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THE ARRIVAL OF FAST INTERNET AND EMPLOYMENT IN AFRICA

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ABSTRACT

To show how fast Internet affects employment in Africa, we exploit the gradual arrival of submarine Internet cables on the coast and maps of the terrestrial cable network. Robust difference-in-differences estimates from three datasets covering 12 countries show large positive effects on employment rates—also for less educated worker groups—with little or no job displacement across space. The sample-wide impact is driven by increased employment in higher-skill occupations, but less educated workers' employment gain less so. Firm level data available for some countries indicate that increased firm entry, productivity, and exporting contribute to higher net job-creation. Average incomes rise.

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1 Introduction

Traditional trade theory predicts a decrease in inequality in developing countries during periods of integration in the global economy. The slow economic progress of poor workers in many parts of Africa, Asia, and Latin America during the last few decades therefore surprised economists. Two potential explanations were proposed and compared: skill-biased technological change (SBTC) and features of international trade—such as outsourcing (see e.g. Feenstra & Hanson, 1996, 1999, 2003) and quality upgrading (see e.g. Verhoogen, 2008; Frías *et al.* , 2009)—that could alter the logic underlying expectations of job growth and greater equality in unskilled labor-abundant countries post-integration (Feenstra & Hanson, 2003; Goldberg & Pavcnik, 2007; Harrison *et al.* , 2011; Goldberg, 2015). Two decades of research led to wide agreement that both explanations play a role, and that they probably interact (Wood, 1995; Acemoglu, 2003; Attanasio *et al.* , 2004; Burstein *et al.* , 2013; Koren & Csillag, 2016; Raveh & Reshef, 2016). But this conclusion was built on studies of *trade-induced* technological change. To date, there is no direct evidence on the average and distributional economic effects in poor countries of the spread of the modern information and communication technologies (ICT) that help explain increasing inequality in rich countries' labor markets.

In this paper, we estimate how fast Internet—"the greatest invention of our time" (The Economist, 2012)—affects poor countries' economies.[1] To do so, we compare individuals and firms in locations in Africa that are on the terrestrial network of Internet cables to those that are not. We compare these two groups during the gradual arrival on the coast of submarine cables from Europe that greatly increase speed and capacity on the terrestrial network. We show how employment rates, occupational employment shares, job inequality across the educational attainment range, and the underlying extensive (Internet take-up) and intensive (Internet speed) margin, respond. We also show evidence on three particular mechanisms through which take-up and speed may affect employment: changes in firm entry; changes in productivity in existing firms; and changes in exporting. Finally, we show how average incomes in locations that see changes in employment patterns with the arrival of fast Internet respond.

It has been difficult to study SBTC directly because, other than in local experiments, ICT technologies are not randomly allocated, but introduced where economic benefits are expected. While this is true everywhere, developing countries additionally tend to lack systematic and detailed labor market and firm level data, especially in the poorest regions of the world, where the economic environment differs the most from the West (see Katz & Autor (1999); Bond & Van Reenen (2007); Goldin & Katz (2007) for overviews of the SBTC literature on rich countries). We overcome the first obstacle by interacting time variation generated by the gradual arrival of submarine Internet cables at landing points on Africa's coast in the late 2000s and early 2010s with cross-sectional variation in whether a given location is connected to the terrestrial "backbone" network that starts at the landing point cities.[2] We overcome the second obstacle by combining employment data from representative household surveys (panels at location level) from 12 African countries with a combined population of roughly half a billion people with firm level datasets (panels at firm or location level) from Ethiopia, South Africa, and a group of six African countries.[3] We use the firm level data to show evidence on three especially important mechanisms—firm entry, productivity, and exporting—through which

[1]We are not aware of existing causal evidence on this relationship. See World Bank (2016) for an overview of the existing correlational evidence, and more details below.

[2]During this period, each coastal country effectively had its own separate backbone network, as explained in Section 2.

[3]One household survey (Afrobarometer) covers Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, Tanzania, and South Africa; and the other (DHS) Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Togo, and Tanzania. We refer to these 12 countries jointly as "Africa" for simplicity. We also use a labor force survey from South Africa, and firm data from Ethiopia and Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania.

fast Internet may affect employment.[4] We also use data on Internet speed and take-up of the Internet to tie the reduced form estimates to the intensive and extensive margin of use. Finally, we use data on night lights from satellite images to study how fast Internet ultimately affects average incomes.[5]

Our approach differs from much of the related literature in that employment rates, rather than wages (among the employed), are our primary outcomes of interest. This is partly for data availability reasons, but it is also a sensible choice in a developing region context. "Job inequality" captures inequality in human capital accumulation, future labor market prospects, and income that is due to (i) current (un)employment—a component of first order importance in Africa that focusing on wage inequality would miss (see e.g. Magruder, 2012; Hardy & McCasland, 2015)—and (ii) the "quality" of the individual's job (if any) (see also Davis & Harrigan, 2011; Card *et al.* , 2013, 2016). Moreover, changes in the probability of a worker being employed in a position belonging to a given type of occupation are informative not only of demand for qualified workers, but also of trends in structural change in developing economies.

Our three main sets of results are as follows.[6] First, we find that the probability that an individual is employed increases by 6.9 and 13.2 percent in the two groups of countries covered by our household survey datasets, and by 3.1 percent in South Africa, when fast Internet becomes available. We show that the increase in employment in connected areas is not due to displacement of jobs in unconnected areas.

Second, in both South Africa and the eight poorer countries covered by a household survey that records occupation information, we find that the probability of being employed in a position belonging to a skilled occupation increases substantially, but the probability of holding an unskilled job is unaffected, when fast Internet becomes available. While the impact on overall trends in structural change is likely modest, fast Internet thus appears to shift employment shares towards higher-productivity occupations.

Third, employment inequality if anything falls when fast Internet arrives in Africa. The percentage point increase in the probability of having a job is, for example, of comparable magnitude for those who only completed primary school and those with secondary or tertiary education in all three of our samples. The estimated increase in employment in a *skilled* occupation is biggest for those with tertiary education in the group of countries covered by a detailed household survey, but is comparable in magnitude across the educational attainment range in South Africa. In both these samples, those with only primary school see increased employment in unskilled occupations.

To compare these results to the existing evidence on recent SBTC in developed countries, we distinguish between the skill level of *jobs* and *workers*. Our findings suggest that fast Internet in Africa affects employers' relative demand for skilled and unskilled positions similarly to "computerization" and broadband Internet in rich countries (Autor *et al.* , 1998, 2003, 2008; Goos *et al.* , 2014; Katz & Margo, 2014; Akerman *et al.* , 2015), although the increase in overall employment and employment in skilled occupations is notably bigger in Africa. In contrast, while ICT tends to increase inequality across the educational attainment range in rich countries, fast Internet if anything decreases (un)employment inequality in Africa.[7] These results

[4] We study a diverse subset of the world's poorest countries and a transformative technology that may affect employment patterns through many different channels. Data limitations thus prevent us from investigating *all* such potential channels, or determining what share of the identified changes in employment patterns firm entry, productivity, and exporting account for. The literature on information frictions in developing countries, for example, hints at additional mechanisms that may also play a role (Bloom *et al.* , 2007; Antrás *et al.* , 2008; Magruder, 2010; Beaman & Magruder, 2012; Allen, 2014; Eaton *et al.* , 2015; Hardy & McCasland, 2015; Atkin *et al.* , 2017; Mitra *et al.* , 2016).

[5] See Henderson *et al.* (2012); Bleakley & Lin (2012); Michalopoulos & Papaioannou (2013, 2018); Lowe (2014) on night lights as a proxy for average incomes.

[6] That a given cable reaches different countries at different times and in a geographically determined order, and that we consider 10 different cables, a priori lowers concerns about non-parallel prior trends in economic outcomes in locations on versus off the backbone network. The collection of datasets we use enables an extensive battery of tests that supports a causal interpretation of our results.

[7] Interestingly, Atasoy (2013) finds a relatively large correlation between Internet access and employment also in the U.S.—

underscore that the factor bias of new technologies varies by context.

The changes in employment patterns observed when submarine Internet cables arrive in Africa occur through a combination of extensive margin (new users) and intensive margin (different use of the Internet by existing users) responses. We find a large and significant increase in net firm entry (in South Africa), notably in sectors that use ICT extensively (e.g. finance), and in the productivity of existing manufacturing firms (in Ethiopia). The latter finding comes from a procedure where we first estimate how factor output elasticities change with fast Internet, controlling for a possible simultaneous change in firm level productivity (see De Loecker, 2011) to uncover the technology's (positional) skill bias in Ethiopia. In the last step of the procedure, we impose additional structure to estimate how firm level productivity responds, and find a significant increase. We also use World Bank Enterprise Survey data to show that firms in Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania export more; communicate with clients online more; and train employees more, after they get access to fast Internet.

In sum, the evidence we present indicates that greater and cheaper access to information and communication due to availability of fast Internet increases employment rates in Africa, and that in at least some countries, this happens in part due to the technology's impact on firm entry, productivity, and exports. In the final part of the paper, we show that, as expected, average incomes rise in the areas that see changes in employment when fast Internet arrives.

This paper contributes to the literatures on the relationship between globalization and jobs, poverty, and inequality; structural change; and constraints on firm growth in developing countries. The "new" features of international trade uncovered in the recent body of work on globalization (see Feenstra & Hanson (2003); Goldberg & Pavcnik (2007); Harrison *et al.* (2011); Goldberg (2015) for overviews) are important in part because they alter traditional models' prediction that locally relatively abundant factors necessarily gain the most from global integration.[8] A parallel literature convincingly demonstrates SBTC's role in slowing wage growth and rising unemployment among less educated workers in rich countries.[9] However, to our knowledge there was never any direct evidence on the causal relationship between employment rates, inequality, and incomes in developing countries and the ICT technologies that were shown to adversely affect the relative labor market outcomes of low-skill workers in rich countries (Goldberg & Pavcnik, 2007).[10]

specifically, that a county gaining access to broadband services is associated with a 1.8 percentage points higher employment rate, and that the correlation is even bigger in rural and isolated areas, among college-educated workers, and in industries and occupations that more heavily utilize college-educated workers. Acemoglu & Autor (2011) and Michaels *et al.* (2014) find that, if three skill levels are considered, ICT technologies substitute most for middle-skill workers in rich countries. Of course, the types of positions that exist within a given skill category in Africa may differ from those in rich countries.

[8] Most existing studies find that trade liberalization tends to increase productivity in developing countries (Goldberg & Pavcnik, 2007), with more varied effects on poverty (Topalova, 2010; Winters *et al.* , 2004) and employment rates (see e.g. Currie & Harrison, 1997; Revenga, 1997; Harrison & Revenga, 1998; Marquez & Pages-Serra, 1998; Levinsohn, 1999; Moreira & Najberg, 2000). Currie & Harrison (1997) is an exception in that they study (trade reform in) Africa (Morocco). Fajgelbaum & Khandelwal (2015) show that trade benefits the poor through another channel, i.e. because their consumption is relatively concentrated in traded goods.

[9] The relative demand for college graduates increased from the late 1980s onwards with take-up of computers in Europe and the U.S. (Krueger, 1993; Berman *et al.* , 1994; DiNardo & Pischke, 1997; Autor *et al.* , 1998; Machin & Van Reenen, 1998; Autor *et al.* , 2003; Beaudry & Green, 2003, 2005; Beaudry *et al.* , 2010; Acemoglu & Autor, 2011; Goos *et al.* , 2014; Katz & Margo, 2014; Michaels *et al.* , 2014). The explanation lies not only in "direct" factor complementaries, but also in associated worker sorting and organizational change (Bartel & Sicherman, 1999; Caroli & Van Reenen, 2001; Bresnahan *et al.* , 2002; Crespi *et al.* , 2007; Bloom *et al.* , 2012). Akerman *et al.* (2015) document an increase in the relative wages and productivity of high-skill workers when broadband Internet became available in Norway. More generally, SBTC studies that focus on advanced Internet technology in rich countries find positive correlations with local wage levels (see e.g. Czernich. *et al.* , 2011; OECD, 2013), and mixed results for the relative wage effects in richer versus poorer U.S. counties (Forman *et al.* , 2012; Champion *et al.* , 2012; Atasoy, 2013). De Stefano *et al.* (2014) find no significant effect of broadband Internet on the performance of British firms.

[10] There are important existing studies of mobile phones, mobile money, and TV in poor countries that focus on price variation across space, risk sharing, and cultural change as outcomes (Jensen, 2007; Jensen & Oster, 2009; Aker, 2010; Chong *et al.* , 2012; Jack & Suri, 2014). Jensen (2007)'s innovative study also shows that fishermen's profits increased and consumer prices decreased when mobile phones helped eliminate price dispersion across markets in Kerala. There is also important indirect evidence on SBTC in developing countries from studies that use trade liberalization episodes or exchange rate variation that simultaneously affect trade

To date, research on the factor bias of new technologies in developing countries has largely focused on how technology-driven improvements in agricultural productivity affect the movement of labor in and out of agriculture (see Syrquin (1988) and Foster & Rosenzweig (2008) for overviews, and Bustos *et al.* (2016) for a prominent recent example). Such movement is a form of structural change (Clark, 1940; Lewis, 1955; Banerjee & Newman, 1993; Baumol, 2012; Herrendorf *et al.* , 2014), i.e. a persistent change in the relative size of different sectors and occupations. Beyond the role of agricultural productivity and openness to trade, the drivers of structural change are not well understood.[11]

The literature on firms in developing countries has made considerable progress in the last decade and a half. The benefits of importing, exporting, and winning government contracts suggest that the size of the input and output markets that can be accessed is important even conditional on a firm's initial productivity (see e.g. Frías *et al.* , 2009; Goldberg *et al.* , 2010a,b; Amiti & Davis, 2012; Brambilla *et al.* , 2012; Atkin *et al.* , 2015; Ferraz *et al.* , 2015). Greater demand from richer consumers abroad has in turn been shown to enable firms to learn, and to produce higher quality products that may require more skilled workers (Verhoogen, 2008; Frías *et al.* , 2009; Atkin *et al.* , 2015; Hansman *et al.* , 2017). Existing evidence also indicates that firms' financial performance is enhanced by improved coordination with suppliers, access to credit, and good management (Bloom *et al.* , 2007; McKenzie *et al.* , 2008; Bloom *et al.* , 2013; Casaburi *et al.* , 2013; Macchiavello & Miquel-Florensa, 2015). However, we know little about what drives job creation, productivity, and exporting among firms in developing countries. This is especially true when the focus is on the poorest countries and/or the role of specific technologies or inputs. The existing literature reviewed here, the role of ICT in the resurgence of U.S. productivity growth (Draca *et al.* , 2007; Oliner *et al.* , 2007; Jorgenson *et al.* , 2008; Syverson, 2011), and a considerable body of important correlational evidence from developing countries all underscore the promise of fast Internet.[12]

We make three main contributions to the literature. First, we use quasi-random variation in access to ICT technology to provide direct evidence on its impact on employment rates, job inequality, and incomes in 12 developing countries. These findings are important because they suggest that the factor bias of modern technologies differs in Africa. This implies that the primary explanation for rising inequality in poor countries may not be SBTC.

