship by reducing barriers to entry, but can also limit the incentive to start a business due to increased intensity of competition in the market. Internet access reduces a number of economic costs (Goldfarb and Tucker, 2019), including search and transportation costs, by supporting the expansion of online platforms that connect firms to clients and suppliers in a more convenient manner than offline alternatives and enable the introduction of new services and business models that expand the size of the market. For instance, e-commerce platforms such as Amazon, Jumia,[1] and

[1] The largest e-commerce platform in Africa

Alibaba have become popular trading platforms for millions of people around the world. These platforms offer buyers and sellers an opportunity to usurp the constraints of the traditional "brick-and-mortar" marketplace, and trade across wider geographical boundaries. As a result, firms, particularly micro-small-and-medium scale enterprises (MSMEs) which hitherto could not afford to trade in traditional markets, can now utilize these online platforms at a much lower cost, and even reach a much larger market.[2]

To buttress these assertions, Figure 1a for instance shows a positive cross-country correlation between the Internet access and the share of MSME's using E-commerce platforms for trading, thus suggesting that the Internet provides a platform for small firms to trade. Figure 1b also shows that higher Internet access is associated with higher rates of innovation across countries. While these relationships may not be causal, they provide suggestive evidence that Internet access plays a role in the cross-country differences in entrepreneurship and innovation rates.

In this paper, we estimate the causal effect of Internet access on innovation and entrepreneurship by leveraging the recent expansion in access to high-speed Internet in Africa. Specifically, the paper is in two strands: first, we estimate the effect of high-speed Internet on firm innovation. We focus on process and product innovation and explore the complementary role of competition, skills and IT equipment. To this end, we leverage a unique dataset on innovation activities among firms in 10 African countries. Second, we examine how access to high-speed Internet is spurring entrepreneurship in Africa. Using household panel data from five African countries, we estimate the effect of access to high-speed Internet on the probability of households (individuals) operating (establishing) a non-farm business. We also analyze the effect across sectors (i.e., agribusiness, service, manufacturing) to identify sectors where entrepreneurial activities are more responsive to Internet access.

The staggered arrival of submarine Internet cables to Africa between 2009 and 2014, and the

[2]In most cases firms using online trading platforms are able to reach customers in international markets without having to go through the bureaucracy of international trading arrangements that hitherto were required in the more traditional markets.

subsequent roll out of terrestrial fiber Internet network across the African continent provide a quasi-experimental setting to causally estimate the effect of access to high-speed Internet. Like in Hjort and Poulsen (2019), our identification strategy therefore exploits plausibly exogenous spatial and time variations in access to high-speed Internet in a difference-in-difference design as well as an instrumental variable approach. To this end, we match spatial data on the roll out of high-speed Internet with geo-referenced data on households and firms in several African countries.

Two main findings emerge from the paper. First, we find evidence of a positive impact of Internet access on both process and product innovation in Africa. Specifically, access to Internet increases the probability of a firm undertaking process and product innovation by 20 and 12 percentage points (pp) respectively. The effect on process innovation largely stems from the digitization of business functions such as sales, distribution and marketing, and is boosted by the availability of advanced digital skills within the firm. The effects of competition intensity and the availability of ICT equipment remain limited.

Second, we find evidence of a positive impact of Internet access on entrepreneurship in Africa. The probability that a household operates a non-farm business increases by 17 pp once the community gets access to high-speed Internet. Interestingly, we find that the effects are largely concentrated in households establishing businesses in the service sector compared to manufacturing and agribusiness. The relatively low entry cost of establishing service related businesses is a plausible explanation for this result. Overall, the findings from this paper suggest a positive impact of access to high-speed Internet on innovation and entrepreneurship in Africa.

The remainder of the paper is structured as follows. Section 2 provides an overview of the related literature, and section 3 presents some background information about the roll out of high-speed Internet in Africa. In section 4, we outline the theoretical framework underlying the relationship between Internet access, innovation and entrepreneurship, while Section 5 presents and describes the data used in the analysis. In section 6, we present the empirical strategy and discussion of results on the effects of Internet access on firm innovation. Similarly in section 7, we present the empirical strategy and results on the effects of Internet on entrepreneurship. We conclude the paper in section 8 with a summary of the findings and policy implications.

2 Related Literature

This paper makes three main contributions to the literature. First, it builds and extends on the strand of literature on the economic impact of broadband Internet. To date, majority of studies on the impact of Internet access have focused on the effects on: firm performance (DeStefano et al., 2018; Hjort and Poulsen, 2019), labor market (Kuhn and Skuterud, 2004; Atasoy, 2013; Akerman et al., 2015; DeStefano et al., 2018; Hjort and Poulsen, 2019; Zuo and Kolliner, 2020), trade (Kneller and Timmis, 2016; Malgouyres et al., 2019; Fernandes et al., 2019) and trust in government (Guriev et al., 2020). Available evidence suggest that access to Internet boosts firm performance via a rise in sales (DeStefano et al., 2018; Hjort and Poulsen, 2019) and productivity (Hjort and Poulsen, 2019). The benefits of Internet also extend beyond firms to the labor market. Evidence from Norway suggest the Internet can be a skill-biased technology, by improving (worsening) the labor market outcomes of (un)skilled workers (Akerman et al., 2015). However, recent evidence from Africa suggests otherwise as both skilled and unskilled workers benefit from the arrival of fast Internet (Hjort and Poulsen, 2019). Nonetheless, very little is known about how the Internet affects firm entry, particularly MSMEs, which constitute the greater share of firms in most emerging economies, as well as the effects on innovation. This paper contributes in this regard.

Secondly, we contribute to the growing strand of literature on the role of modern technologies such as mobile phones and Internet in economic transformation in developing countries which were late adopters of these technologies (Aker and Mbiti, 2010; Beuermann et al., 2012; Hjort and Poulsen, 2019; Manacorda and Tesei, 2020; Masaki et al., 2020; Bahia et al., 2020). Masaki et al. (2020) and Bahia et al. (2020) for instance, find that mobile broadband Internet is associated with increased household welfare in Senegal and Nigeria, with increased labor force participation as a plausible channel. Our findings of innovation and entrepreneurial activities induced by Internet access contributes to the understanding of how Internet stimulates development in local economies and its associated impact on household welfare.

Third, we add to the literature on the drivers of innovation and entrepreneurship in developing countries (Blattman et al., 2014; Fafchamps et al., 2014; Banerjee et al., 2017; McKenzie, 2017). A recent review by Jayachandran (2020) shows a huge gap in the literature in terms of the effects of ambient infrastructure such as access to electricity, Internet, and mobile phones on entry and performance of firms, despite the increasing trend in uptake of these infrastructure by households and firms in these countries. Thus, findings from this paper contribute to our understanding of the role of modern infrastructure in spurring innovation and entrepreneurship in the developing world.

3 Background: Submarine Internet in Africa

In the 1990s and early 2000s, Internet connection between Africa and the rest of the world was transmitted mainly via satellite. The only submarine Internet cable connecting Sub-Saharan Africa (SSA) to Europe was the "SAT-3/WASC", constructed in 2002, connecting few countries (Senegal, Ghana, Nigeria) on the West Coast and South Africa.[3] This period was characterized by low Internet speed and high prices, thereby limiting the uptake of quality connectivity. To expand access to quality connectivity, African governments together with a consortium of private investors and multilateral development banks embarked on a series of investments into the construction of undersea fiber-optic Internet cables linking Africa to Europe and the rest of the world. The cables were laid on the sea-bed starting from the United Kingdom, France, Spain and Portugal and linking several African countries on the East and West Coast through to

[3] This submarine cable did not significantly affect the Internet landscape as the cost was very high and also low bandwidth speed.

South Africa.

In 2009, the push for increased Internet connectivity with Europe via submarine cables began to be realized with arrival of several cables. Between 2009 and 2014, at least 10 submarine cables arrived on the African shore lines. Figure 2 shows the gradual arrival of the submarine cables between 2009 and 2015. Once the cables reached the landing points (along the coast) in the respective countries, they were connected to a network of terrestrial[4] fiber network connecting several cities and towns in the country. This forms the fiber optic backbone network, i.e., the middle-mile. Along the fiber backbone network, a series of nodes were constructed to serve as connection points to the last mile network: mobile and fixed Internet access. The construction (expansion) of the fiber backbone network was also undertaken over time and continues to be expanded in many African countries.[5] As of June 2019, a total of 1.025 million kilometers of fiber network were in operation up from 278,056 km in June 2009.[6] Estimates from Hamilton Research suggest that about 54.2% of the population in SSA lived within 25km from an operational fiber-optic node network in 2018 up from about 31% in 2010.