Second, we provide evidence on the relationship between structural change and ICT technology. This represents a first step towards understanding what drives structural change beyond the role of agricultural productivity and openness to trade. Our results qualify negative views of (other manifestations of) globalization in that fast Internet appears to increase both the share of skilled jobs and average incomes in Africa,

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and technological change for identification, including Harrison & Hanson (1999); Acemoglu (2003); Attanasio *et al.* (2004); Aghion *et al.* (2005); Amiti & Cameron (2012); Frazer (2013); Raveh & Reshef (2016). Another indirect form of evidence that has been taken to suggest that SBTC has occurred in Latin America and India in recent decades is that the share of skilled workers has increased in most industries there (see Goldberg & Pavcnik (2007, p. 27)). Goldberg & Pavcnik (2007) note that the skill premium increased around the same time as trade reform occurred in several Latin American countries and India, but that inequality *decreased* in several South East Asian countries and China when they opened up their markets (see also Wood, 1999; Wei & Wu, 2002). Interestingly, while income inequality has increased in many African countries in recent decades, the picture for Africa as a whole is less clear than for Asia and Latin America (Harrison *et al.* , 2011; Dabla-Norris *et al.* , 2015).

[11] Recent work on structural change has emphasized the importance of the manufacturing sector (Gollin *et al.* , 2002; Lagakos & Waugh, 2013; Gollin *et al.* , 2014; Rodrik, 2015); improvements in trends in structural change in Africa in the 2000s (McMillan & Harttgen, 2014; McMillan & Rodrik, 2014); and how trade liberalization can shift workers across sectors and across firms within sectors (see e.g. Attanasio *et al.* , 2004; Davis & Harrigan, 2011; Young, 2014).

[12] Qiang & Rossotto (2009) find that, across developing countries, a 10 percent increase in broadband penetration is associated with a 1.38 percentage point higher GDP per capita growth rate. Clarke & Wallsten (2006) find that a 1 percentage point increase in Internet users is associated with 3.8 percentage points higher exports from low-income to high-income countries. Paunov & Rollo (2015) find that use of the Internet correlates positively with firm performance in a range of poor countries. Basant *et al.* (2011), using more detailed data on Brazilian and Indian manufacturing firms and more extensive controls, find the same for ICT technologies. Their novel results point to much higher rates of return to investment in ICT in Brazil and India than in developed countries.

and—at least in the Ethiopian context—productivity and employment in manufacturing.

Finally, we demonstrate how fast Internet affects employment, productivity, and exporting in African firms, expanding the body of evidence on why firms tend to grow slowly, and ways to stimulate job growth, in poor countries. Our findings on fast Internet and exports represent evidence of an interaction between technological change and trade that differs from trade-induced SBTC as analyzed by the existing literature.

The rest of the paper is organized as follows. In Section 2 we lay out the background on Internet and jobs in Africa, and discuss examples of job creation often attributed to the submarine cables. In Section 3 we present our data, and in Section 4 the empirical strategy. The paper's main results are in Section 5, and in Section 6 we analyze *how* fast Internet affects employment in Africa. Section 7 explores the ultimate impact on incomes. Section 8 concludes.

2 Background

2.1 Internet infrastructure and use in Africa

In 2000, Africa as a whole had less international Internet bandwidth than the country of Luxembourg (ITU, 2000). By 2013, 13 percent of all Africans used the Internet, compared to 36 percent globally (Internet Society, 2013), and more than half of urban African adults owned Internet-capable devices (McKinsey Global Institute, 2013). Listed in decreasing order of average speeds and increasing order of frequency in Africa, the forms of Internet infrastructure that reach users—the "last mile"—are fiber cables, copper cables, wireless transmission using cell towers, and satellites (de M. Cordeiro *et al.* , 2003; Gallaugher, 2012). Prior to the last mile, Internet traffic travels through a national "backbone" of bigger (typically fiber) cables, as depicted in Figure I for South Africa. The backbone was built by a national telecom in almost all countries, sometimes with "branches" added by private telecoms. Since Internet traffic was initially transmitted through telephone cables, the majority of the backbone network cables date back many decades (ITU, 2013).

In the 2000s, submarine Internet cables from Europe were built by consortia made up of private investors, African governments, and/or multilateral organizations (OECD, 2014).[13] The submarine cables were brought to shore at landing points along the coast, typically one in each country passed by the cable. These were usually located just outside of a big city that was connected to the national backbone. Figure II shows the 10 submarine cables that arrived in Africa during 2006-2014, as reported by Mahlknecht (2014).

Once plugged in, the submarine cables brought much faster speed and traffic capacities on Internet traffic to and from other continents to locations in Africa connected to the terrestrial network.[14] On a fiber-optic cable network, the technologically feasible increase in speeds and traffic post-submarine cable plug-in decays with cable length to the landing point to a negligible extent. In general, technological bottlenecks therefore arise at the backbone level only where networks owned by different owners connect to each other. In such cases, the Internet service providers (ISPs) operating on network A will transmit content to (physically connected) network B directly only if the two networks are collaborating, for example through "peering" (ITU, 2013). If not, the fees that African networks charge each other for the exchange of traffic ("transit") are such that content stored on network A would likely be sent via other continents to users on network B ("tromboning"). This partly explains the submarine cables' predicted effect on "experienced" speed and

[13] One of the 10 submarine cables that arrived in Africa during our data period connected the continent with both Europe and India, and another one with the U.A.E. We refer to the connection point of the submarine cables outside of Africa as "Europe" for simplicity.

[14] Being reached by submarine Internet cables from Europe implies a faster connection also to North America and other continents because of the extensive Internet infrastructure that connects Europe with other continents.

capacity, but a more important contributor is that "in Africa very little Internet content is sourced locally, with the vast majority sourced internationally—including local content that is hosted overseas." (Kende & Rose, 2015, p. 15).[15] For example, Chavula *et al.* (2014) found that on average 75 percent of the traffic originating in Africa that is destined for African universities traverse links outside the continent, and Kende & Rose (2015) report that all of the top 14 commercial websites in Rwanda are hosted in Europe or the U.S.

The need for African Internet traffic to travel overseas is important for this paper. In combination with each country being covered by a single backbone network, the lack of spillovers from one coastal country's submarine connection to neighboring countries means that each country has a specific treatment date—the date when the first cable has arrived at the country's landing point and is plugged in.[16]

In Table I we show the mean and standard deviation of Internet speeds and use of the Internet across locations in Africa before the submarine cables arrived. The average (measured) speed was 430 kbps, with a standard deviation of 419 kbps.[17] These relatively high numbers partly reflect the fact that our speed data measure non-mobile connections. (In Section 3 we describe the data in detail; some limitations of the speed measure are discussed in Sub-section 5.1). The proportion of individuals in the countries covered by one of our household survey datasets who used the Internet daily and weekly was 10 and 20 percent on average, with standard deviations of 30 and 40 percent. 38 percent of firms in the multi-country firm dataset communicated with clients via email, while 12 percent used a website.

2.2 Jobs and firms in Africa

The 2006-2014 period we focus on was a period of high growth in many African countries.[18] Given their diversity, we do not attempt to describe an average labor market among the 12 countries in our sample here. Instead the second panel of Table I displays, for the groups of countries covered by our respective datasets, and focusing again on the period before fast Internet became available, the proportion of individuals that have a job, and the proportion that have a job in a skilled occupation. In Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Togo, and Tanzania (the DHS sample), the employment rate is on average 68 percent, with a standard deviation of 47 percent. In Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, Tanzania, and South Africa (the Afrobarometer sample), the employment rate is on average 58 percent, with a standard deviation of 49 percent. In South Africa, the employment rate is 71 percent, with a standard deviation of 45 percent.

In the first group of countries, 58 percent have a job that belongs to a skilled occupation as defined by the International Labour Organization (ILO), with a standard deviation of 49 percent.[19] We also observe the type of occupation to which an individual's job belongs—and several additional employment related outcomes—in South Africa. There, 50 percent have a skilled job (s.d. = 50 percent); average hours worked per week among the employed are 45 (s.d. = 15 hours); 66 percent "want to work more" (s.d. = 47 percent); 48 percent have a formal job (s.d. = 50 percent); and 12 percent have an informal job (s.d. = 33 percent).

In the third panel of Table I, we show the average number of workers, and workers in skilled positions, per firm in respectively Ethiopia and Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania (World Bank Enterprise Survey countries. See Section 3 for information on the firms included). In the latter group

[15]The main reason is cost: "one content developer reported spending USD 49.99 per year for up to 150GB capacity overseas, compared to a Rwandan offer of over USD 900 for 50GB capacity" (Kende & Rose, 2015, p. 3). Africa pays over USD 600 million a year for within-Africa traffic exchange that is carried outside the continent (Internet Society, 2013).

[16]We exclude landlocked countries from analysis because the extent to which they get treated (through coastal neighbors) is unclear.

[17]These numbers exclude the four biggest cities in each country (see Table II).

[18]However, some countries in our sample, especially South Africa, were badly affected by the 2008 global financial crisis.

[19]ILO's definition of skilled occupations is fairly broad; in Section 5.5 we consider each of the underlying sub-categories.

of countries, firms have 31 employees on average, with a standard deviation of 95 across firms, while large- and medium-sized Ethiopian manufacturing firms have 76 employees on average, with a standard deviation of 192. The number of skilled positions per firm, as proxied respectively by high salary positions and non-production positions, is 24 in Ethiopia and 10 in the first group of countries.

We return to the comparison between eventually treated and untreated locations in Section 4.

2.3 Examples of new job creation after the arrival of fast Internet

Many media articles and case studies illustrate new, and new types, of jobs in Africa being created after the arrival of fast Internet. Scruggs (2015) reports that "In 2009, a submarine fiber-optic cable landed in Mombassa [...] Six years later, Nairobi is bursting with technology startups like Shop Soko, a sort of Etsy for Africa that allows shopkeepers to sell handmade goods to consumers worldwide. The Kenyan capital has also emerged as [a] base for high-tech heavyweights such as Google, IBM and Intel. From 2002 to 2010, the value of Kenya's tech exports rose from USD 16 million to USD 360 million." Nairobi's iHub incubator had helped develop more than 150 new businesses by 2013 (McKinsey Global Institute, 2013). Similarly, Harris (2012) reports that "With the landing of new submarine telecom cables off South Africa's coastline starting in 2009, bandwidth prices began to tumble, removing one of the most significant barriers to the global competitiveness of the country's IT industry. That was a catalyst for the explosion of Cape Town's tech scene [...] [and] stature as a business process outsourcing [BPO] and offshoring hub." In 2013 there were more than 54,000 jobs in South Africa's new BPO sector, and Morocco's was at similar scale (McKinsey Global Institute, 2013). Growth in the technology sector also has add-on benefits in other sectors, e.g. construction.[20]

Nigeria is one of the African countries where "eCommerce" has taken off, driven in part by major online retailers that also operate e.g. in Egypt, Ivory Coast, Kenya, and Morocco (Rice, 2013). Online purchases in Nigeria stood at more than USD 1 billion in 2014, tripling in three years (Atuanya & Augie, 2013). Adepetun (2014) of the online news site AllAfrica.com argues, based on interviews with officials and industry executives, that Nigeria's ICT sector from 2004 to 2014 created 100,000 direct jobs, and 1.1 million jobs indirectly, and that eCommerce and ICT's success in Nigeria is due in part to the arrival of the submarine cables.

Kenya, Nigeria and South Africa all now have a manufacturing sector producing Internet-capable devices for the African market, such as low-cost cell phones and computers (McKinsey Global Institute, 2013).

There are also signs that the arrival of fast Internet helped make supply chain coordination easier. Mozambican moWoza and similar start-ups elsewhere use apps and websites to deploy drivers to deliver parcels from wholesalers to traders, and doing the bureaucracy required to import and export in Ghana online has decreased delays considerably (McKinsey Global Institute, 2013). Such supply chain improvement is believed to enhance productivity in agribusiness and manufacturing. For example, the adoption of cloud-based supply-chain management solutions by the Kenyan Tea Development Agency connected around 60 tea factories with the farmers that supply them. This reportedly reduced delays at collection points and fraud, and increased tea factories' productivity and farmers' incomes (Business Daily, 2009; GIZ, 2014).

Technology start-ups, BPO, eCommerce, new forms of manufacturing, and innovative supply-chain management companies and regulatory agencies that make doing business easier for factories and farmers are of course only examples of the ways in which fast Internet may enable greater job creation. But the technology may also eliminate jobs in some occupations—or conceivably even on average—for example due to automation or increased exposure to Asian competition. In the next section we present the data that we use to investigate the causal impact of fast Internet on employment in Africa.

[20] Scruggs (2015): "In Nairobi's Kilimani area, where the tech scene is centered, ten-story office buildings are shooting up."

3 Data

Our outcome data come from the following sources:

Afrobarometer surveys are nationally representative repeated cross-sections conducted every two-three years in many African countries. The order in which locations are surveyed is randomly determined. We geo-code the location based on information provided on the respondent's residence. Men and women of voting age are interviewed. The survey asks socioeconomic questions. We use Afrobarometer data from coastal countries that had survey rounds both before and after submarine cable arrival in the relevant country: Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, Tanzania, and South Africa.

From Afrobarometer we construct an outcome variable for the individual being employed.[21] We also use variables on educational attainment and Internet use.

Demographic and Health Surveys (DHS) are nationally representative repeated cross-sections. The order in which sampling clusters are surveyed is randomly determined. GPS coordinates for sampling clusters are recorded. Women and men between 15 and 49 years old are interviewed.[22] The survey asks questions about labor market participation, health, and demographic background. We use DHS data from coastal countries that had survey rounds both before and after submarine cable arrival in the relevant country: Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Togo, and Tanzania.

From DHS we construct outcome variables for the individual being employed[23], and for being employed in a specific type of occupation. We also use educational attainment variables.

The South Africa Quarterly Labor Force Survey (QLFS) is a nationally representative repeated cross-section. Unlike in Afrobarometer and DHS, QLFS surveys are carried out every quarter. GPS coordinates for enumeration areas are recorded. The current version of the survey began in 2008.[24]

From QLFS we construct outcome variables for the individual being employed[25], and for being employed in a specific type of occupation. We also use educational attainment and other employment-related variables.

South African companies are required to register with the **Companies and Intellectual Property Commission (CIPC) Firm Registry**. We use the resulting zip-code$\times$date level panel registry, which captures entry and exit of formal firms. CIPC provided us with data from 2007 quarter 1 to 2014 quarter 4. We code up each firm's sector when its name contains sufficient information to do so.[26]

The Ethiopia Large and Medium Scale Manufacturing Industries Survey (LMMIS) is an annual survey of all Ethiopian manufacturing establishments that engage 10 or more persons and use power-driven machines. We use the 2006 to 2013 rounds. The survey collects information on employees, inputs, production, sales, and assets, and is used to construct the country's national accounts.