For landlocked countries, connection to the submarine cables were made possible through bilateral connections with neighboring coastal countries via cross-border links and the fiber backbone network of neighboring coastal countries.[7] In some instances such as the ACE submarine cable, members of the consortium included companies from landlocked countries (e.g., Orange Mali, Orange Niger). Many of the bilateral arrangements for cross-border links were made prior to the arrival of the cable.[8] As at the end of 2018, only three African countries (Central African Republic, Eritrea, and South Sudan) lacked access to submarine Internet cables. Also with the exception of Guinea-Bissau and Eritrea, every seaboard country in Africa had at

[4]Including aerial fiber cables

[5]For a map of the terrestrial fiber network, see https://afterfibre.nsrc.org/

[6]http://www.africabandwidthmaps.com/?p=6158 and http://www.africabandwidthmaps.com/?p=5822. Accessed in November, 2020.

[7]https://www.dw.com/en/high-speed-Internet-reaches-uganda/a-5214935

[8]It is important to emphasize that landlocked countries or countries that did not have direct access to the submarine cables had to pay for the cost of transit across countries, thereby inflating the cost of Internet services in these countries.

least one submarine cable landing.[9]

How did the arrival of submarine Internet cables improve connectivity in Africa? The influx of submarine Internet cables and subsequent roll out of terrestrial fiber-optic network has had a significant impact on availability of affordable high-speed Internet on the continent. Africa's international Internet bandwidth capacity has since 2009 increased by more than 200 folds from 67 Gbps in 2007 to 15.13 Tbps (8.6 Tbps in SSA) in 2019.[10] The surge in bandwidth is largely attributed to the arrival of submarine Internet cables since 2009. Figure 3 for instance shows the trend in international bandwidth capacity of four countries between 2000 and 2011. The chart shows a surge in the international bandwidth for most countries starting 2009. The pre 2009 period had a relatively (low) flat trend in bandwidth capacity. Thus, we conclude that the arrival of submarine Internet cables to Africa since 2009 enabled the roll out of high-speed Internet across locations in the continent, and this is what we seek to exploit to measure the economic impact of high-speed Internet on innovation and entrepreneurship.

4 Theoretical Framework

In this section, we propose a theoretical framework to articulate the impact of Internet access on innovation and entrepreneurship. Our framework considers a market with entry cost and horizontally differentiated products, where firms innovate through research and development (R&D); and compete in price to serve a unit mass of consumers. These settings have been derived from the theoretical model proposed by Jeanjean and Houngbonon (2017), which builds on the Salop's model (Salop, 1979), to investigate the impact of competition on investment in digital technologies.

Under this framework, access to high-speed Internet can affect innovation and entrepreneurship through two channels: (i) reduced barriers to entry stemming from a drop in entry cost;

[9] https://www.broadbandcommission.org/Documents/working-groups/DigitalMoonshotforAfrica_Report.pdf

[10] see http://www.africabandwidthmaps.com/?p=5822

and (ii) reduced horizontal differentiation, stemming from a drop in a number of economic costs such as search, verification and transportation costs (Goldfarb and Tucker, 2019). Internet access can reduce entry cost by enabling the development of online platforms that support asset-light businesses. Examples abound in the technology sector where Internet access has enabled the development of e-commerce marketplaces, e-logistics that connect sellers and buyers, or drivers and riders, without incurring the upfront cost of acquiring a warehouse, cars or trucks fleet. In traditional sectors, small and medium-sized businesses can take advantage of social media platforms to interact with suppliers and customers without the need to invest in a supply chain and a distribution network. Internet access can reduce horizontal differentiation by enabling transparency in economic transactions. E-commerce websites with consumer reviews are a case in point.

Against this background, the impact of Internet access on innovation depends on the competitive advantage induced by R&D investment. For a given firm, such competitive advantage can be expressed as follows:[11]

$$B = \frac{1}{N} + \frac{d}{t} \tag{1}$$

Where, N denotes the number of active firms in the market and t is the horizontal differentiation parameter. d denotes the quality or cost advantage associated with innovation, and is greater than zero.

Equation (1) shows that the competitive advantage derives from two additive effects: a competition effect stemming from the number of firms in the market; and an efficiency effect stemming from the quality improvement or cost reduction enabled by the innovation compared to competitors. The latter is, however, normalized by the cost of transportation to account for the cost incurred by consumers to benefit from the efficiency effect and, therefore, generate demand for the innovative firm. Internet access reduces that transportation cost and, as a result,

[11] Derived from the theoretical model presented in Jeanjean and Houngbonon (2017).

increase the competitive advantage of innovation through a larger efficiency effect. However, such increase in competitive advantage can be moderated by a reduction in the competition effect as Internet access reduces barriers to entry. The overall effect on innovation depends on the balance between these two effects.

Likewise, the impact of Internet access on entrepreneurship can be analyzed from the number of firms that enter the market in equilibrium:

$$N = \sqrt{\frac{t}{F}} - \frac{d}{F} \tag{2}$$

where F denotes the cost of entry, and d as defined above. Thus the number of entrants (N) depends on two effects: a market power effect enabled by the prevailing product differentiation in the market; and an efficiency effect stemming from the quality or cost advantage that is necessary for firms to remain active in the market. The market power effect, which commands profit, is discounted by the cost of investment in R&D that is necessary to maintain a quality or cost advantage. Both effects are normalized by the cost of entry. By reducing the entry cost, Internet access provides an opportunity for new entrants to benefit from existing rents in the market. However, their survival in the market requires investment in R&D to maintain a competitive advantage. In markets with limited quality or cost differentiation, the effect of Internet access is expected to be positive. However, in the presence of strong quality differentiation, Internet access may result in reduced number of firms in the market.

5 Data

This section provides a brief description of the main datasets used in paper.

5.1 Innovation

Firm-level data on innovation is scant in many developing countries. The only known dataset available on firm innovation in SSA is the World Bank Enterprise Survey – Innovation Follow-up Survey (WBES-IFS) conducted between 2011 and 2015. The WBES-IFS is a subset of the Enterprise Surveys which focuses solely on innovation practices of firms in developing countries. In SSA, the survey covers 15 countries; but, for the purpose of this study, we focus on 10 countries for which nationally representative data is available. These countries include the Democratic Republic of Congo (DRC), Ghana, Kenya, Malawi, Namibia, Nigeria, Sudan, Tanzania, Uganda and Zambia.

The WBES-IFS contains unique firm identifiers that enable users to match the innovation data to firms in the WBES to have complete data on innovation, ICT usage, production and characteristics as listed in Table 1. Data on process and product innovation is self-declared by the firm, but cross-checked with a description of the innovation activities. Process innovation involves the introduction of a new method for manufacturing a product or servicing; managing logistics, delivery or distribution; or supporting activities of purchasing, accounting or computing. Product innovation entails the introduction of a new product to replace existing ones, extend the product range, open new markets, decrease cost of production, offer similar product to competitor, or comply with regulation and standards. The survey also collects data on internal R&D activities which are found to be correlated with self-declared innovation activities.

Data on ICT usage includes Internet connection and the year of the connection. These two variables will be used to measure Internet uptake at the firm level. They are complemented by data on IT skills and equipment such as the share of staff using a computer and the use of an internal software. Data on production pertain to sales and cost and have been used to estimate the average operating costs, as well as amortization and depreciation, two proxies of the competitive pressure experienced by a firm. Firms' characteristics include the sector (manufacturing or services), the size, measured by the number of employees grouped into three types (small, medium and large), and the year of entry. Firm size is defined in terms of the number of full-time equivalent employees: less than 20 for small-sized firms; between 20 and 100 for medium-sized firms; and more than 100 for large-sized firms.

Table 1 reports summary statistics for firm innovation data. The firm innovation sample is composed of 4,438 unique firms of which 47% were surveyed in 2013, 30% in 2014 and 23% in 2015. Between 35% and 50% of firms introduced a process innovation in the three years prior to the survey, compared to 33%-43% that introduced product innovation. Most process innovations pertain to the introduction of a new method of manufacturing or service, while most product innovations seek to extend the product range or open new markets as opposed to replacing existing products. Between 17% and 21% of firms reported conducting internal R&D activities. The average firm got connected to the Internet around 2006-2007, which corresponds to fixed Internet access, generally of low speed. Nearly half of the firms are in the manufacturing sector and 25%-29% are medium-sized.

5.2 Entrepreneurship

The main data on entrepreneurship comes from the Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA). This is a nationally representative household panel data conducted every few years in eight Sub-Saharan African (SSA) countries. The survey is designed to improve the understanding of the links between agriculture, socioeconomic status, and non-farm income activities. The survey has an extensive section on the characteristics and operation of non-farm businesses owned by households. The data contains information on firm's creation, sector, location, employment, management and ownership status, and access to infrastructure. The records also distinguish between registered and non-registered establishments. Our analysis includes five countries with available panel data: Ethiopia, Malawi, Nigeria, Tanzania and Uganda.

A unique feature of this dataset is that it is geocoded at the enumeration area (EA) level thereby allowing us to spatially match it with other spatial datasets such as the Internet infrastructure data used in this paper. Our measure of entrepreneurship is a dummy variable equal to 1 if a household (individual) operates a non-farm enterprise and 0 if otherwise. In addition, we also account for the sector in which the business operates: agribusiness, manufacturing, service.

Table 2 presents descriptive statistics for the estimation sample. The final data consist of 25,567 unique households or 63,084 household-year observations. The unit of observation is household-year. Most of the households reside in rural settlements, with only 29 percent of the households in urban areas. The average head of household is 47 years, while about 77 percent of household's heads are male, and 69 percent of them are educated. Over the study period, about 37 percent of the households owned a non-farm business. Majority of household businesses operate in the services sector accounting for 28% of total households in our data. The share of household enterprises in manufacturing and agribusiness are 5.7% and 0.9% respectively.

5.3 Internet Infrastructure data

To measure access to high-speed Internet, we rely on two main datasets. First is data on the arrival of submarine Internet cables on the coast of Africa from Europe. The second dataset is the fiber Internet node data which shows the deployment of terrestrial fiber-optic Internet cable network, which forms the Internet backbone network that links various locations to the landing points of the submarine cables. These datasets were obtained from Africa Bandwidth Maps[12] – a private consulting company that focuses on providing spatial maps and data on Internet infrastructure in Africa. The Internet node data shows the location of each Internet node along the fiber backbone network, and the period when the node was active. Likewise, the data on submarine cables shows when each cable reached landing points in the respective countries. We also complement our data with information on when the landlocked countries

[12] http://www.africabandwidthmaps.com/

in our dataset were connected to the submarine cable through the backbone infrastructure of their neighboring coastal countries. Essentially, combining the Internet node data and submarine cable data allows us to know when a given location got connected to high-speed Internet brought by the submarine cables.

5.4 Complementary Datasets

Our analysis also uses data from Facebook's Future of Business Survey (FBS), which is a survey of small and medium scale businesses that use Facebook's platform for their business in more than 100 countries. We use the FBS data to provide descriptive evidence on how small and medium scale enterprises (SMEs) use the social media platforms to market their products.

6 High-Speed Internet and Innovation

In this section, we combine firm level data on innovation activities and internet access with Internet infrastructure data to examine the impact of Internet access on innovation activities by firms. Specifically, we ask: to what extent does uptake of Internet by firms influence their innovation activities.

6.1 Empirical Strategy

An OLS estimation of the relationship between Internet uptake and innovation is unlikely to yield causal estimates since the uptake and innovation decisions are likely to be endogenous. A major source of endogeneity bias is reverse causality. A firm's uptake decision and even the timing of the uptake may be correlated with observed and unobserved characteristics of the firm which may depend on their level of innovation. For instance, firms at the frontier of innovation may be clustered in a location that makes it easier for them to access the Internet infrastructure relative to other firms.[13] Also unobserved efficiencies such as cost advantage can jointly affect Internet uptake and innovation.

To address these potential biases, we use an instrumental variable (IV) approach, relying on an instrument that predicts the probability of Internet uptake by a firm based on the firm's year of entry into the market and the timing of the availability of high-speed Internet in the city where the firm is located (Czernich et al., 2011). As shown in Hjort and Poulsen (2019) , the diffusion of high-speed Internet across African cities was spurred by the staggered arrival of submarine cables along the African coastline linking the continent with the rest of the world. Subsequently, inland locations (towns and cities) were connected to high-speed Internet via the terrestrial fiber network. This created plausibly exogenous spatial and temporal variations in high-speed Internet access across cities. In addition, firms in our datasets have varying years of establishment (entry) as well as the year in which they got connection to the Internet. Therefore, using data on year of firm entry, year of Internet connection and year of arrival high-speed Internet in the city measured by the presence of a broadband network node in the city and connection of the country to at least one submarine Internet cable, we build a retrospective firm level panel data[14] and estimate the expected probability of a firm connecting to the Internet conditional on year of entry, high-speed Internet availability in the city, and firm fixed effects. The model is specified as follows:

$$AdoptInternet_{ikct} = \beta_0 + \sum_{\tau=1}^{T} \beta_\tau \times \mathbb{1}(t=\tau) + \sum_{k=1}^{K} \sum_{t=1}^{T} \theta_{kt} \times \mathbb{1}(Fiber_{kt} \times Submarine_{ct}) + \mathbf{FE}_i + \varepsilon_{ikct} \tag{3}$$

where $AdoptInternet_{ikct}$ is a dummy variable equal 1 if firm i in city k, country c adopted Internet in year t, and 0 if otherwise. β_τ captures the trend in Internet uptake that is common to all firms across all countries in the sample. $Fiber_{kt} \times Submarine_{ct}$ is the interaction be-

[13]Internet uptake by peer firms may also influence the timing and uptake decision of a firm.

[14]This is an unbalanced panel due to difference in entry year across firms.

tween the availability of broadband infrastructure in the city and a country's connection to a submarine Internet cable. It measures the availability of high-speed Internet in a city at a given time period. Thus, θ_{kt} captures the trend in Internet uptake that is specific to city k induced by the availability of high-speed Internet in the city. $\mathbf{FE}_i$ on the other hand represents firm fixed effects. We estimate equation (3) by OLS and predict the probability of Internet adoption $\widetilde{AdoptInternet}_{ikc(t)}$ by the respective firms which we use as the instrument for the observed Internet uptake by firms.

Using this instrument, we return to our cross-sectional data on firm innovation to estimate the effect of Internet access on innovation via two-stage least squares (2SLS) specified as follows:

First stage:

$$Internet_{ikc} = \phi \times \widetilde{AdoptInternet}_{ikc} + \gamma \times \mathbf{X}_{ikc} + \mathbf{FE}_{YOE} + \mathbf{FE}_c + \epsilon_{ikc} \tag{4}$$

Second stage:

$$Innovation_{ikc} = \beta \times \widehat{Internet}_{ikc} + \gamma \times \mathbf{X}_{ikc} + \mathbf{FE}_{YOE} + \mathbf{FE}_c + \mu_{ikc} \tag{5}$$

where $Innovation_{ikc}$ is a placeholder for the innovation activities of firm i in city k, country c. Here we focus on product and process innovation.[15] $Internet_{ikc}$ is a dummy variable equal to 1 if firm i is connected to the Internet at the time of the survey and 0 if otherwise. $\mathbf{X}_{ikct}$ is a set of firm characteristics such as sector, size, IT skills and equipment and the intensity of competition. We also include fixed effect for firms' year of entry (establishment) denoted by $\mathbf{FE}_{YOE}$. This fixed effect absorbs observed and unobserved trends in firm entry that may be correlated with Internet uptake and innovation decisions. Finally, we include country fixed effects, $\mathbf{FE}_c$, to absorb time-invariant cross-country correlates of innovation among firms. β is

[15] It is important to emphasize here that our innovation survey asked firms about their innovation activities over the past three years preceding the survey. Also, the dataset is a cross sectional survey across different countries.

the parameter of interest, capturing the local average treatment effect (LATE) of Internet uptake on innovation.