From LMMIS we construct an outcome variable for the number of employees per firm. As proxies for skilled and unskilled positions, we use high-salary and low-salary positions.[27] When estimating production

[21] The question is "Do you have a job that pays a cash income?".

[22] DHS surveys both women and men, but its primary focus is on women (and children) and fewer men are surveyed. About 30 percent of the DHS sample we use is male. Note also that, for two of the countries in our DHS sample (Tanzania and Togo), the pre-treatment survey round we use was conducted in the late 1990s, rather than in the years preceding the arrival of submarine cables as for the other countries (these two countries did not have a survey round in the years preceding the arrival of submarine cables). Our results are essentially unchanged if these two countries are excluded. In Afrobarometer, Tanzania was surveyed in 2008.

[23] The question is "Aside from your own housework, have you done any work in the last seven days?".

[24] From 2010 quarter 3 onwards, the QLFS changed the way observations are linked to enumeration areas and locations. We thus restrict attention to the period prior to then.

[25] The question is "In the last week, did you work for a wage, salary, commission or any payment in kind (including paid domestic work), even if it was only one hour?".

[26] The procedure is described in the Appendix. We were able to assign a sector to 67 percent of the firms based on their names.

[27] LMMIS does not contain information on occupational categories. Skilled (high-salary) / unskilled (low-salary) positions are de-

functions, we also use measures of output (value added), capital (total book value), and intermediate inputs.

The World Bank Enterprise Survey (WBES) is a nationally representative sample of formal firms from all sectors with five or more employees. The survey asks about the business environment, operations, output, and input use. We use WBES data from coastal countries that had survey rounds both before and after submarine cable arrival in the relevant country: Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania. The surveys for these countries were carried out in 2006, 2007, 2013, and 2014.

From WBES we use an outcome variable for the number of employees per firm. As proxies for skilled and unskilled positions, we use non-production and production positions. We also use measures of sales per unit of labor costs; national sales, indirect exports, and direct exports; communication with clients through a website and email; and whether the firm provides training to its employees.

We also use Internet infrastructure and speed data. We use **Mahlknecht's map of submarine cables** to measure landing points and -times (Mahlknecht, 2014), and **www.africabandwidthmaps.com** and **AfTerFibre** (AfTerFibre, 2014)'s maps of terrestrial backbone networks to measure locations' connectivity.[28]

Our data on Internet speeds come from the content delivery network **Akamai** Technologies, Inc., which owns servers worldwide and serves 15-30 percent of all Internet traffic. Akamai averages the speeds recorded for residential users, educational institutions, government offices, and firms in a given location× quarter, excluding those who connect via mobile networks. (We discuss a limitation of this measurement method in Sub-section 5.1). Akamai provided us with quarterly data on average connection speeds for ∼900 African locations during the 2007-2014 period. These locations are shown in Appendix Figure AI.

4 Empirical Strategy

We analyze the relationship between employment patterns in a given location and time period on the one hand and whether or not the location is connected to submarine Internet cables from Europe via the terrestrial backbone network on the other. We run

$$y_{i\mathbf{j}(i)\mathbf{c}(i)t} = \alpha + \beta \text{SubmarineCables}_{\mathbf{c}(i)t} \times \text{Connected}_i + \delta_{\mathbf{j}(i)} \times \text{Connected}_i + \gamma_{\mathbf{c}(i)t} + \epsilon_{i\mathbf{j}(i)\mathbf{c}(i)t} \tag{1}$$

where $y_{i\mathbf{j}(i)\mathbf{c}(i)t}$ is an outcome for individual i in grid-cell $\mathbf{j}(i)$, country $\mathbf{c}(i)$, and time period t. $\text{SubmarineCables}_{\mathbf{c}(i)t}$ is a dummy variable equal to one if the backbone network in country $\mathbf{c}(i)$ has been connected to at least one submarine cable at t, and Connected_i is a dummy variable equal to one if individual i's location is connected to the backbone network. In some parts of our analysis, i represents a firm or geographical location rather than an individual.

The interaction between 0.1×0.1 degree (∼10×10 km) grid-cell fixed effects—$\delta_{\mathbf{j}(i)}$—and the Connected_i indicator controls for any time-invariant differences in employment outcomes that may be correlated with access to fast Internet. These can be included because all our datasets are panels at "$\delta_{\mathbf{j}(i)} \times \text{Connected}_i$ level". Some of our datasets are sufficiently balanced across time at the lowest geographical level at which i's location is reported—e.g. an enumeration area—that $\delta_{\mathbf{j}(i)} \times \text{Connected}_i$ can be replaced with location fixed effects defined at that level.[29]

fined as those where salary is higher/lower than 800 Birr per year, approximately the sample salary median.

[28] We consider Ethiopia "treated" because it is well-documented that its backbone became internationally connected via the submarine cable landing in Djibouti, which was planned and built to also cover Ethiopia (Giorgis, 2010; Oxford Business Group, 2015).

[29] In such cases there is no need to include interactions between location fixed effects and Connected_i because the lowest geographical level at which i's location is reported is either connected or not in these datasets. On the other hand, in DHS and Afrobarometer, information on an individual's village or neighborhood is reported, but during our data period specific villages/neighborhoods rarely

Country-specific time period (quarter or year) fixed effects—$\gamma_{\mathbf{c}(i)t}$—control for any within-country-location-invariant differences in employment outcomes that may be correlated with access to fast Internet.[30] The effect of fast Internet is thus identified off of the comparison between the change in outcomes for locations that gain access to fast Internet in a given quarter or year and the change in outcomes for other locations in the same country that do not gain access at the same point in time.

We cluster the standard errors at location—ie., $\mathbf{j}(i)$—level. Most of our outcome variables are 0/1; the ones that are not are highly skewed. We transform these using the inverse hyperbolic sine (asinh).[31]

Since we lack information on last mile infrastructure at the local level[32], we define i's location as *connected* if it is near infrastructure that makes availability of fast Internet possible, i.e. the country's backbone network. (We refer to a location as "treated" at t if additionally at least one submarine cable has arrived in the country at t). We use maps of Africa's backbone networks prior to the arrival of the 10 submarine cables to measure such connectivity.[33] Specifically, we define as connected those locations that are less than 500 meters from the backbone network. Dividing the sample into two groups facilitates easy inspection of possible differences in pre-trends in the outcomes across connected versus unconnected locations, and this approach also simplifies interpretation of the estimates. In Section 5, we show that our results are robust to varying the radius used to define connectivity, and to relaxing the binary definition of connectivity.[34]

We exclude locations that are further from 10 km from the backbone network. The identifying assumption is thus that locations close to and somewhat further away from the terrestrial backbone network were on parallel trends in employment outcomes prior to the arrival of submarine Internet cables in Africa, and did not experience systematically different idiosyncratic shocks after the cables arrived. To illustrate the geographical variation we exploit, Figures I and III display points where we observe individuals' location, the backbone networks, and the areas we use to define location fixed effects, for two specific areas and datasets (Southwestern South Africa for the QLFS dataset, and Southern Ghana for the Afrobarometer dataset).

Table I shows, in addition to the overall employment rates by groups of countries covered by our respec-

appear in two different survey rounds of which one is conducted before and one after submarine cable arrival. The connected and unconnected parts of 10×10 km grid-cells, however, often do. Note that $\delta_{\mathbf{j}(i)} \times \text{Connected}_i$ is shorthand in (1) in the sense that we interact $\delta_{\mathbf{j}(i)}$ both with the Connected_i dummy and the converse dummy for *not* being connected.

[30] Appendix Table AI lists when the countries in our sample were surveyed and when they were reached by submarine cables. We use the quarter in which the survey was conducted (or to which the observation belongs) to designate a given observation as pre- versus post- submarine cable arrival in all our outcome datasets as this is the time level at which Mahlknecht (2014)'s map of submarine cables reports arrival times in the various landing point cities along the coast.

[31] Our results are robust to instead clustering the standard errors at the level of administrative units and to computing standard errors using methods designed to account for spatial correlation, as discussed in Section 5. The asinh function closely parallels the natural logarithm function, but is well defined at 0 (see Card & DellaVigna, 2017).

[32] In Sub-section 2.1 we discussed how the technologically feasible increase in traffic and speeds post-submarine cable arrival decays with cable length *along* fiber backbone networks to a negligible extent. Connectivity *is* lower further away from than close to the backbone network, but the connectivity reach beyond the backbone network depends on the last mile infrastructure in place in a given area (Commonwealth Telecommunications Organisation, 2012; Banerji & Chowdhury, 2013).

[33] To construct our map of the initial backbone network, we start with AfTerFibre's 2013 map (which is publicly and freely available, and for which corresponding GIS shape files are provided). We then use a map of backbone networks in Africa from www.africabandwidthmaps.com that is available (for purchase, and without shape files) both for 2009 quarter 2 and 2013 quarter 2 to identify the (few) backbone segments built during that period. Finally, we "remove" these new segments from the AfTerFibre map. We calculate the distance between an individual, firm or location in the sample and the nearest point on the country's backbone network. (For QLFS, we observe the location of the (∼80,000) enumeration areas individuals belong to. In QLFS we thus define the location of the individual as the GPS coordinates of the centroid of his or her enumeration area).

[34] Given that backhaul networks (such as metropolitan loops) were generally lacking in Sub-Saharan Africa during our data period, most telephone and Internet exchange points were likely located along the national backbones. Technological considerations indicate that 500 meters is a reasonable proxy for potential fast Internet "reach" beyond the backbone cables for copper-cable last mile technologies. (For last mile transmission via microwaves, the distance-connectivity relationship beyond the backbone is less clear-cut. We thus choose a conservative radius based on copper-cable technologies.) Our empirical strategy may underestimate the true effect of fast Internet in treated locations since locations further than 500 meters from the backbone network may also benefit from the arrival of submarine cables, even if they do so to a lesser extent. It is also possible that neighboring locations suffer (or benefit) from the greater increase in access to fast Internet in connected locations. In Section 5 we vary the assumed connectivity radius and also compare locations at varying distances to the backbone network.

tive datasets, the breakdown by connected versus unconnected areas. Differences in employment rates are small in most countries; in the DHS and Afrobarometer countries the employment rate is respectively two and three percentage points higher in unconnected areas, while in South Africa the employment rate is six percentage points higher in connected areas. The rate of employment in skilled positions is one percentage point higher in unconnected areas in the DHS countries, and six percentage points higher in connected areas in South Africa. Firms on average employ 33/14 and 11/3 workers overall and in skilled positions in connected/unconnected areas WBES countries, and 74/81 and 24/24 workers overall and in skilled positions in connected/unconnected areas in Ethiopia. Internet speeds are slightly higher in connected areas, whereas take-up rates are slightly higher in unconnected areas.

In Sub-section 5.3 we investigate possible violations of the identifying assumption of parallel trends. We show that our results are robust to varying the radius around the backbone network used to define connectivity status; to varying the size of the grid-cells used to define location fixed effects; to defining the backbone network as the intersection of cables reported by two different data sources; to excluding landing point locations; to including placebo treatments that interact $\text{SubmarineCables}_{it}$ with proximity to roads, electricity networks or 3G coverage; to controlling for location-specific linear and non-linear trends in the outcomes; to including leads and lags of $\text{SubmarineCables}_{it}$; and to alternative ways to compute standard errors. We also show direct evidence of parallel pre-trends, and that our estimates remain significant if we use a non-parametric permutation test for inference.

Figure II shows the submarine cables that had arrived in different landing point locations along the coast at various times during our data period. The figure illustrates two important aspects of the identifying variation we exploit. First, submarine cables arrive at many different points in time, and at different points in time in different countries. This means that we compare connected and unconnected locations across many different points in time rather than a single date. Second, the order in which different countries are reached by a given submarine cable is geographically determined. It is thus a priori unlikely that arrival times correlate with temporal variation across countries in differences between the economic trajectories of connected and unconnected areas.

5 Results

5.1 Submarine cable arrival and Internet speed and use

Before analyzing how access to fast Internet affects employment in Africa, we document that the arrival of submarine cables increases both average speeds and use of the Internet. Columns 1 to 3 of Table II show results from running (1) with the outcome defined as the average Internet speed in a given location×quarter as measured in Akamai's data. We find that cable arrival increases measured speed in connected locations, relative to unconnected locations, by around 35 percent in the full sample; 36 percent when we leave out the biggest cities in each country; and by around 38 percent when we also control for interactions between the Connected_i indicator and the time period fixed effects. (We motivate this control in Sub-section 5.3).[35]

Akamai informed us that, because only a fraction of their African speed tests were "sent" to servers on other continents during our data period, the coefficients estimated in columns 1 to 3 of Table II are likely much smaller than the true effect of the submarine cables on speeds experienced by users.[36] This is in line

[35]We display results excluding the biggest cities because the 500 meter connectivity radius may misclassify the biggest, connected cities in Akamai's sample as unconnected, as explained in more detail in the notes to the table.

[36]The reason is that Akamai's technology normally tests a user's speed of connection to a nearby server. In general, during our data

with numerous media articles and existing analyses reporting large increases in speed with the arrival of submarine cables in Africa (see e.g. BBC, 2009; CNN, 2009; State of the Internet Report, 2012).

In the Afrobarometer surveys, respondents are asked if they use the Internet daily or weekly. In columns 4 and 6 of Table II, we show results from again running (1), except that the outcome variable is now a dummy for the individual reporting that she uses the Internet. We find that submarine cable arrival increases the probability that an individual uses the Internet daily in connected relative to unconnected locations by about eight percent on average, and the probability that she uses the Internet weekly by about 12 percent. When we control for interactions between the Connected_i indicator and time period fixed effects in columns 5 and 7, the estimated effect on daily and weekly Internet use is respectively 12 and 14 percent.

There are likely two reasons why use of the Internet increases with submarine cable arrival. First, the technology becomes more useful to potential users. Second, the arrival of the submarine cables led to "drastic falls in prices for international capacity" (Kende & Rose, 2015, p. 15); a cost decrease that ISPs likely partly pass on to users via lower prices. Such a fall in prices could be especially important in Africa, where many potential users are credit constrained.

Of course, the increase in take-up by *employers* after the arrival of the submarine cables may differ from that for individuals. In Section 6, where we use firm level data to explore channels through which fast Internet may affect employment, we analyze how firms' use of websites and email responds.

We conclude that, while data limitations prevent us from pinning down the exact magnitude of the increase in experienced speeds and commercial use of the Internet with the arrival of fast Internet in Africa, both rise considerably. This highlights that an impact on employment patterns may arise both through inframarginal users increasing and changing their use of the Internet, and through take-up by new users.

5.2 Fast Internet and employment rates

In Table III we report this paper's first main findings: the estimated effect of the arrival of fast Internet on employment rates in Africa. In the eight countries for which we have DHS data—Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Togo, and Tanzania—we find a 4.6 percentage point, or 6.9 percent, increase in the probability that an individual is employed when fast Internet arrives. In the nine countries for which we have Afrobarometer data—Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, Tanzania, and South Africa—we find an even bigger 7.7 percentage point, or 13.2 percent, increase in the employment rate. In South Africa—for which we use labor force survey data—we find a 2.2 percentage point or 3.1 percent increase in employment.