6.2 Results

In this section, we present and discuss the results on the effects of Internet access on innovation with specific reference to product and process innovation as shown in Tables 3 and 4 respectively using the IV framework discussed in Section 6.1. We begin by looking at the first stage relationship between our instrument (the predicted probability of internet adoption, $\widetilde{AdoptInternet}$) and the endogenous variable, $Internet(0/1)$ as shown in column 1 of Table 5. The results show a positive association between the instrument and uptake of Internet by firms. The corresponding tests for weak instruments and under-identification are shown in the respective columns in Tables 3 and 4 and confirm that the instrument is a good predictor of Internet uptake.

6.2.1 Process innovation

In Table 3, we present the OLS (column 1-3) and IV (column 4-8) estimates of the effect of internet uptake on process innovation among firms in our dataset. In column 1-5, we focus on process innovation as a whole,[16] while in column 6-8 we focus on specific types of innovation. In particular, we look at innovation related to introduction of new method of production or service (column 6); introduction of new improved ways of managing logistics (column 7); and process innovation related to supporting activities of purchasing, accounting or computing (column 8).

Overall we find a positive relationship between (high-speed) Internet access and process innovation. The IV estimates however, are slightly larger than the OLS estimates, lending support to a potential downward bias in the OLS estimates due to unobserved timing of Internet connection. In column 5 for instance, we find that Internet access increases the probability of

[16] That is, any type of activities related to process innovation

process innovation among firms by 20 percentage points. Also the results in column 6-8 suggest that the most affected type of process innovation are those related to supporting activities of purchasing, accounting or computing (column 8), followed by introduction of new method of managing logistics (column 7), and new methods on manufacturing or service (column 6).

How does innovation vary between manufacturing and service sector firms? Our results suggest that process innovation is more prevalent in the manufacturing sector than in the service sector. The rate of process innovation is 5.9-6.5 percentage point higher in the manufacturing sector than in the services sector. This finding corroborates the observation that new methods of manufacturing are the most prevalent type of process innovation in our dataset (Table 1).

Also, large and medium sized-firms have higher rate of process innovation than small firms, especially in innovations that involve new methods of logistics, delivery or distribution (column 7). Compared to small-sized firms, the rate of innovation in logistics is 4.6 percentage point higher for medium-sized firms, and 12.8 percentage point higher for large-sized firms. These findings are consistent with an increasing return to scale as found in Audretsch and Acs (1991).

ICT skills and equipment enable process innovation, especially in presence of Internet access. Firms with a high share of staff using a computer have high rate of process innovation when they are connected to the Internet: a 10 percentage point increase in the share of staff using a computer is associated with a 6 percentage point increase in the rate of innovation in support functions among firms with Internet access relative to firms without Internet access (column 8). The effect is limited for other types of process innovation. The availability of IT equipment, measured by the purchase of software, is associated with higher rates of process innovation. The impact of competition is however not statistically significant.

6.2.2 Product innovation

In column 1-5 of Table 4, we present the results of the association between internet access and the probability of a firm engaging in product innovation. The results shows that product innovation increases with access to high-speed Internet access, albeit the magnitude of the effect is relatively smaller than the effect of internet on process innovation shown in the previous section. Specifically, Internet access is associated with a 12 percentage point increase (column 5) in the rate of product innovation among firms compared with a 20 percentage point for process innovation (Tables 3, column 5).

Additionally, we explore the relationship between Internet access and the motives and gains from firm's participation in product innovation. We find no increasing marginal gain from product innovation with Internet access: the share of sales induced by product innovation is not affected by Internet access (column 6). Also, the type of products developed are not related to Internet access. For instance, innovation (development) of products aimed at opening a new market (column 7) or replicating competitors products (column 8) do vary between firms with and without Internet access.

Further, unlike process innovation, we find no statistically significant difference in the rate of product innovation between the manufacturing and services sectors. Likewise, only large-size firms have higher rate of product innovation than smaller firms. Medium-sized firms have a similar rate of product innovation to small-sized firms. ICT skills and equipment are also strong determinants of product innovation, as firms with higher share of staff using a computer or with an internal software have higher rate of product innovation than those with lower availability of skills or equipment. However, these effects do not depend on Internet access. Competition intensity appears to reduce the effect of Internet access on product innovation, but such effect is no longer significant with the IV estimation.

Finally, we conduct additional analysis by evaluating the relationship between Internet access and firms' decision to undertake research and development (R&D) activities as R&D is an input into the innovation process. In other words, we use R&D as an alternative measure of innovation and test if Internet access plays any role in firms' R&D decisions. The results as shown in column 2-3 show a positive association between Internet access and the probability of a firm undertaking R&D. These results lend support to our main findings that indeed Internet access is a key determinant of innovation at the firm level.

7 High-Speed Internet and Entrepreneurship

In this section, we utilize household panel data on entrepreneurial activities matched with a dataset on Internet infrastructure roll out to assess the causal impact of access to high-speed Internet on entrepreneurship.

7.1 Empirical Strategy

To causally estimate the effect of Internet access on entrepreneurship, we use a difference-in-difference design that exploits spatial and temporal variations in the roll out of high-speed Internet. Specifically we exploit two sources of variations: The first source of variation comes from the staggered variations in the arrival of submarine fiber-optic Internet cables on the coast of Africa linking the continent to Europe as shown in Figure 2. The second source of variation we exploit is the subsequent deployment of the terrestrial Internet backbone network. After the submarine cables arrived at the coast, they were subsequently connected to the national backbone network, which consist of a network of terrestrial fiber cables connecting several areas in the country. Since many of these countries were previously reliant (mostly) on satellite for Internet, the construction of the terrestrial fiber network began almost at the same time as the submarine cables arrived. This therefore created a temporal variation in the availability of the Internet across various locations in the country. To demonstrate this, we show in Figure 4 the variations in the roll out of fiber Internet nodes in Nigeria across space and time. Thus, combining these variations yields a plausibly exogenous variation in access to high-speed Internet across space and time. Our baseline equation is expressed as:

$$Y_{ikct} = \phi \times \mathbb{1}(Fiber_{kt} \times Submarine_{ct}) + \alpha \times \mathbb{1}(Fiber_{kt}) + \beta \times \mathbf{X}_{it} + \mathbf{FE}_k + \mathbf{FE}_{c\times t} + \mu_{ikct} \quad (6)$$

where Y_{ikct} is the outcome variable for household i in $(0.1° \times 0.1°)$ grid-cell k, country c, at time t. $Fiber_{kt}$ is a measure of whether a given location is connected to the terrestrial fiber backbone network at time t or otherwise. This is measured using the distance between a given location and the nearest active fiber Internet node. Specifically, the indicator variable $\mathbb{1}(Fiber_{kt})$ is set equal to 1 if a location is within 10km from the nearest (active) "Internet node" along the fiber optic backbone network, and 0 if otherwise. We explore alternate measures of fiber connection using varying distance threshold in section 7.2.3 and show that results are not driven by potential errors in our baseline measure. $Submarine_{ct}$ on the other hand, is an indicator variable equal to 1 if a country's backbone infrastructure is connected to at least one submarine Internet cable in the relevant year. Thus, the interaction $Fiber_{kt} \times Submarine_{ct}$ turns on if a given location plausibly gains access to high-speed Internet through the submarine cables and turns off if otherwise. $\mathbf{X}_i$ is a vector of household controls.

We also control grid-cell fixed effects ($\mathbf{FE}_k$) to absorb time invariant correlates of entrepreneurship rates at a given location. Implicitly, by absorbing these fixed effects we compare the changes in the outcome variables (entrepreneurship) before and after the arrival of high speed Internet within a given location. In a variant specification, we replace grid-cell fixed effect with household fixed effects and find consistent estimates. Further, we control for country×year fixed effects, $\mathbf{FE}_{c\times t}$, to absorb country-specific time varying confounders. Our parameter of interest is ϕ which measures the causal impact of access to Internet on entrepreneurship (innovation) rates. It is important to emphasize that since our treatment variable captures access at the community level as opposed to household uptake, $\hat{\phi}$, can be interpreted as an "intent-to-treat" (ITT) estimate of the effect of access to high-speed Internet. Following Abadie et al. (2017), we cluster standard errors at grid-cell level–which is the level of variation in our treatment variable.

Our identification design relies on the assumption that the rates of entrepreneurship between connected and unconnected communities would have evolved along the same pattern in the absence of the Internet roll-out, i.e., the so-called "parallel trends" assumption. To validate this assumption, we use an event-study design to trace the trends in the outcome variable(s) before and after high-speed Internet connection by estimating a dynamic version of equation 6 expressed as follows:

$$Y_{ikct} = \sum_{\tau=-5}^{5} \phi_\tau \times \mathbb{1}(Fiber_{kt} \times Submarine_{ct}) + \sum_{\tau=-5}^{5} \alpha_\tau \times \mathbb{1}(Fiber_{kt}) + \mathbf{FE}_k + \mathbf{FE}_{c\times t} + \mu_{ikct} \quad (7)$$

where τ is the year relative to when a location was connected to Internet through the fiber network. We use $\tau = -1$, the year before connection, as the base period.

7.2 Results

7.2.1 Event-study analysis

We begin by showing the trends in entrepreneurship rates (measured by households' ownership/operation of a non-farm enterprise) in connected and unconnected locations overtime using the event study model outlined in equation 7. The ϕ_τ coefficients are plotted in Figure 5. The results show the absence of pre-trends: before the arrival of high-speed Internet, the point estimates are generally low and none of them is statistically significant[17]. However, we observe a general increase in the point estimate in the periods after the arrival of high-speed Internet connection. In particular, we observe a positive and statistically significant event in the second and fourth year after the arrival of high-speed Internet. This provides suggestive evidence that availability of fast Internet has a positive impact on entrepreneurial activities in connected communities. Overall, the statistical non-significance of the pre-treatment trends suggest that entrepreneurship rates in connected and unconnected communities would have followed similar trends in absence of Internet connectivity in the treated communities. The results are reassuring that our difference-in-difference design satisfies the parallel trend assumption.

[17] Even at the 90% confidence level

7.2.2 Baseline analysis

Having established the validity of our research design, we proceed to analyze how entrepreneurial activities respond to the roll out of Internet in the study areas. We focus primarily on entrepreneurial activities among households via the establishment of non-farm enterprises.

In Table 6, we present results on the effects of Internet on the probability of a household operating (establishing) a non-farm business. Using the baseline specification in equation 6, we estimate two variant models alternating between household and grid-cell fixed effects in columns 1 and 2 respectively. The columns where we control for household fixed effects are the most restrictive specifications. Our preferred specifications are those where we control for grid-cell fixed effects, socioeconomic attributes (age, sex and education) of the household head, and rural urban status of the community where the household resides. In column 1, the results indicate that access to high-speed Internet is associated with an 18.2 pp increase in the probability that a household operates a non-farm enterprise. Similarly, accounting for grid-cell fixed effects, in column 2, the results indicate that access to high-speed Internet is associated with a 17.4 pp increase in the probability that a household operates a non-farm enterprise. Relative to the sample mean, the results in columns 1 and 2, suggest that access to high-speed Internet increases entrepreneurship by 49% and 48% respectively.

Having established the effect of Internet access on entrepreneurship, identifying the sectors where these new businesses are concentrated is especially important for developing countries. To explore this question, we classify household enterprises into three main sectors (agribusiness, manufacturing, and services) based on the activities these enterprises are engaged in. In columns 3-4, the results show a negative relationship between Internet access and ownership (operation) of an agribusiness enterprise, albeit the effects are not statistically significant. Also, in columns 5-6, we observe a positive and statistically insignificant effect of Internet access on ownership (operation) of a manufacturing enterprise. Interestingly, we find a statistically significant effect of Internet access on ownership (operation) of an enterprise in the service sector in columns 7 and 8. The results suggest that access to high-speed Internet is associated with about 14 pp increase in the probability of a household establishing a services oriented enterprise. Overall, the results provide suggestive evidence that Internet access increases entrepreneurship mainly in the service sector.

A plausible reason behind our finding that entrepreneurial activities induced by Internet access are concentrated mainly in the service sector relates to the relatively low cost of entry for service sector firms compared to for example, manufacturing sector firms. Many service sector businesses in developing countries are small-scale often undertaken within the household compound or at the market place with relatively low initial capital. Thus, with the opportunities the Internet offers, it is relatively easier for households to establish service related enterprises relative to manufacturing enterprises. For instance, data from the 2019 (spring edition) Facebook Survey of Future Businesses shows a greater share (66%) of small firms in Africa[18] using digital platforms such as Facebook operate in the service sector compared to just 13% for manufacturing firms.

7.2.3 Robustness Test: Spatial distribution of effects

In our baseline analysis, we define a location as connected to the fiber Internet network if it is located within a 10km radius from an active Internet node. Although this distance threshold conforms to the practice in the literature, it could affect our research design if actual access to Internet in practice extends beyond the 10km radius from an active Internet node. In addition, an alternative hypothesis is that the estimated effects could arise from a decline in entrepreneurial activities in the control locations (i.e. beyond 10km from a node) and not necessarily due to an increase in entrepreneurial activities in connected locations induced by access to Internet.

To understand the geographic distribution of the effects of Internet access, we estimate a

[18] African countries in the survey include Algeria, Angola, Benin, Botswana, Cameroon, Egypt, Ethiopia, Ghana, Ivory Coast, Kenya, Libya, Morocco, Mozambique, Nigeria, Senegal, South Africa, Tanzania, Uganda, and Zambia

spatial lag model using the doughnut approach shown in equation 8 and examine the changes in the treatment effect at varying distance bins across a 100km plane from the location of Internet nodes.

$$Y_{ikct} = \sum_{d} \phi_d \times \mathbb{1}(Fiber_{kt} \times Submarine_{ct}) + \sum_{d} \alpha_d \times \mathbb{1}(Fiber_{kt}) + \beta \times \mathbf{X}_{it} + \mathbf{FE}_k + \mathbf{FE}_{c\times t} + \mu_{ikct} \quad (8)$$

$\forall d \in \{0-10, 10-25, 25-40, 40-55, 55-70, 70-100\}$. ϕ_d measures the treatment effect for each distance bin, with 70-100km from the node as the reference category. All other variables remain as previously defined.

The results as depicted in Figure 6 show a positive and statistically significant effect on entrepreneurship in locations within 0-10km from a node. Beyond 10km from the node, we do not find statistically significant results. In addition, coefficients are negative and sometimes close to zero. This provide suggestive evidence that the effects of Internet on entrepreneurship is largely concentrated within 10km from the node thereby providing support for the choice of the 10km radius in defining treatment and control locations.

8 Conclusion

This paper presents evidence on the development impact of access to high-speed Internet in developing countries with specific reference to the effects on innovation and entrepreneurship in Africa. Using data on firm innovation and household panel data on entrepreneurship in several African countries matched with granular spatial data on fiber broadband Internet infrastructure roll out, we examine how Internet availability spurs innovation and entrepreneurship in the continent. Two main findings emerge from this study.

First, access to Internet has a positive impact on innovation activities among firms. The rate of process and product innovation increases with firms' access to fast internet. The availability of digital skills at the firm level plays a key role in the relationship between Internet access and innovation. Second, access to fast internet is an important driver of entrepreneurial activities, as Internet relaxes constraints to entry and incentivizes potential entrepreneurs to establish businesses, particularly in the service sector.

The findings of the paper underscore the potential of Internet access to support jobs and long run growth through increased innovation and entrepreneurship. However, skills, including advanced digital skills, are critical to these outcomes.