Given the large magnitude of these estimates, one may wonder to what extent they reflect "real" additional economic activity. In Panel B of Table III, we use more detailed work-related questions available in the QLFS dataset to investigate this. In column 1, we show that access to fast Internet increases hours worked by about 10 percent on average in South Africa. This helps rule out, for example, that fast Internet simply allows individuals to smooth out their work hours over time (which could affect how they answer employment questions in a survey). The increase in hours worked also helps explain why the technology reduces the probability that an individual "wants to work more" by 2.2 percent, as seen in column 2. Another

period, the speed recorded was that to a server in another country—typically in or via Europe—only in cases where Akamai did not own a server that was located within the user's ISP's own network or directly upstream. It is, however, primarily speeds on traffic to other continents that are affected by the submarine cables, as discussed in Sub-section 2.1. Almost all Internet traffic from Africa did indeed travel to or via other continents during our data period, as also discussed in Sub-section 2.1. Despite significant efforts, we have not managed to find Internet speed data covering our data period that explicitly measure speeds between specific locations in Africa and other continents over time, and Akamai would not share a more detailed version of their data (that could allow us to separate out the speed tests that were sent to other continents) with us.

possibility is that the estimates in the top panel of Table III reflect formalization of pre-existing informal jobs rather than additional employment. This is unlikely because all the surveys we use ask about employment status in a way that should capture also informal employment (see Section 3). The QLFS survey explicitly records both formal and informal employment. As seen in columns 3 and 4 of Panel B, the estimated increase in formal employment is only slightly smaller than the estimated increase in any employment, while the estimated effect on informal employment is positive but close to zero and insignificant.

The evidence thus suggests that "real" employment in Africa increases substantially when fast Internet becomes available. In the next sub-section we probe the identifying assumption underlying our causal interpretation of the estimates in depth.

5.3 Robustness

We start by confirming that the estimated effect of fast Internet is not sensitive to the radius around the backbone network used to define locations' connection status. In Figure IV we display point estimates and confidence intervals for a wide range of radii, each used to define connectivity in a separate regression. For each of our three main outcome datasets, we display results for several radii beyond the connection radius at which the point estimate becomes insignificant. In all three datasets, the point estimate falls as the connection radius is increased, as we would expect. The decay in the estimate as we increase the assumed connection radius is steepest in the DHS sample and least steep in the Afrobarometer sample. In all three samples, the point estimate remains significant well beyond the 500 meter radius we use to define connectivity in our baseline approach. In Appendix Table AII, we show that the results are also not sensitive to the size of the grid-cells used to define location fixed effects.

In Appendix Table AIV, we vary the backbone cables used to define connection status and the sample analyzed in several ways. We first use the intersection of the AfTerFibre and www.africabandwidthmaps.com maps to define connectivity.[37] When we do so, the estimated effect of fast Internet is essentially unchanged in two of our samples, as seen in Panel A. In the Afrobarometer sample, the point estimates decreases somewhat and becomes insignificant, but remains large in magnitude when we use only backbone cables reported by both these sources to define connectivity.

In Panel B of Appendix Table AIV, we exclude from the sample all individuals located less than 20 km from a landing point. The locations that were chosen as landing points are, in addition to being on the coast, typically in or near large cities. If such locations were on a different trend in employment before the arrival of submarine cables, we may incorrectly attribute an estimated treatment effect to the arrival of fast Internet. However, the results are essentially unchanged—if anything the point estimates are slightly larger in magnitude—when we exclude near-landing point locations.[38]

In Panel C of Appendix Table AIV, we exclude from the sample all observations in locations that are more than 5 km from the backbone network itself. Though there are arguments for including more remote locations in the sample—they are presumably less likely to be indirectly affected by the arrival of fast Internet than unconnected locations closer to the backbone—such locations likely differ more from connected locations. The estimates in Panel C make clear that our findings in Table III are not driven by the inclusion of more remote, less comparable locations in the analysis sample.

[37] The drawback of this approach is that we can only implement it with "post-treatment"—2013—backbone maps (see Section 4). However, few backbone cables were finalized and "turned on" during our data period.

[38] This finding also implies that an increase in demand due to the building of the submarine cables themselves cannot explain the effect on overall employment rates. Locations near the landing points are presumably places where a lot of the submarine cable- driven increase in construction and related employment would have occurred.

In Table IV we include additional controls. In most African countries, a part of the backbone network runs parallel to other infrastructure such as roads or electricity cables (see Appendix Figure AII). If locations near such infrastructure saw faster employment growth over time, irrespective of whether they were also connected to the Internet backbone, there is a risk of misattributing employment growth to the arrival of submarine cables. We thus use maps of Africa's road and electricity network to define each location's "road-connectivity" and "electricity-connectivity" status, exactly as we do for Internet backbone-connectivity. We interact these with the arrival of submarine Internet cables—analogously to the construction of $\text{SubmarineCables}_{it} \times \text{Connected}_i$ in (1)—to construct placebo road- and electricity treatments. When these are included, the estimated effect of fast Internet is essentially unchanged and the estimated coefficients on the placebo treatments are small and insignificant, as seen in columns 1, 3, and 5 of Table IV.

In column 5 of Table IV, we also include a placebo treatment that interacts $\text{SubmarineCables}_{it}$ with an indicator for the location having 3G mobile coverage at t, similarly to the approach for roads and electricity connectivity (except that 3G coverage varies over time). This is possible when we use the QLFS sample since 3G coverage data is available for South Africa. The coefficient on the treatment variable for access to fast Internet remains essentially unchanged; it is thus clear that Internet affects employment rates whether or not the area is covered by the 3G network.

We next control for a non-linear trend in employment that is specific to the connected locations. Specifically, we include interactions between the Connected indicator and the time fixed effects in columns 2 and 4 of Table IV. This is possible for the multi-country DHS and Afrobarometer samples, where the arrival of fast Internet is staggered across time. Estimating the treatment effect of interest while controlling for Connected×Time FEs is unusually demanding on the data. Remarkably, the estimated coefficient on $\text{SubmarineCables}_{it} \times \text{Connected}_i$ remains large and significant in both the DHS and the Afrobarometer sample (and in fact the point estimate increases in magnitude in both samples). In column 6, we approximate this multi-country specification in the South Africa sample by including linear grid-cell specific trends. The estimated coefficient on the access-to-fast-Internet indicator is essentially unchanged.

Finally, in columns 6 and 7, we include a lead and a lag of $\text{SubmarineCables}_{it}$. This is possible in the QLFS dataset, wherein data is collected every quarter. Perhaps somewhat surprisingly, the effect of $\text{SubmarineCables}_{it} \times \text{Connected}_i$ loads on the quarter-of-arrival treatment indicator when a lag is included. More importantly, the estimated coefficient on the lead is near zero and insignificant, supporting the identifying assumption of parallel trends.

Bertrand *et al.* (2004) point out that serial correlation can bias standard errors in difference-in-differences analysis. To address this concern, we follow Chetty *et al.* (2009) and conduct a non-parametric permutation test of $\beta = 0$. We can do so in the QLFS dataset, where data is collected every quarter. We sample from the set of possible submarine cable arrival times, assigning a randomly chosen "fake" arrival time to each location while maintaining each observation's backbone connectivity status. Figure V depicts the empirical cdf of estimates resulting from permuting arrival times 500 times and running (1) on the fake datasets. The vertical line represent the true estimate: where it falls in the empirical cdf of estimates from datasets with permuted arrival times implies its p-value. As seen in the figure, the true estimate is near the top of the empirical cdf, with an implied p-value of 0.046.

Conley (1999) emphasizes that *spatial* correlation may also require corrections to standard errors, and develops a method for implementing such corrections. In Panel A of Appendix Table AV, we present the estimates from Table III and standard errors that are calculated using Conley's method. In Panel B of the same table, we cluster the standard errors by administrative unit, rather than grid-cells. In both cases, the estimated effect of fast Internet on employment rates remains statistically significant.

Finally, in Figure VI, we again take advantage of the quarterly surveying in QLFS to display the path of the employment rate in connected and unconnected areas before and after the arrival of the first submarine cable in South Africa. This allows us to inspect how the gap between the two areas evolves after fast Internet arrives, and, more importantly, to check if the identifying assumption of parallel pre-trends appears to hold. Indeed, while the employment rate in both areas declines between 2008 and 2011, in part due to the financial crisis that hit South Africa during that period, the shape of the graph is virtually identical for connected and unconnected areas before the submarine cable arrives in mid-2009. The gap in the employment rate between the connected and unconnected areas starts to increase soon after submarine cable arrival and widens further over time, illustrating the treatment effect estimated in Table III.

We conclude that the estimated effect of access to fast Internet on employment rates in Africa is robust and likely represents a causal response.

5.4 Fast Internet and employment rates across space

We have established that the arrival of fast Internet in Africa led to a large increase in employment rates in connected areas relative to unconnected areas. This finding would hold even if employment in unconnected areas was also affected. However, it is possible that the impact we estimate in Sub-section 5.2 does not capture the total effect of fast Internet across space. We would overestimate the total effect if for example (existing or newly created) jobs are shifted from unconnected to connected areas. We would underestimate the total effect if for example surveyed individuals commute to work in or migrate to connected areas. We now investigate these possibilities.

First, note that we find no effect of access to fast Internet on migration in South Africa and Tanzania (for which the required data is available).[39]

Second, recall that we confirmed in Figure IV that the estimated effect of fast Internet is not sensitive to the radius around the backbone network used to define connection status. This finding implies that our results are unlikely to be driven by a simultaneous decrease (or increase) in employment in areas neighboring connected locations.

Finally, we investigate more directly in Figure VII. Recall that we consider individuals and areas located within 500 meters of the backbone network connected. We now divide those located outside of this connection radius into a maintained control group (those located more than 3500 meters from the backbone network) and three additional treatment groups that are equally spaced geographically: those 500–1500 meters, 1500–2500 meters, and 2500-3500 meters from the backbone respectively. We compare the four groups closest to the backbone to those furthest away, before and after the arrival of submarine cables on the coast. As seen in the figure, the estimated coefficients on $\text{SubmarineCables}_{\mathbf{c}(i)t}$ interacted with indicators for the three additional treatment groups are statistically insignificant and generally near zero. Consequently, the estimated coefficient for those nearest to the backbone network remains essentially unchanged in comparison to the estimates in sub-section 5.2 (except in the Afrobarometer sample, where the estimate increases in magnitude when individuals intermediate distance from the backbone are excluded from the control group[40]). We conclude that the estimated increase in employment in connected areas is not due to shifting

[39]None of the surveys we use elicited respondents' migration status or place of birth in both "pre" and "post" survey rounds conducted during our data period. (QLFS contains a question about migration, but the variable is missing for the majority of the sample). But in South Africa and Tanzania, it is possible to run (1) with migration status on the left-hand side by using another data source (South Africa) or adding a later survey round conducted by DHS (Tanzania). Results available from the authors upon request.

[40]In the Afrobarometer sample, the point estimate for areas that are intermediate distance from the backbone network suggests that

of employment across space.

We now explore how fast Internet affects structural change as measured by occupational employment shares in Africa.

5.5 Fast Internet and employment in skilled and unskilled jobs

The overall response of employment to the arrival of fast Internet in Africa is made up of underlying changes in job creation and destruction across specific occupations and the sectors associated with those occupations. How technological change affects occupational and sectoral employment shares is especially important in poor countries (Herrendorf *et al.* , 2014). To explore this question, we distinguish between *jobs* and *workers*. "The employment rate in occupation X" will here mean the probability of holding a job in occupation X (not the overall employment rate of workers who ("permanently") belong to occupation X). We believe that the changes in occupational employment rates we document mostly reflect changes in the size of different sectors.[41] However, readers can alternatively interpret the results in this sub-section as reflecting a combination of within- and across-sector changes in employment in skilled and unskilled occupations.

In Table V we use the DHS and QLFS datasets, where occupations are recorded and can thus be categorized. In the first two columns of Panel A, we define skilled and unskilled employment categories following the ILO's ISCO categorization of occupations' skill level (ILO, 2012).[42] In the DHS countries and South Africa, the arrival of fast Internet increases the probability that an individual holds a skilled job by respectively 4.4 and 1.4 percent. The probability of unskilled employment is unaffected in both the first group of countries and South Africa. Our findings thus imply a *positional* skill bias of fast Internet in Africa that is directionally similar to what has been found for computerization and fast Internet in the U.S. and Europe. However, it is noteworthy that the large estimated increase in overall employment in Africa is entirely made up of increased employment in skilled occupations.

In columns 3-6 of Table V, we break the skilled category (ISCO levels 2-4) into its sub-categories as defined by the ILO.[43] We lack power to estimate the impact on each of these separately with precision, but the point estimates are nevertheless worth noting. In both the DHS countries and South Africa, a relatively large increase in the probability of "moderately" skilled (ISCO level 2) employment appears to contribute most to the overall increase in skilled employment. The point estimates also point towards a sizable increase in "highly" skilled (ISCO level 4) employment in the DHS countries, when fast Internet becomes available.

McMillan & Rodrik (2014) and McMillan & Harttgen (2014) show that the overall trends in structural change in Africa improved after 2000. The estimates in Table V suggest that greater and cheaper access

these may also experience employment *gains*, but the estimates are far from significant.

[41] In addition to our expectation that low rates of tertiary education make African workers comparatively likely to switch sectors, this is because we in Section 6 find that when fast Internet arrives, there are noteworthy changes in firm entry across sectors in South Africa and an expansion of the manufacturing sector in Ethiopia. Note that we cannot estimate how the impact of fast Internet differs for individuals who "permanently" belong to different occupations because none of our individual level datasets include (non-missing) information on the occupations workers' *past* jobs belong to.

[42] Unskilled jobs (ISCO level 1) "typically involve performance of simple and routine physical or manual tasks" (ILO, 2012, p. 12). ILO defines the following DHS occupational categories as skilled work: professional, sales, services, and skilled manual; and the following DHS occupational categories as unskilled work: self-employed agriculture, domestic, and unskilled manual. ILO defines the following QLFS occupational categories as skilled work: legislative, professional, services, skilled manufacturing, and technical; and the following QLFS occupational categories as unskilled work: elementary, and domestic.

[43] Moderately skilled jobs (ISCO level 2) "typically involve performance of tasks such as operating machinery and electronic equipment; driving vehicles; maintenance and repair of electrical and mechanical equipment; and manipulation, ordering and storage of information". Somewhat skilled jobs (ISCO level 3) "typically involve performance of complex technical and practical tasks that require an extensive body of factual, technical and procedural knowledge in a specialized field". Highly skilled jobs (ISCO level 4) "typically involve performance of tasks that require complex problem-solving, decision-making and creativity based on an extensive body of theoretical and factual knowledge in a specialized field" (ILO, 2012, pp. 12-13). There are no observations in the ISCO level 3 categories in the DHS sample.

to information and communication may be among the changes in the economic environment that helped shift workers towards occupations that usually display higher productivity. We return to this question in sections 6 and 7, where we investigate whether firms whose productivity increased, or which started exporting more, also hired more workers when fast Internet became available, and how the technology affects incomes in Africa. In the next sub-section we explore how job inequality in Africa responds to the arrival of fast Internet.