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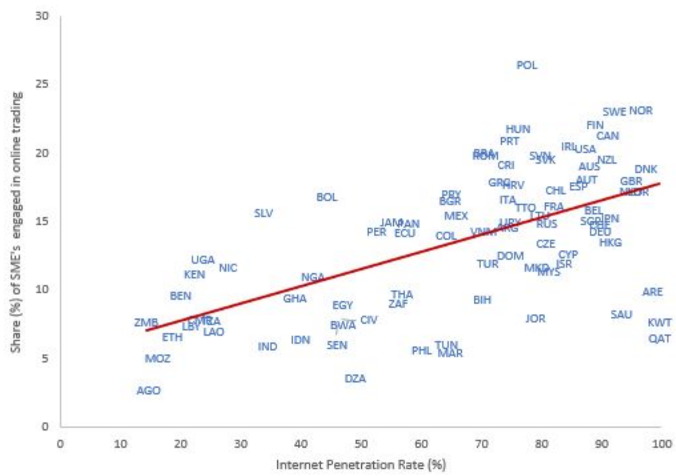
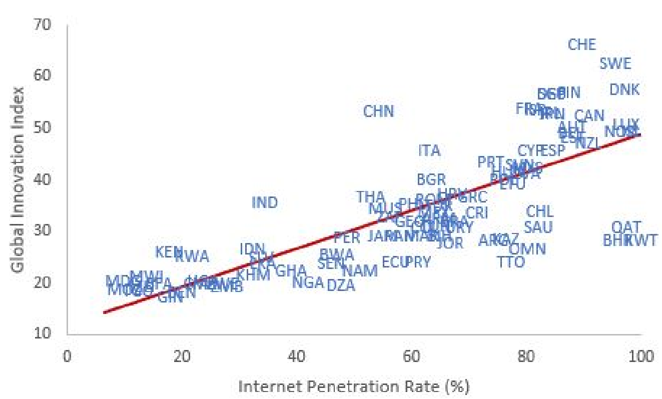
Figures

Figure 1: Relationship between Internet Access, E-Commerce and Innovation

(a) Internet Access and Firms' participation in E-Commerce

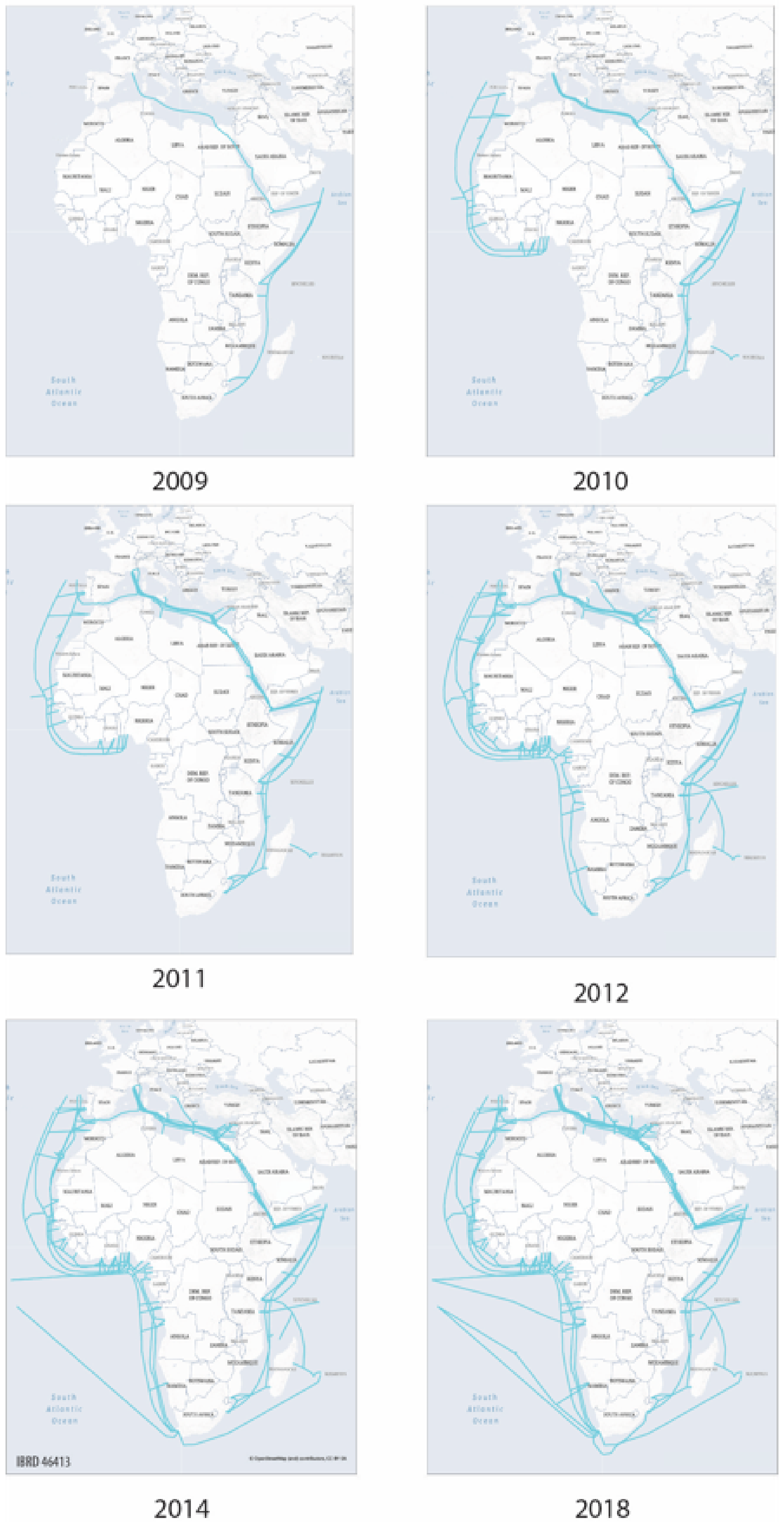


(b) Internet Access and Innovation



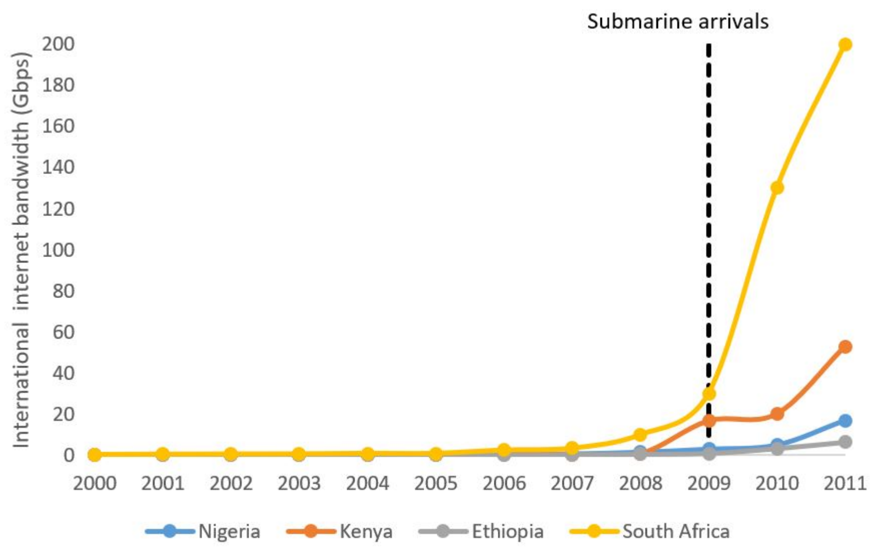
Note: The above figures show the cross-country correlation between (a) share of small firms (MSMEs) participating in E-commerce or (b) Global Innovation Index and Internet penetration rate. The Global Innovation Index is obtained from the World Intellectual Property Organization.[19] Firms' participation in E-commerce is obtained from Facebook Survey of Future Businesses, while Internet penetration rate is obtained from the International Telecommunications Union.

Figure 2: Arrival of Submarine Fiber Internet Cables in Africa



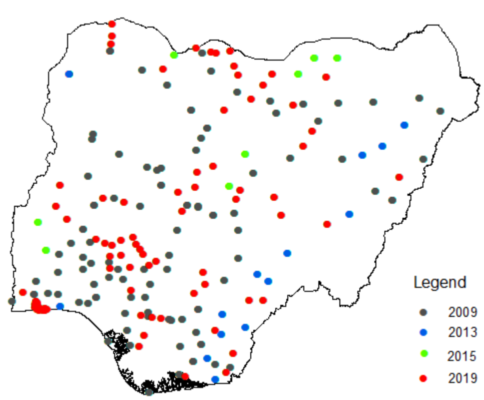
This figure shows the gradual arrival of undersea fiber Internet cables to Africa between 2009 and 2015. Maps were constructed using data from https://cablemap.info/_default.aspx

Figure 3: International Internet Bandwidth



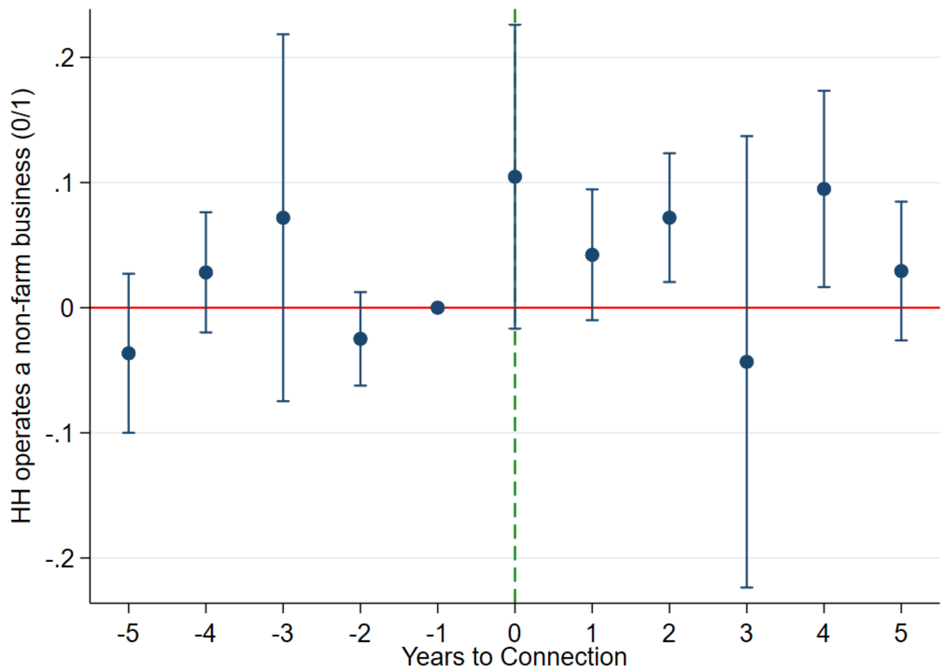
This figure shows trends in international Internet bandwidth (IIB) capacity in selected African countries. Source: https://tradingeconomics.com/search.aspx?q=international%20bandwith

Figure 4: Roll out of Internet fiber nodes in Nigeria



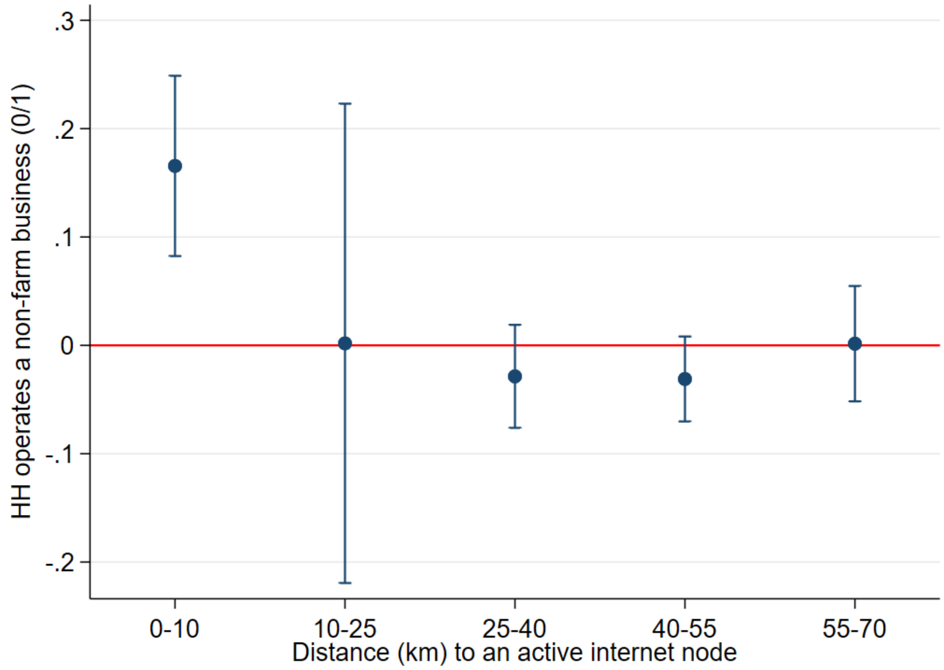
Note: The figure shows the location of active fiber Internet nodes in 2009 and the additional nodes that became active in the respective years

Figure 5: Event study analysis: Internet Access and Entrepreneurship



Note: This figure plots coefficients and their 95% confidence intervals from an event study regression of a dummy variable equal 1 if a household operated a non-farm enterprise in year t on event dummies while controlling for grid-cell fixed effects, and country× time fixed effects

Figure 6: Spatial Lag: Internet Access and Entrepreneurship



Note: This figure plots coefficients their 95% confidence intervals from a spatial lag regression of a dummy variable equal 1 if a household operated a non-farm enterprise in year t on distance from a node connected to a fiber backbone and submarine cables, while controlling for grid-cell fixed effects, and country× time fixed effects

Tables

Table 1: Summary Statistics: Innovation Dataset

Year of Innovation Survey	2013		2014		2015	
	Mean	Obs.	Mean	Obs.	Mean	Obs.
Process innovation:	50%	2081	35%	1346	45%	1011
New method of manufacturing/service	39%	2070	28%	1340	37%	1002
New method of logistics/delivery/distribution	31%	2074	20%	1333	34%	1001
Support activities of purchasing, accounting, computing	30%	2069	18%	1328	32%	999
Product innovation:	43%	2075	33%	1332	38%	1000
% increase in sale	42%	314	55%	161	50%	347
Replace existing products	36%	884	28%	412	46%	381
Extend product range	90%	885	82%	416	92%	383
Open new markets	85%	886	81%	407	77%	378
Decrease cost of products	50%	886	26%	401	39%	378
Offer same product as competitor	76%	884	61%	404	72%	377
Comply with regulation/standards	46%	883	37%	394	64%	382
Conduct R&D	21%	2054	17%	1303	21%	986
Internet connection	48%	2079	44%	1297	63%	990
Year of Internet connection	2006	954	2007	437	2007	588
Share of staff using computer	17%	2044	18%	1058	26%	812
Use of software	22%	2081	15%	1346	29%	1011
Average operating costs	0.22	1509	0.25	935	1.4	648
Amortization, depreciation, in % sales	2.8%	1509	2.4%	935	2.9%	648
In the manufacturing sector	49%	2081	40%	1346	42%	1011
Medium-sized firms	29%	2081	29%	1346	25%	1011
Large firms (more than 100 staffs)	11%	2081	7%	1346	8%	1011
Year of entry	1996	2000	2000	1311	1999	964
Countries	Kenya Tanzania Uganda Zambia		DRC Ghana Sudan		Malawi Namibia Nigeria	

Table 2: Summary Statistics: Entrepreneurship Dataset

Variable	Mean	Std. Dev	Min	Max	N
HH operates a non-farm enterprise	0.372	0.483	0	1	63084
HH operates an Agribiz Enterprise	0.009	0.095	0	1	63084
HH operates a Manufacturing Enterprise	0.057	0.232	0	1	63084
HH operates a Services Enterprise	0.276	0.447	0	1	63084
Urban	0.288	0.453	0	1	63084
HHH has formal education	0.690	0.463	0	1	61253
Male headed HH	0.759	0.428	0	1	61498
Age of HH head	46.871	14.815	25	76	61159
Fiber ($\leq$ 10 km)	0.157	0.363	0	1	63084
Fiber $\times$ Submarine	0.154	0.361	0	1	63084