5.6 Fast Internet and job inequality

Given the lack of direct evidence on the factor bias of ICT in poor countries, it is a priori unclear if fast Internet affects job inequality across the educational attainment range in Africa in the same way that "computerization" has been shown to do in rich countries (Katz & Autor, 1999; Bond & Van Reenen, 2007; Goldin & Katz, 2007; Akerman *et al.* , 2015). We investigate this question in Table VI, where we report results from interacting $\text{SubmarineCables}_{it} \times \text{Connected}_i$ with educational attainment.

Remarkably, the estimated increase in the employment rate is of comparable magnitude for those with primary school, those with secondary school, and those with tertiary education in all three samples.[44] Those with primary school in fact see a moderately bigger estimated employment gain than those with secondary school in all three samples, though not statistically significantly differentially so. In the Afrobarometer countries—but not in the DHS countries and South Africa—fast Internet also increases the employment rate for those who did not complete primary school significantly.

In the DHS countries, those with tertiary education see by far the biggest increase in *skilled* employment. The smaller, but nevertheless noteworthy, estimated increase in skilled employment is of identical magnitude for those with primary and those with secondary education, but more precisely estimated for the latter group.[45] Employment in unskilled occupations increases significantly for those with primary school in both the DHS countries and South Africa.

The results in Table VI in combination with those in Table V illuminate important similarities and differences in the way modern ICT technologies affect job inequality in Africa versus rich countries. We saw in Table V that the skill complementarity of fast Internet as defined by its relative impact on net creation (and/or saving) of high and low skill *jobs* in Africa resembles the skill-bias documented in the West. However, the results in Table VI show that, in the eight DHS countries in our sample, those with almost no education are the only group of *individuals* whose employment outcomes do not benefit from fast Internet. In these countries, while the technology increases *skilled* employment among more educated workers the most, fast Internet thus reduces (un)employment inequality across the majority of the adult population. In the Afrobarometer countries, even those who did not complete primary school see significant employment gains with the arrival of fast Internet. These results partially contrast both with existing findings on computers and fast Internet as SBTC in rich countries, and with the adverse estimated effect of another important form of globalization—trade liberalization—on (income and wage) inequality in developing countries (Goldberg & Pavcnik, 2007; Harrison *et al.* , 2011; Goldberg, 2015).

The magnitude of the estimated increase in "any" and skilled employment with the arrival of fast Internet in Africa is surprising, but the overall pattern that emerges across the educational attainment range—

[44] The initial employment rates that the estimates shown can be compared to are in Appendix Table AIII.

[45] For the South African sample, the increase in skilled employment is imprecisely estimated for all educational attainment groups. (The point estimate for the increase in skilled employment is of roughly comparable magnitude across the educational attainment range, but it is noteworthy that the estimate for those without primary school in South Africa is comparatively large (but statistically insignificant). Recall, however, ILO's fairly broad definition of skilled occupations, e.g. including jobs in services).

particularly in the DHS sample—is arguably less surprising. The especially large increase in skilled employment for workers with tertiary education suggests that fast Internet is in one sense a high education-biased technology in these countries. The productivity of workers with less education may also benefit from fast Internet, however, if for example employers choose to provide targeted on-the-job training to such workers (Green *et al.* , 2001; Frías *et al.* , 2009). This may help explain why we observe a considerable increase in skilled employment also for less educated workers in the DHS countries. The increase in employment for workers with primary school in all three samples (and those without primary school in the Afrobarometer countries) may be due, for example, to the emergence of new types of positions that are complementary to jobs wherein more educated workers make more direct use of Internet technology.

In the next section we investigate *how* fast Internet affects employment in Africa.

6 Understanding how Fast Internet Affects Employment in Africa

6.1 Firm entry

The changes in average speeds and use of the Internet after the arrival of the submarine cables we documented in Sub-section 5.1 suggest that new, and new forms of, employment may arise both through extensive margin (new Internet users) and intensive margin (different use of the Internet by existing users) responses. In this sub-section, we analyze how fast Internet affects firm entry and exit; in the next two sub-sections we explore possible changes in the productivity and exports of existing firms.

We first use a dataset from South Africa's CIPC that records the names and addresses (including zip-codes) of firms that register or de-register, and the date of registration/de-registration. We run (1) at the zip-code×quarter level. As seen in Table VII, we find a significant increase in net firm entry per quarter of around 23 percent when fast Internet arrives in South Africa. This overall impact is due both to a large increase in firm entry, and to a decrease in firm exit of similar magnitude. Greater net firm entry likely helps explain the estimated increase in employment when fast Internet arrives in South Africa.

As also seen in Table VII, we find a significant increase in net firm entry in many sectors, but the biggest point estimates are is seen in sectors that use ICT extensively (World Bank, 2006), such as finance and services.

These results reinforce the view that fast Internet's impact on structural change was at least partly favorable insofar as productivity in the sectors that saw the biggest increase in net firm entry is likely high relative to other sectors in South Africa.

6.2 Firm and labor productivity in existing firms

6.2.1 OLS results

We have seen that access to fast Internet increases firm entry, which appears to contribute to its impact on employment rates. Does the new technology also affect employment within existing firms, and, if so, why? To investigate these questions, we first use Ethiopia's LMMIS dataset of large and medium- sized manufacturing firms, which is to our knowledge the only African dataset with detailed enough information and the geographical and time coverage needed to estimate changes in firms' production function with the arrival of fast Internet. We restrict the sample to firms that are observed both before and after the submarine cable that gets connected to Ethiopia's backbone network arrives on the coast.

In columns 1-6 of Table VIII, we continue to use a similar specification and definition of right hand-side variables as in (1), but i now represents a firm and observations are at the firm×year level. The estimated increase in total employment per firm when fast Internet arrives is about 16 percent in column 1, where we control for firm and year fixed effects[46], and about 22 percent in column 2, where we control instead for grid-cell×connected and industry×year fixed effects. The estimated increase in skilled and unskilled positions per firm (as discussed in Section 3, these are proxied using salary bins) is respectively 3.4 and 11.5 percent (but not statistically significant) when we control for firm and year fixed effects, and 20 and 12.4 percent when we control instead for grid-cell×connected and industry×year fixed effects (in which case the estimated increase in skilled employment is statistically significant). The firm level estimates of changes in employment when fast Internet arrives in Ethiopia are thus broadly comparable to the individual level employment results for the broader samples of African countries and South Africa in Section 5. The relative increase in unskilled positions may be larger in Ethiopian manufacturing firms.

In the last three columns of Table VIII, we explore whether the increase in employment in Ethiopian manufacturing firms may be explained by an increase in the output elasticity of labor and/or firm level productivity with the arrival of fast Internet. We start with the following OLS regression:

$$\text{va}_{\mathbf{ij}(i)jt} = x'_{ijt}\alpha + \text{SubmarineCablesConnected}_{ijt}x'_{ijt}\beta + \delta_{\mathbf{j}(i)} \times \text{Connected}_i + \psi_{jt} + \epsilon_{\mathbf{ij}(i)jt} \tag{2}$$

where va_{ijt} is the value added of firm i, in grid-cell $\mathbf{j}(i)$, industry j, and year t; x'_{ijt} is a set of inputs (labor, capital) used by the firm and a constant term; ψ_{jt} is an industry×year fixed effect, and the other variables are as defined previously.[47] Results from this specification are in column 7 in Table VIII. The coefficients on capital and labor are of similar magnitude to what other studies have found for comparable contexts. The estimated output elasticity of labor in skilled positions increases (insignificantly) from 0.497 to 0.523 with the arrival of fast Internet, but that of labor in unskilled positions falls significantly.

6.2.2 Structural estimation

OLS estimates of the share of variation in output attributable to different input factors may partly reflect the fact that some input factors—such as labor—are chosen after a firm's productivity (unobserved to the researcher) is fully or partially known to the firm. Olley & Pakes (1996) (OP) and Levinsohn & Petrin (2003) (LP) developed practical methods that help overcome such simultaneity bias. The commonly used LP method involves using intermediate inputs to proxy for a firm's unobserved productivity in the production function (see LP for details). We posit the following "structural" model:

$$\text{va}_{ijt} = l_{ijt}\theta + \text{SubmarineCablesConnected}_{ijt}l_{ijt}\phi + \kappa k_{ijt} + \omega_{ijt} + \epsilon_{ijt} \tag{3}$$

where l_{ijt} are labor inputs and the productivity term ω_{ijt} subsumes the constant term and the fixed effects. ϵ_{ijt} represents a standard i.i.d. error term capturing unanticipated shocks to productivity and measurement error. We present LP estimates in column 8 of Table VIII. As expected, both $\hat{\theta}$ and $\hat{\phi}$ are now much smaller in magnitude than the OLS estimates, and the $\hat{\phi}$ from the interaction of $\text{SubmarineCablesConnected}_{ijt}$ and workers in unskilled positions is no longer significant.

[46]We match firms across years using all available information in LMMIS, and cross-check our matches against those of Abebe *et al.* (2017) (the most in-depth and authoritative existing work on such matching in LMMIS). Our matches are nearly identical to theirs. We are grateful to the authors for allowing this cross-check.

[47]To ease comparison with the structural results in columns 8 and 9 of Table VIII, we interact only labor and the constant term with $\text{SubmarineCablesConnected}_{\mathbf{ij}(i)jt}$.

De Loecker (2011) points out an important methodological tension when using the OP/LP methods to investigate how a change in the operating environment affects output elasticities. Suppose that a firm's productivity *itself* is influenced by the change in the operating environment. If the productivity response in turn influences hiring, investment, and value added—as conventional models of firm behavior predict—then changes in the coefficients on labor and capital estimated using methods that do not account for the firm level productivity response will be incorrect.

Inspired by De Loecker (2011), we assume the following law-of-motion for firm productivity:

$$\omega_{ij,t+1} = \alpha\omega_{ijt} + \tau \text{SubmarineCablesConnected}_{ijt+1} + \delta_{\mathbf{j}(i)} \times \text{Connected}_i + \psi_{jt} + \xi_{ij,t+1} \tag{4}$$

where grid-cell×connected and industry×year fixed effects control for differences across space in, and industry-wide shocks to, productivity. We continue to use the LP estimation procedure, but adjust the method to allow both the output elasticity of labor and firm level productivity itself to change. We first estimate ϕ while controlling for a possible response in firm level productivity to fast Internet. As in the conventional LP method, we use a flexible polynomial in the other input factors—including intermediate inputs—to proxy for ω_{ijt}. The adjustment we make in this first step is that we include $\text{SubmarineCablesConnected}_{ijt}$ among the factors included in the polynomial. We run:

$$\begin{aligned} \text{va}_{ijt} = \; & l_{ijt}\theta + \text{SubmarineCablesConnected}_{ijt} l_{ijt}\phi \\ & + \Psi\left[m_{ijt}, k_{ijt}, \text{SubmarineCablesConnected}_{ijt}, \delta_{\mathbf{j}(i)} \times \text{Connected}_i, \psi_{jt}\right] + \epsilon_{ijt} \end{aligned} \tag{5}$$

where $\Psi\left[m_{ijt}, k_{ijt}, \text{SubmarineCablesConnected}_{ijt}, \delta_{\mathbf{j}(i)} \times \text{Connected}_i, \psi_{jt}\right]$ is a polynomial of inputs used (m_{ijt}), capital (k_{ijt}), access to fast Internet, and grid-cell×connected and industry×year fixed effects.

The estimated effect of fast Internet on the output elasticity of labor estimated through this procedure is reported in column 9 of Table VIII. The estimated decrease in the output elasticity of labor in unskilled positions increases in absolute magnitude to -0.063 and becomes significant. The estimated increase in the output elasticity of labor in skilled positions is very similar to the estimate from the conventional LP method—0.016.

In the second step of the procedure, we estimate the coefficient on capital by GMM using the moment condition $\mathbb{E}\left[\xi_{ijt}(\kappa)\, k_{ijt}\right] = 0$, which is motivated by the assumption that capital cannot be adjusted in response to unobserved shocks to productivity.[48] $\hat{\xi}_{ij,t+1}$ is obtained by taking the OLS residual from (4), where ω_{ijt} and ω_{ijt-1} come from applying (3), that is, by subtracting the labor coefficients estimated in (5) and the coefficient for capital from the predicted value added obtained from (5).

For our purposes the coefficient on capital is needed only as an input into the procedure for estimating how fast Internet affects firm level productivity. With estimates of the coefficients on labor, capital, and the interaction between labor and $\text{SubmarineCablesConnected}_{ijt}$ in hand, we can construct $\hat{\omega}_{ijt}$ using (3) and then estimate the law-of-motion for productivity in the third step. The results are reported in column 9 of the bottom panel of Table VIII. The estimated increase in firm level productivity when fast Internet becomes available is around 13 percent and statistically significant.[49]

We conclude that an increase in firm level productivity likely contributes to increased hiring in existing

[48]We use the OLS estimates as starting values, and bootstrap the standard errors.

[49]There are many potential channels through which fast Internet can boost firm productivity above and beyond the output elasticity of labor. The technology may e.g. allow firms to sell more per unit of marketing cost, give access to information about more efficient production processes, or allow firms to increase the quality of their products. Note that the estimated impact on firm productivity remains statistically significant if we bootstrap also the standard error corresponding to this last step of the procedure, as seen in Panel C of Appendix Table AV.

Ethiopian manufacturing firms after the arrival of fast Internet, and that changes in the relative output elasticity of workers in skilled and unskilled positions *may* also help explain the hiring response.

6.3 Firms' exports, on-the-job training, and Internet communication

In Table IX, we use data from the World Bank Enterprise Surveys (WBES) to explore how the arrival of the submarine Internet cables changed the behavior and performance of firms in Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania. We include country×year, location, and industry fixed effects in the regressions and thereby approximate (1) as closely as we can with the WBES dataset, where firms are relatively clustered in space and their location is reported only at city/town level.[50]

As seen in column 1, access to fast Internet leads African firms in the WBES sample to employ about 17 percent more workers per firm. We find a significant increase in the number of employees in skilled positions (as proxied by non-production positions) per firm of around 23 percent, while the corresponding estimate for workers in unskilled positions (as proxied by production positions) is of slightly smaller magnitude and insignificant. The firm level estimates of changes in employment when fast Internet arrives in the WBES countries are thus broadly comparable to the individual level employment results in Section 5.

In column 4, we show that firms are more than twice as likely to provide on-the-job training to their employees when fast Internet becomes available. This finding may help explain why the technology in general boosts employment not only for highly educated workers, but also less educated workers, in Africa. We also find a large (but imprecisely estimated) increase in WBES firms' sales per unit of labor costs—a measure of productivity (World Bank Group, 2017)—when fast Internet becomes available, as seen in column 5.

In columns 6 to 8, we explore how the composition of firms' sales responds to the arrival of fast Internet. We find a decrease in in-country sales, and large increases in both indirect and direct exports. In light of the existing literature documenting the benefits to firms and employment consequences of exporting (see e.g. Verhoogen, 2008; Frías *et al.* , 2009; Goldberg *et al.* , 2010b; Atkin *et al.* , 2015), this finding suggests that one way in which fast Internet increases employment in Africa is by making it easier for firms to sell to customers abroad. The increase in exports is also evidence of an interaction between technological change and trade that differs from the trade-induced SBTC analyzed by an existing literature (Wood, 1995; Acemoglu, 2003; Attanasio *et al.* , 2004; Burstein *et al.* , 2013; Koren & Csillag, 2016; Raveh & Reshef, 2016). Here, causality runs from technological change to trade, rather than the other way around.

Unlike our other datasets, WBES contains information on firms' use of the Internet. As seen in columns 9 and 10, we find a significant increase in firms' probability of communicating with clients through email and through a website, each of about 13 percent. Easier communication with clients may be part of the reason why African firms' ability to export increased when submarine Internet cables reached the continent.

In sum, we have seen evidence in this section indicating that the increase in employment when fast Internet arrived in Africa was driven in part by greater firm entry in South Africa; by higher firm level productivity in existing Ethiopian manufacturing firms; and by an increase in exports, on-the-job training, and use of online communication among firms in the six WBES countries in our sample. While the large magnitudes of these economic responses is important in their own right, data limitations prevent us from

[50] Almost all firms in WBES are located in relatively large cities and towns, and sub-city/town information on location is not reported. We classify a city/town as connected if the backbone network passes through its perimeter. (This yields the same classification of connected/unconnected cities/towns as "extending" the perimeter by 500 meters when categorizing locations). This issue is not relevant to our other datasets, where we have much more fine-grained information on individuals' and firms' location. Note also that the results in Table IX are nearly identical if industry×year fixed effects are included in place of the industry fixed effects.

investigating what *share* of the changes in employment patterns they account for. Additional mechanisms likely also played a role.

7 Fast Internet, Employment, and Incomes

Some would consider employment a means to an end more than an end in itself. In Table X, we explore how the arrival of fast Internet ultimately affects incomes in Africa. Increasing access to, and lowering the cost of, information and communication may affect incomes also through other channels than employment outcomes. But to the extent that fast Internet affects overall and skilled net job creation, we would a priori also expect such an employment response to ultimately translate into higher incomes.

We follow a growing literature and proxy for average incomes at location level with light density at night as measured by satellites (see e.g. Henderson *et al.* , 2012; Bleakley & Lin, 2012; Michalopoulos & Papaioannou, 2013, 2018; Lowe, 2014). In addition to capturing the *aggregate* economic benefits of fast Internet, an advantage of this income proxy is that it is available for all 12 countries in our sample. The National Oceanic and Atmospheric Administration (NOAA) provides pixel-level measures of average night light density from satellite images. We thus construct a grid of such pixels that are 0.1 degree ($\sim$10 km) apart, in the spirit of Michalopoulos & Papaioannou (2013). The estimating equation we use is (1) as throughout the paper; the i subscript now indexes the pixels. In column 1, we see that night light density rises by about 2.4 percent when fast Internet becomes available. Controlling for a non-linear trend in average incomes that is specific to the connected locations—interactions between the Connected indicator and the time fixed effects—in column 2 increases the estimated impact of fast Internet on night light density to 3.3 percent.

The balanced panel, "high(er)-*T*" format of the night lights data allows us to trace out how fast Internet affects economic activity over time better than the household surveys we use allow. We do so in Appendix Figure AIII by interacting a location's connectivity status with years-to/since-cable-arrival-dummies, as in an event study. First, we see that year-to-year changes in average incomes in connected locations relative to unconnected locations hover around zero prior to the arrival of submarine cables. Second, relative average incomes in connected locations start to rise the year fast Internet arrives. Third, the rise continues in each of the two following years, before relative average incomes in connected locations level off in the third "post" year. It thus appears that the impact of fast Internet on incomes in Africa persist over time, but that the *growth* effect may be especially large in the first few years after the submarine cables arrive.

8 Conclusion

This paper provides evidence on how fast Internet affects employment in Africa. We exploit the gradual arrival of 10 submarine Internet cables from Europe in cities on Africa's coast in the late 2000s and early 2010s and interact landing points and -times with an indicator for whether a given location is on the terrestrial cable network that connects users with the coast. We first show that both average speeds and use of the technology increase when the submarine cables arrive. We then compare the changes in employment patterns in cities and towns with a bigger versus a smaller increase in access to fast Internet, controlling for location and time effects. In each of three different datasets that together cover 12 African countries with a combined population of roughly half a billion people, we find a significant and large relative increase in the employment rate in connected areas when fast Internet becomes available. Extensive prodding of the identifying assumptions that underlie our "dynamic" difference-in-differences approach suggests that these estimates reflect a causal effect of access to fast Internet on employment rates. Employment responses of the magnitude we document indicate that building fast Internet infrastructure may be among the currently feasible policy options with the greatest employment-creating potential in Africa. We also show that the technology's impact is due to an increase in employment in higher-skill occupations. Finally, fast Internet if anything lowers (un)employment inequality across the educational attainment range in Africa.

The observed changes in average speeds and use of the Internet after the arrival of the submarine cables suggest that new and new types of jobs may have been (net) created both via "extensive margin" (new Internet users) and "intensive margin" (different use of the Internet by existing users) responses. We explore these possibilities with more detailed firm level data available for some countries. In South Africa, firm entry increases—notably in sectors that tend to benefit from ICT—as does the productivity of existing manufacturing firms in Ethiopia, when fast Internet becomes available. We also show that fast Internet enables firms in Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania to export (much) more, perhaps in part because online communication with clients became easier.

The impact on job inequality we document indicates that the skill bias of fast Internet in Africa is much more nuanced than what has been found for "computerization" and fast Internet in rich countries. This in turn suggests that the primary explanation for the slow economic progress of poor workers in Africa and other similar contexts during the last few decades is unlikely to be the factor bias of recent technological change. The sectors that ex ante appear to have been most constrained by lack of access to ICT, and that create more "good" jobs when fast Internet becomes available, are broadly speaking sectors associated with high relative productivity in Africa. In at least some of these sectors in some parts of the continent, fast Internet further increases productivity, and enables exporting. This suggests that the technology contributed positively to structural change in Africa during our data period.

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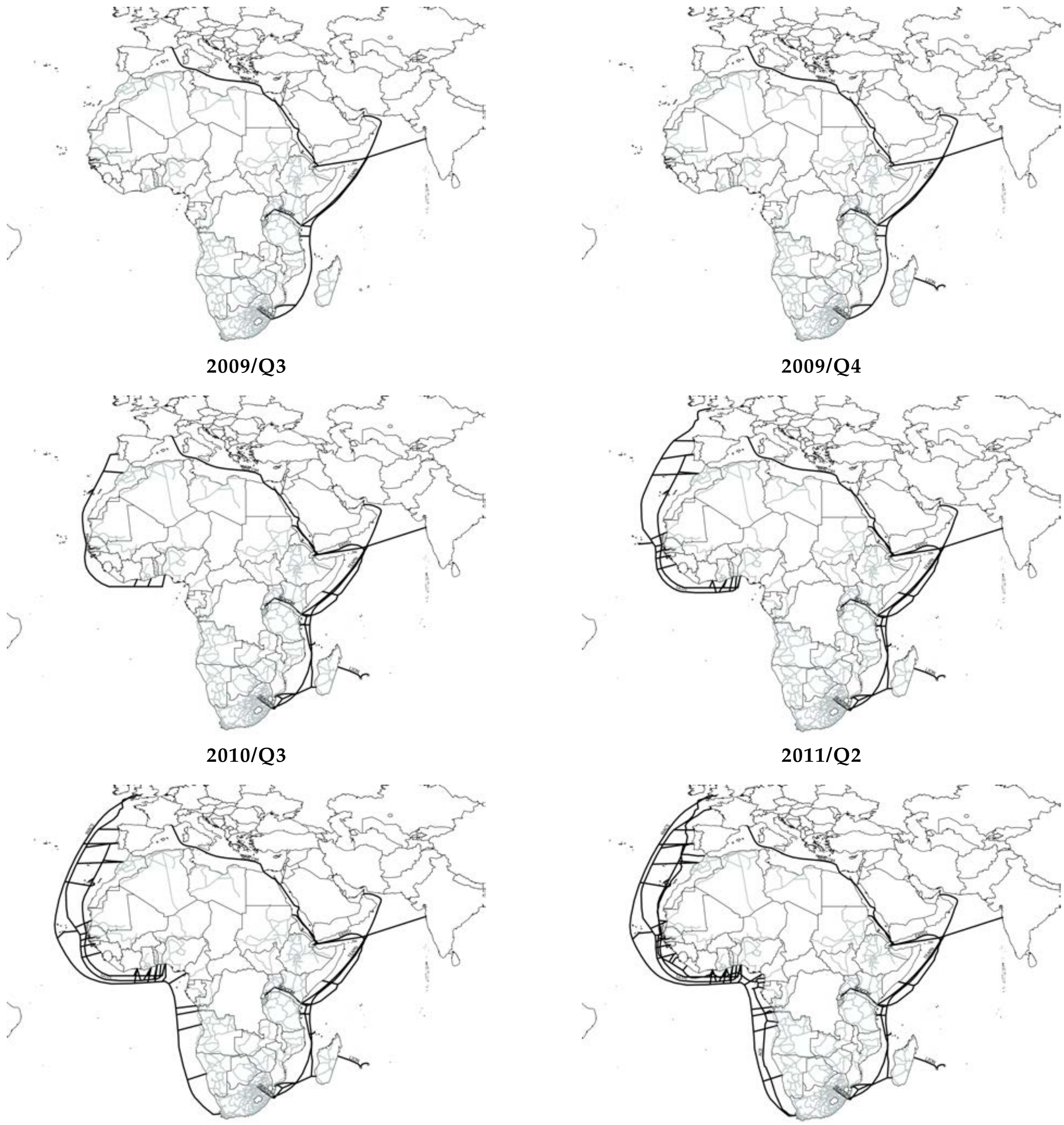
Figures

FIGURE I: THE TERRESTRIAL BACKBONE NETWORK, ENUMERATION AREAS USED FOR LOCATION FIXED EFFECTS, AND SAMPLING CLUSTERS (SOUTHWESTERN SOUTH AFRICA AND SA-QLFS DATASET AS EXAMPLE)

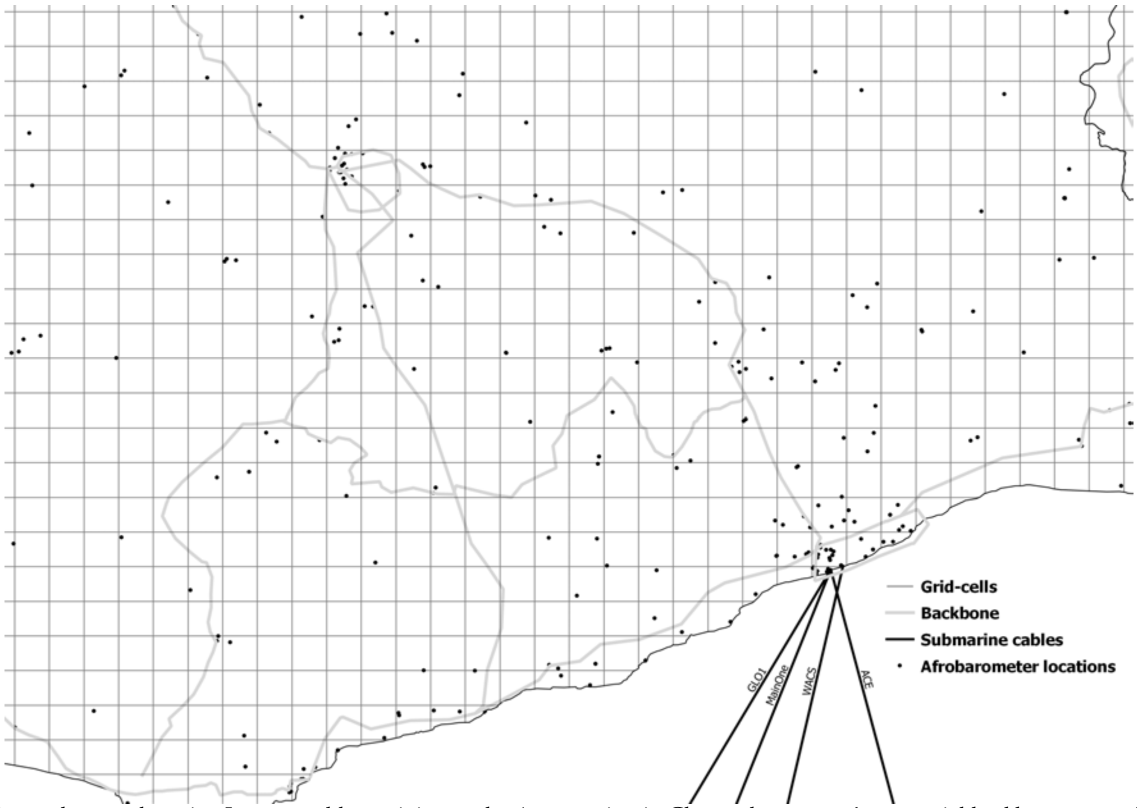
This figure shows submarine Internet cables arriving to Yzerfontein, just north of Cape Town in South Africa, the country's terrestrial backbone network, and centroids of the SA-QLFS enumeration areas. Enumeration areas are used for location fixed effects.