Table 3: Internet and Process Innovation

	OLS		IV					
	Process innovation (0/1)							
	All					Method	Logistics	Support
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Internet (0/1)	0.202***	0.114***	0.170***	0.197***	0.202***	0.109***	0.115***	0.215***
	(0.022)	(0.029)	(0.030)	(0.044)	(0.037)	(0.037)	(0.032)	(0.045)
Manufacturing	0.059***	0.062***	0.065***	0.061***	0.061***	0.059***	0.006	0.011
	(0.016)	(0.020)	(0.020)	(0.021)	(0.021)	(0.019)	(0.019)	(0.016)
Medium-sized	0.020	0.041**	0.034*	0.023	0.024	0.027	0.046**	0.025
	(0.020)	(0.019)	(0.018)	(0.020)	(0.019)	(0.026)	(0.021)	(0.022)
Large-sized	0.054*	0.064*	0.053	0.039	0.045	0.058*	0.128***	0.018
	(0.027)	(0.034)	(0.035)	(0.034)	(0.034)	(0.034)	(0.034)	(0.041)
Computer usage (%)		0.001**	0.003***	0.001	-0.002	-0.002	-0.002	-0.004
		(0.000)	(0.001)	(0.001)	(0.003)	(0.003)	(0.002)	(0.003)
Internet X Computer usage (%)			-0.002*		0.003	0.003	0.003	0.006**
			(0.001)		(0.003)	(0.003)	(0.002)	(0.003)
Software usage		0.173***	0.410***	0.154***	0.335***	0.215**	0.233*	0.481***
		(0.025)	(0.052)	(0.027)	(0.117)	(0.098)	(0.120)	(0.148)
Internet X Software			-0.291***		-0.223*	-0.099	-0.104	-0.350*
			(0.056)		(0.130)	(0.106)	(0.140)	(0.175)
Competition		0.220	0.063	0.216	0.309	0.392	-0.040	0.144
		(0.137)	(0.221)	(0.137)	(0.287)	(0.296)	(0.155)	(0.197)
Internet X Competition			0.309		-0.194	-0.089	-0.010	-0.342
			(0.274)		(0.460)	(0.470)	(0.253)	(0.392)
Constant	0.307***	0.290***	0.268***					
	(0.019)	(0.017)	(0.018)					
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Entry Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.132	0.178	0.189	0.070	0.071	0.039	0.066	0.098
F stat	34.480	43.863	33.033	37.677	34.977	31.073	44.022	47.379
LM statistic				659.6	90.75	90.5	90.6	90.6
Wald F-stat				1797.4	118.8	119.2	119.1	119.1
Observations	4195	2699	2699	2699	2699	2692	2693	2686

Notes: Standard errors clustered at the city level in parentheses. The LM statistic tests the under-identification of the instrument. The associated P-value is zero in all regressions, rejecting the hypothesis that the first stage is under-identified. The Wald F-stat supports the weak identification test. It is compared to Stock-Yogo critical values of 16.38 for 10% maximal IV size.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 4: Internet and Product Innovation

	OLS			IV				
	Product innovation (0/1)					Sales	Market	Competitor
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Internet (0/1)	0.168***	0.086***	0.126***	0.129**	0.118***	1.834	0.058	-0.079
	(0.024)	(0.029)	(0.032)	(0.055)	(0.043)	(5.266)	(0.048)	(0.079)
Manufacturing	0.029	0.022	0.022	0.022	0.020	-0.968	-0.017	0.020
	(0.018)	(0.024)	(0.024)	(0.024)	(0.023)	(2.636)	(0.022)	(0.033)
Medium-sized	0.002	0.005	0.006	-0.004	-0.001	-1.373	-0.050**	-0.037
	(0.019)	(0.017)	(0.017)	(0.020)	(0.019)	(2.975)	(0.023)	(0.031)
Large-sized	0.063**	0.091***	0.096***	0.079**	0.087**	-4.391	-0.039	-0.055
	(0.027)	(0.032)	(0.032)	(0.035)	(0.033)	(4.711)	(0.046)	(0.056)
Computer usage (%)		0.001***	0.001	0.001**	-0.001	0.011	-0.000	0.000
		(0.000)	(0.001)	(0.001)	(0.003)	(0.047)	(0.000)	(0.001)
Internet X Computer usage (%)			0.001		0.003			
			(0.001)		(0.003)			
Software usage		0.114***	0.159**	0.104***	0.133	2.103	0.017	-0.094*
		(0.022)	(0.060)	(0.028)	(0.106)	(2.744)	(0.033)	(0.047)
Internet X Software			-0.057		-0.036			
			(0.065)		(0.111)			
Competition		-0.012	0.089*	-0.013	0.014	10.829**	-0.008	-0.010
		(0.032)	(0.049)	(0.032)	(0.062)	(5.171)	(0.064)	(0.073)
Internet X Competition			-0.195**		-0.057			
			(0.084)		(0.102)			
Constant	0.284***	0.285***	0.264***					
	(0.021)	(0.022)	(0.021)					
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Entry Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.121	0.151	0.153	0.045	0.045	0.010	0.008	0.016
F stat	33.7	18.1	13.6	17.7	12.7	0.81	0.87	3.03
LM statistic				656.9	90.2	138.2	266.6	268.7
Wald F-stat				1791.8	117.4	247.6	562.7	568.5
Observations	4177	2674	2674	2674	2674	479	1055	1056

Notes: All regressions include fixed effects for year of entry, as well as country and survey's year. Standard errors clustered at the city level in parentheses. The LM statistic tests the under-identification of the instrument. The associated P-value is nil in all regressions, rejecting the hypothesis that the first stage is under-identified. The Wald F-stat supports the weak identification test. It is compared to Stock-Yogo critical values of 16.38 for 10% maximal IV size.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 5: First-stage regression, and Robustness Checks

	First Stage IV	OLS	IV
	Internet (0/1)	Firm engage in R&D (0/1)	
	(1)	(2)	(3)
$\widetilde{AdoptInternet}$	0.698***		
	(0.014)		
Internet		0.053***	0.086**
		(0.020)	(0.034)
Manufacturing	0.010	0.055***	0.055***
	(0.013)	(0.017)	(0.017)
Medium-sized	0.160***	0.011	0.004
	(0.014)	(0.019)	(0.020)
Large-sized	0.212***	0.075**	0.065*
	(0.026)	(0.036)	(0.037)
Computer usage	0.004***	0.002***	0.002***
	(0.000)	(0.000)	(0.000)
Software usage	0.118***	0.183***	0.176***
	(0.016)	(0.023)	(0.024)
Competition	0.043*	-0.025	-0.025
	(0.026)	(0.034)	(0.034)
Country Fixed Effects	Yes	Yes	Yes
Firm Entry Year Fixed Effects	Yes	Yes	Yes
R-squared	0.669	0.102	0.101
F stat		33.54	33.06
Observations	2684	2656	2656

Notes: Column 1 shows the first stage relationship between our instrument and the variable of interest : a dummy equal 1 if a firm is connected to the internet and 0 if other wise. Columns 2 and 3 presents the relationship between internet connection and the probability that a firm engages in research and development (R&D) estimated via OLS and IV respectively. Standard errors clustered at the city level in parentheses. * Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 6: High-Speed Internet and Entrepreneurship

	Enterprise(0/1)		Agribiz Enter. (0/1)		Manuf Enter. (0/1)		Service Enter. (0/1)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fiber X Submarine	0.1823***	0.1741***	-0.0008	-0.0017	0.0161	0.0344	0.1657***	0.1386***
	(0.0464)	(0.0422)	(0.0023)	(0.0020)	(0.0347)	(0.0393)	(0.0406)	(0.0395)
Fiber	-0.1522***	-0.1325***	0.0030	0.0022	-0.0127	-0.0240	-0.1454***	-0.1145***
	(0.0460)	(0.0435)	(0.0025)	(0.0021)	(0.0348)	(0.0400)	(0.0417)	(0.0416)
HH controls	No	Yes	No	Yes	No	Yes	No	Yes
HH FE	Yes	No	Yes	No	Yes	No	Yes	No
Grid-cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country X Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mean dep. var	0.3688	0.3581	0.0096	0.0091	0.0600	0.0552	0.2689	0.2630
R-squared	0.7878	0.3519	0.4720	0.1459	0.6603	0.1547	0.7148	0.3109
Observations	58646	60322	58646	60322	58646	60322	58646	60322

Notes: Fiber X Submarine is a dummy variable equal to 1 if a location is connected to a node along the terrestrial fiber-optic backbone network that is connected to the submarine cable at time t and 0 if otherwise. Fiber is a dummy equal to 1 if a location is connected (within 10 km) to a to a node along the terrestrial fiber-optic backbone network. Enterprise(0/1) is an indicator variable which turns 1 if a household operates a non-farm enterprise at time t. Agricbiz Enter. (0/1) is an indicator variable which turns 1 if a household operates an agribusiness enterprise. Manuf Enter. (0/1) and Service Enter. (0/1) are indicator variables equal to 1 if a household operates a manufacturing and services sector enterprises respectively and 0 if otherwise. Estimations are done using OLS. Robust standard errors clustered at grid-cell level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level