FIGURE II: SUBMARINE INTERNET CABLE ARRIVAL IN AFRICA



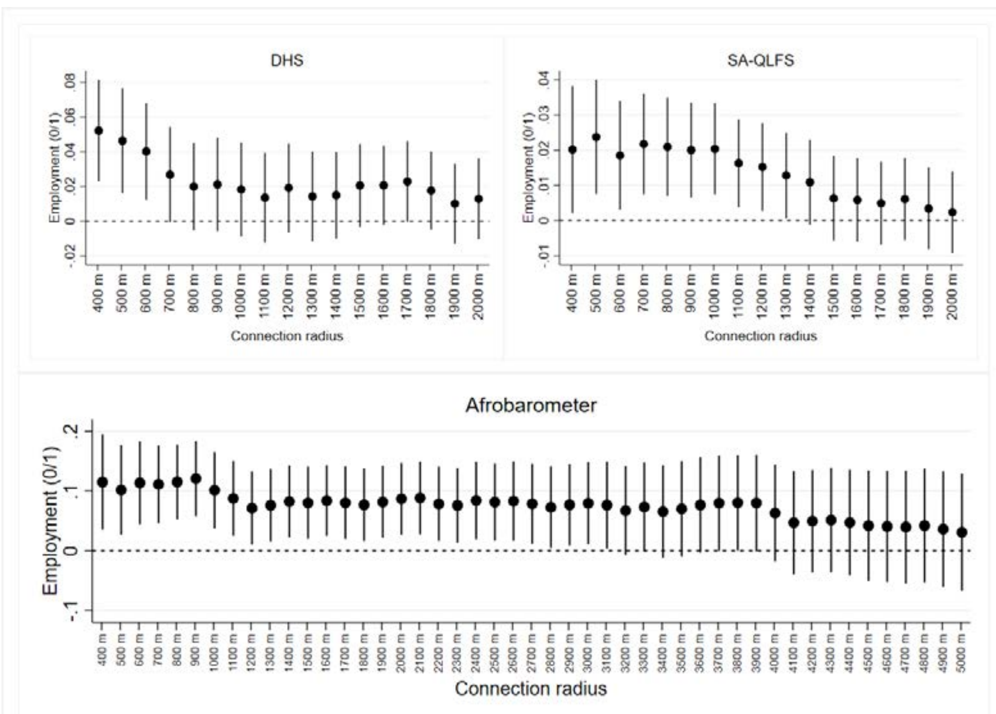
This figure shows the arrival of submarine Internet cables in Africa over time. The first two cables during our analysis period arrived in 2009/Q3 and the last in 2012/Q4. The submarine cables are Seacom and Teams (2009/Q3), Lion (2009/Q4), Eassy and MainOne (2010/Q3), Glo1 (2011/Q2), WACS (2012/Q2), and ACE (2012/Q4).

FIGURE III: THE TERRESTRIAL BACKBONE NETWORK, GRID-CELLS USED FOR LOCATION FIXED EFFECTS, AND SAMPLING CLUSTERS (SOUTHERN GHANA AND AFROBAROMETER DATASET AS EXAMPLE)



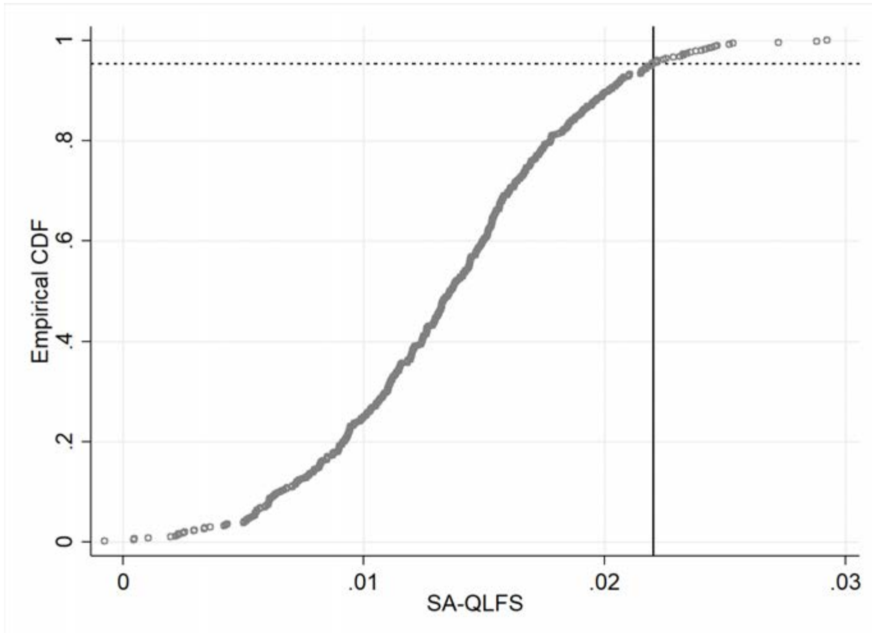
This figure shows submarine Internet cables arriving to the Accra region in Ghana, the country's terrestrial backbone network, and locations from the Afrobarometer. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km, and are used for location fixed effects.

FIGURE IV: THE ESTIMATED EFFECT OF FAST INTERNET ON EMPLOYMENT, VARYING THE ASSUMED CONNECTION RADIUS



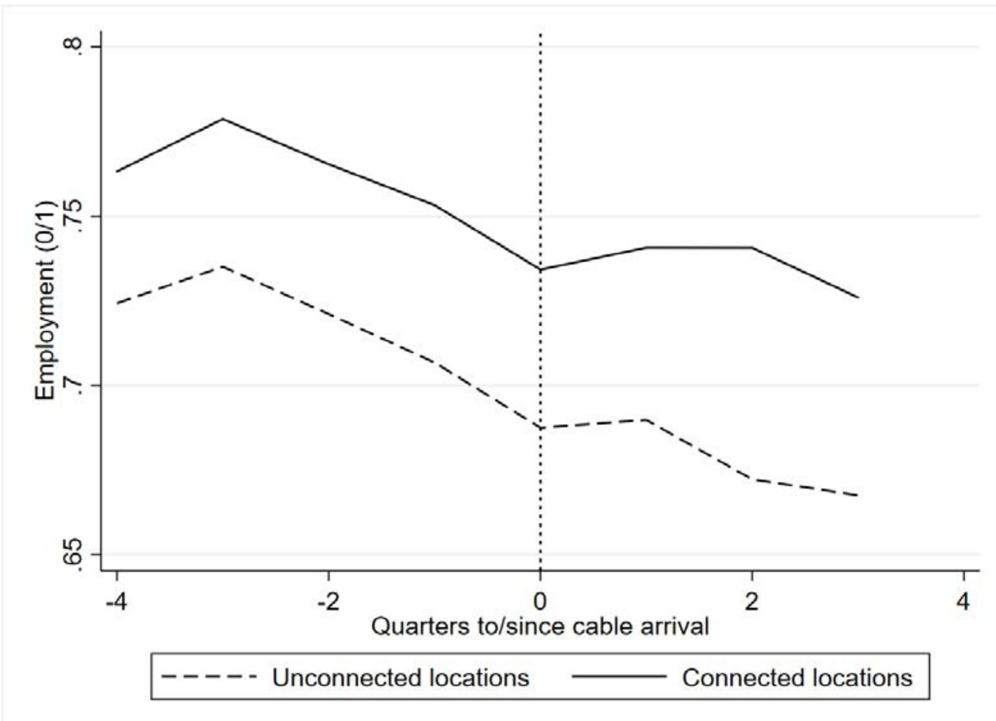
This figure plots the coefficients from running (1) using varying connection radii. The coefficients thus come from separate regressions. We display a longer x axis for Afrobarometer since the estimated effect becomes insignificant "further out" in that sample.

FIGURE V: DISTRIBUTION OF PLACEBO ESTIMATES: FAST INTERNET AND EMPLOYMENT IN SOUTH AFRICA



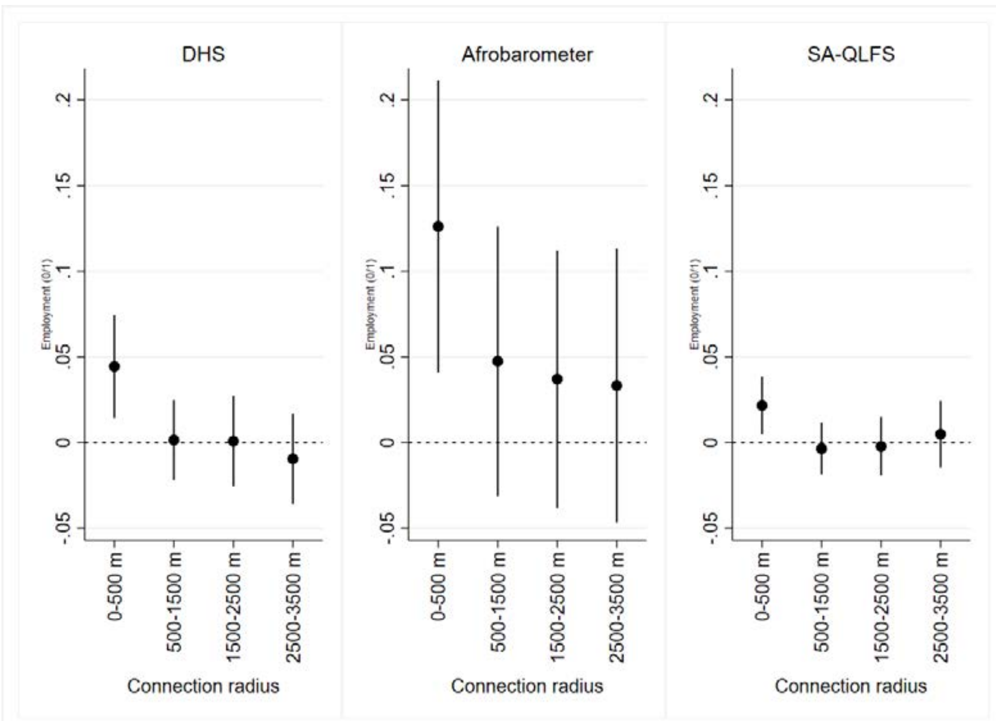
This figure shows a non-parametric permutation test of $\beta = 0$. We sample from all possible submarine cable arrival times, assigning a randomly chosen "fake" arrival time to each location while maintaining each observation's backbone connectivity status. There are as many possible arrival times as there are quarters in the SA-QLFS sample. The figure depicts the empirical cdf of estimates resulting from permuting arrival times 500 times and running (1) on each fake dataset. The vertical line represents the true estimate; where it falls in the empirical cdf of estimates from the dataset with permuted arrival times implies its p-value, which is 0.046.

FIGURE VI: EMPLOYMENT RATE IN CONNECTED AND UNCONNECTED LOCATIONS IN SOUTH AFRICA BEFORE AND AFTER FAST INTERNET ARRIVAL



This figure plots the employment rate in connected and unconnected locations in South Africa before and after the first submarine cable during our data period arrived in the country (2009/Q3).

FIGURE VII: THE EFFECT OF FAST INTERNET ON EMPLOYMENT ACROSS SPACE



This figure plots the coefficients from running (1) using several connection radii. The coefficients thus come from the same regression for each sample. The first radius is the baseline specification in the paper, i.e. 0-500 meters. We then include three "bands" further away from the backbone to display effects across space. These additional treatment groups are each 1 km wide since there are fewer and fewer observations the further out from the backbone.

Tables

TABLE I: INTERNET SPEED AND USE, AND EMPLOYMENT OUTCOMES, BEFORE SUBMARINE CABLE ARRIVAL

	Connected	Un-connected	All
INTERNET OUTCOMES – LOCATION, INDIVIDUAL, AND FIRM LEVEL			
Internet speed, kbps (location, from Akamai)	453.6	423.5	429.6
	[319.9]	[443.9]	[419.3]
Daily Internet use (individual, from Afrobarometer)	0.08	0.11	0.10
	[0.27]	[0.32]	[0.30]
Weekly Internet use (individual, from Afrobarometer)	0.16	0.21	0.20
	[0.37]	[0.41]	[0.40]
Email communication (firm, from WBES)	0.40	0.24	0.38
	[0.49]	[0.43]	[0.49]
Website use (firm, from WBES)	0.13	0.10	0.12
	[0.33]	[0.30]	[0.33]
EMPLOYMENT OUTCOMES – INDIVIDUAL LEVEL			
Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Togo, Tanzania (DHS)			
Employment	0.67	0.69	0.68
	[0.47]	[0.47]	[0.47]
Skilled	0.57	0.58	0.58
	[0.49]	[0.49]	[0.49]
Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, Tanzania (Afrobarometer)			
Employment	0.56	0.59	0.58
	[0.50]	[0.49]	[0.49]
South Africa (QLFS)			
Employment	0.77	0.71	0.72
	[0.42]	[0.45]	[0.45]
Skilled	0.55	0.49	0.50
	[0.50]	[0.50]	[0.50]
Hours worked	45.26	45.38	45.36
	[14.20]	[15.03]	[14.92]
Wants to work more	0.62	0.66	0.66
	[0.48]	[0.47]	[0.47]
Formal employment	0.54	0.47	0.48
	[0.50]	[0.50]	[0.50]
Informal employment	0.12	0.12	0.12
	[0.33]	[0.33]	[0.33]
EMPLOYMENT OUTCOMES – FIRM LEVEL			
# employees (from WBES)	33.2	14.3	30.9
	[123.7]	[32.5]	[95.0]
# skilled positions (from WBES)	11.1	3.0	10.2
	[44.5]	[6.5]	[42.1]
# employees (from Ethiopia LMMIS)	73.9	80.8	75.5
	[146.4]	[300.1]	[192.3]
# skilled positions (from Ethiopia LMMIS)	24.3	23.9	24.2
	[73.2]	[132.8]	[90.2]

All measures displayed are from the period before submarine cable arrival. Internet speed data come from Akamai. They provided us with quarterly data on average connection speeds for ∼900 African locations during the 2007-2013 period. These locations are shown in Appendix Figure AI. Akamai averages the speeds recorded for residential users, educational institutions, government offices, and firms in a given location × quarter, excluding those who connect via mobile networks. We restrict to location × quarters for which the speed measure is based on more than 10 unique IP addresses. (We also exclude the four biggest cities in each country from the speed data sample in this table; see Table II). Internet use rates come from Afrobarometer (survey countries and years are listed in Table AI). We restrict the (individual level) Afrobarometer sample to observations near (<20 km) Akamai locations for comparability (in Table II). Employment rates are from Demographic Health Surveys (DHS), Afrobarometer, and South African Quarterly Labor Force Surveys (QLFS). Occupational skill levels in DHS and QLFS are defined according to ILO ISCO standards. Firm data are from the Ethiopia Large and Medium Scale Manufacturing Industries Survey (LMMIS), and the World Bank Enterprise Survey (WBES). In WBES, skilled positions are proxied by the number of non-production employees. In LMMIS, skilled positions are defined as those where earnings are more than 800 Birr per year (roughly the sample salary median). In WBES information is also provided on whether firms communicate with clients via website and/or email. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. Standard deviations are shown in square brackets.

TABLE II: SUBMARINE CABLE ARRIVAL AND INTERNET SPEED AND USE

Outcome:	Internet speed (asinh)			Internet use Daily (0/1)		Weekly (0/1)	
Unit of analysis:	Location			Individual			
Sample:	Akamai			Afrobarometer			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
SubmarineCables × Connected	0.354**	0.362**	0.380**	0.082***	0.124**	0.123***	0.142***
	(0.137)	(0.176)	(0.191)	(0.028)	(0.050)	(0.032)	(0.053)
Observations	2533	1670	1670	4160	4160	4160	4160
Mean of Outcome				0.10	0.10	0.20	0.20
Country×Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# unique IP's > 10	Yes	Yes	Yes	No	No	No	No
Connected×Time FE	No	No	Yes	No	Yes	No	Yes
Including biggest cities	Yes	No	No	No	No	No	No

Internet speed (kbps) and use (0/1) data come from Akamai and Afrobarometer respectively (more details in Table I). Akamai data is for 2007-2014 and the locations shown in Appendix Figure AI. Afrobarometer survey countries and years are listed in Table AI. Akamai recommends focusing on location×quarters for which the speed measure is based on more than 1000 unique IP addresses, but this dramatically reduces the sample size. We thus restrict to #unique IP>10. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. This indicator may incorrectly classify large, connected cities as unconnected when the city is considered as one geographical unit. Since the Akamai data is at location/city×quarter level (e.g., Cape Town×2009/Q1), we exclude each country's four largest cities (as defined by UNData) from the Akamai sample (if they are present in the sample to begin with). As seen in column 1, the estimated effect of fast Internet is of similar magnitude and significant also in the full sample. (Note that this issue is not relevant to our other datasets, where we have much more fine-grained information on individuals and firms' location). We restrict the (individual level) Afrobarometer sample to observations near (<20 km) Akamai locations for comparability. Time FEs are years. Location FEs are the reported location (a village/neighborhood or city) in both samples. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE III: FAST INTERNET AND EMPLOYMENT

Panel A: Employment				
Outcome:	**Employment (0/1)**			
Unit of analysis:	Individual			
	DHS	**Afro-barometer**	**SA-QLFS**	
	(1)	(2)	(3)	
SubmarineCables × Connected	0.046***	0.077**	0.022***	
	(0.014)	(0.037)	(0.008)	
Observations	59914	7918	280641	
Mean of Outcome	0.68	0.58	0.72	
Country×Time FE	Yes	Yes	No	
Grid-cell×Connected FE	Yes	Yes	No	
Time FE	No	No	Yes	
Location FE	No	No	Yes	
Panel B: Work-related outcomes from SA-QLFS				
Outcome:	**Hours worked (asinh)**	**Wants to work more (0/1)**	**Formal employment (0/1)**	**Informal employment (0/1)**
Unit of analysis:	Individual			
	(1)	(2)	(3)	(4)
SubmarineCables × Connected	0.101***	-0.022***	0.017*	0.004
	(0.035)	(0.008)	(0.009)	(0.005)
Observations	279482	457192	280641	280641
Mean of Outcome		0.66	0.48	0.12
Time FE	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. The QLFS survey is from South Africa. Survey years for each DHS and Afrobarometer country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time FEs are quarters in QLFS and years in DHS and Afrobarometer. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. Hours worked is defined as zero for unemployed individuals. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE IV: FAST INTERNET AND EMPLOYMENT, INCLUDING PLACEBO "TREATMENTS", AND CONTROLLING FOR TRENDS

Outcome:	**Employment (0/1)**							
Unit of analysis:	Individual							
Sample:	**DHS**		**Afrobarometer**		**SA-QLFS**			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SubmarineCables × Connected	0.049***	0.108***	0.084**	0.142**	0.021**	0.017*	0.022**	0.018*
	(0.014)	(0.040)	(0.037)	(0.071)	(0.008)	(0.010)	(0.009)	(0.010)
SubmarineCables × Connected to road network	-0.014		-0.016		0.000			
	(0.009)		(0.024)		(0.006)			
SubmarineCables × Connected to electricity grid	0.006		0.004		-0.012			
	(0.009)		(0.032)		(0.017)			
SubmarineCables × Connected to 3G					0.007			
					(0.006)			
SubmarineCables × Connected, t-1							0.000	
							(0.008)	
SubmarineCables × Connected, t+1								0.005
								(0.007)
Observations	59914	59914	7900	7900	280641	280641	280641	280641
Mean of Outcome	0.68	0.68	0.58	0.58	0.72	0.72	0.72	0.72
Country×Time FE	Yes	Yes	Yes	Yes	No	No	No	No
Grid-cell×Connected FE	Yes	Yes	Yes	Yes	No	No	No	No
Time FE	No	No	No	No	Yes	Yes	Yes	Yes
Location FE	No	No	No	No	Yes	Yes	Yes	Yes
Linear grid-cell trend	No	No	No	No	No	Yes	No	No
Connected×Time FE	No	Yes	No	Yes	No	No	No	No

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. The QLFS survey is from South Africa. Survey years for each DHS and Afrobarometer country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time FEs are quarters in QLFS and years in DHS and Afrobarometer. Individuals (locations) are considered connected to the backbone, roads, and electricity if they are closer than 0.5 km to the backbone network, the road network, and the electricity grid respectively; and to 3G if the individual (location) is within 3G coverage. The GIS shapefile for African electricity grids comes from The Africa Infrastructure Country Diagnostic (AICD), that for African road networks from the Socioeconomic Data and Applications Center (SEDAC) at the Center for International Earth Science Information Network at Columbia University, and that for 3G data from Collins Bartholomew. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE V: FAST INTERNET AND EMPLOYMENT IN SKILLED AND UNSKILLED POSITIONS

Outcome:	**Skilled (0/1)**	**Un-skilled (0/1)**	**Highly skilled (0/1)**	**Somewhat skilled (0/1)**	**Moderately skilled (0/1)**	**Un-skilled (0/1)**
Unit of analysis:	Individual					
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: DHS						
SubmarineCables × Connected	0.044**	0.003	0.017		0.027	0.003
	(0.018)	(0.015)	(0.011)		(0.020)	(0.015)
Observations	59966	59923	59923		59957	59923
Mean of Outcome	0.58	0.11	0.09		0.49	0.11
Country×Time FE	Yes	Yes	Yes		Yes	Yes
Grid-cell×Connected FE	Yes	Yes	Yes		Yes	Yes
Panel B: SA-QLFS						
SubmarineCables × Connected	0.014**	-0.001	0.001	0.003	0.010	-0.001
	(0.006)	(0.005)	(0.004)	(0.004)	(0.006)	(0.005)
Observations	280641	280641	280641	280641	280641	280641
Mean of Outcome	0.50	0.22	0.08	0.08	0.34	0.22
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes	Yes	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The QLFS survey is from South Africa. Survey years for each DHS country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time FEs are quarters in QLFS and years in DHS. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. We categorize occupations' skill level following the ILO's ISCO categorization (ILO, 2012). For DHS, the Highly skilled occupation group includes professional; the Moderately skilled group clerical, skilled manufacturing, retail and sales, services, and employed agriculture; and the Unskilled group unskilled manufacturing, self-employed agriculture, and domestic work. There are no observations in the Somewhat skilled occupation group in the DHS sample. For QLFS, the Highly skilled occupation group includes legislative work and professional; the Somewhat skilled group technical work; the Moderately skilled group clerical, skilled agriculture, crafts workers, services, and plant workers; and the Unskilled group elementary work and domestic work. The Skilled category corresponds to the Highly, Somewhat, and Moderate skilled occupation groups. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE VI: FAST INTERNET, EMPLOYMENT, AND EMPLOYMENT IN SKILLED AND UNSKILLED POSITIONS, BY EDUCATIONAL ATTAINMENT

Outcome:	Employed (0/1)	Skilled (0/1)	Unskilled (0/1)
Unit of analysis:		Individual	
	(1)	(2)	(3)
DHS:			
SubmarineCables × Connected			
× **Not primary**	-0.013	-0.001	-0.024
	(0.032)	(0.036)	(0.023)
× **Primary**	0.061***	0.033	0.035*
	(0.023)	(0.028)	(0.019)
× **Secondary**	0.047***	0.033*	0.012
	(0.015)	(0.018)	(0.015)
× **Higher**	0.067**	0.119***	-0.041
	(0.028)	(0.036)	(0.027)
Observations	59914	59966	59923
Country×Time FE	Yes	Yes	Yes
Grid-cell×Connected FE	Yes	Yes	Yes
Afrobarometer:			
SubmarineCables × Connected			
× **Not primary**	0.109**		
	(0.055)		
× **Primary**	0.077*		
	(0.042)		
× **Secondary**	0.060		
	(0.050)		
× **Higher**	0.097*		
	(0.053)		
Observations	7902		
Country×Time FE	Yes		
Grid-cell×Connected FE	Yes		
SA-QLFS:			
SubmarineCables × Connected			
× **Not primary**	0.012	0.021	-0.009
	(0.017)	(0.018)	(0.018)
× **Primary**	0.028**	0.007	0.021**
	(0.011)	(0.011)	(0.010)
× **Secondary**	0.022*	0.015	0.007
	(0.012)	(0.013)	(0.009)
× **Higher**	0.019*	0.012	0.007
	(0.011)	(0.012)	(0.008)
Observations	277737	277737	277737
Time FE	Yes	Yes	Yes
Location FE	Yes	Yes	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. The QLFS survey is from South Africa. Survey years for each Afrobarometer and DHS country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time FEs are quarters in QLFS and years in Afrobarometer and DHS. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. We categorize occupations' skill level following the ILO's ISCO categorization (more details in Table V). Afrobarometer does not record respondents' occupation. Controls for educational attainment (primary school not completed, primary school completed, secondary school completed, and higher education) are included. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE VII: FAST INTERNET AND FIRM ENTRY IN SOUTH AFRICA

Outcome:	**All firms (asinh)**	**Agri-culture (asinh)**	**Retail/ sales (asinh)**	**Tech-nology (asinh)**	**Manu-facturing (asinh)**	**Services (asinh)**	**Finan-cial (asinh)**	**White-collar (asinh)**	**Blue-collar (asinh)**
Unit of analysis:	Location								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Net firm entry									
SubmarineCables × Connected	0.227***	0.026*	0.086**	0.022	0.020	0.120**	0.158**	0.060*	0.076**
	(0.079)	(0.014)	(0.043)	(0.028)	(0.013)	(0.052)	(0.063)	(0.033)	(0.034)
Observations	38108	38108	38108	38108	38108	38108	38108	38108	38108
Panel B: Firm entry									
SubmarineCables × Connected	0.089**	0.007	0.033	0.015	0.012	0.046	0.103**	0.029	0.043*
	(0.038)	(0.012)	(0.030)	(0.020)	(0.009)	(0.034)	(0.046)	(0.023)	(0.025)
Observations	38108	38108	38108	38108	38108	38108	38108	38108	38108
Panel C: Firm exit									
SubmarineCables × Connected	-0.088**	-0.021*	-0.053**	-0.007	-0.008	-0.059**	-0.043	-0.031*	-0.032*
	(0.038)	(0.012)	(0.023)	(0.015)	(0.009)	(0.029)	(0.029)	(0.017)	(0.018)
Observations	38108	38108	38108	38108	38108	38108	38108	38108	38108
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location×Connected FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Data at location×quarter level, 2007-2014. Location FEs are zip-codes. Time FEs are quarters. See Table AVI for information on how firms are categorized into sectors. Sectors not shown are mining and tourism. The point estimate is positive and insignificant for these sectors. Firms are considered connected if they are closer than 0.5 km to the backbone network. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE VIII: FAST INTERNET, EMPLOYMENT, OUTPUT ELASTICITY OF LABOR, AND PRODUCTIVITY IN ETHIOPIAN FIRMS

Outcome:	**Emplo-yees (asinh)**		**Skilled emplo-yees (asinh)**		**Unskilled emplo-yees (asinh)**		**Value added (asinh)**	**Value added (asinh)**	**Value added (asinh)**
Unit of analysis:	Firm								
Method:	OLS		OLS		OLS		OLS	Reg LP	Adj LP
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Submarine Cables × Connected	0.156*	0.224***	0.034	0.201*	0.115	0.124			
	(0.091)	(0.081)	(0.080)	(0.106)	(0.078)	(0.095)			
Capital							0.276***	0.263***	0.249***
							(0.018)	(0.023)	(0.020)
Unskilled							0.337***	0.127***	0.135***
							(0.064)	(0.043)	(0.045)
Skilled							0.497***	0.198***	0.198***
							(0.043)	(0.025)	(0.026)
Submarine Cables × Connected ×									
Unskilled							-0.176***	-0.048	-0.063*
							(0.058)	(0.031)	(0.034)
Skilled							0.026	0.017	0.016
							(0.033)	(0.027)	(0.027)
Control for Productivity							No	Yes	Yes
Control for Submarine Cables × Connected × Productivity							No	No	Yes
Outcome									**Produc-tivity**
Submarine Cables × Connected									0.127**
									(0.058)
Time FE	Yes	No	Yes	No	Yes	No	No	No	No
Grid-cell×Connected FE	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Industry×Time FE	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes
Firm FE	Yes	No	Yes	No	Yes	No	No	No	No
Observations	5360	5360	5360	5360	5360	5360	4321	4321	4321

Data from the Ethiopian LMMIS manufacturing firm census. 2006-2013. Grid-cells (for location FEs) are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Time FEs are years. Firms are considered connected if they are closer than 0.5 km to the backbone network. The sample is restricted to firms observed both before and after submarine cable arrival and includes 1,103 firms. Skilled (unskilled) positions are defined as those earning more (less) than 800 Birr per year, approximately the sample salary median. Capital is the average of start-of-year and end-of-year book value. The production function specifications allow fast Internet to directly affect value added via a change in the intercept (not shown). Robust standard errors clustered at grid-cell level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE IX: FAST INTERNET, EMPLOYMENT, EXPORTING, ON-THE-JOB TRAINING, SALES AND FIRM COMMUNICATION

	Employment				**Sales**	**Trade**			**Internet use**	
Outcome:	**Emplo-yees (asinh)**	**Prod-uction emp-loyees (asinh)**	**Non-prod-uction emp-loyees (asinh)**	**On-the -job train-ing (0/1)**	**Sales per labor cost (asinh)**	**National sales (asinh)**	**Indirect exports (asinh)**	**Direct exports (asinh)**	**Email commu-nica-tion (0/1)**	**Website use (0/1)**
Unit of analysis:	Firm									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SubmarineCables × Connected	0.172**	0.205	0.227***	0.145***	0.248	-0.502*	1.318*	1.539**	0.131**	0.130*
	(0.073)	(0.161)	(0.069)	(0.046)	(0.546)	(0.684)	(0.053)	(0.074)		
Observations	4897	3155	3144	5164	3667	4033	4035	4037	5132	5128
Mean of Outcome				0.09					0.38	0.12
Country×Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Location FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Data from World Bank Enterprise Surveys. World Bank Group (2017) have produced a dataset accompanying the full WBES dataset that includes cleaned versions of sales variables and the number of employees. The authors account for outliers and deflate sales to 2009 USD. We use of the accompanying dataset for these variables. The WBES includes firms from Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania. 2006-2014. Time FEs are years. Location FEs are cities. We use the number of production employees as a proxy for unskilled labor, and the number of non-production employees as a proxy for skilled labor. The trade outcomes are defined (by WBES) as shares of annual sales, and we interact that variable with annual sales to get, e.g., the value of exports in 2009 USD. Indirect exports are defined as going through a third party. The Internet use variables are equal to one if the firm states that it uses email or a website to communicate with clients. Because almost all firms in WBES are located in large cities and sub-city information on their location is not reported, a within-500-meters-of-the-backbone indicator incorrectly classifies many connected WBES firms/cities as unconnected (for example those in Abuja, Accra, Dar es Salaam, and Kano. That these cities are in fact connected to the backbone is clear: the maps show backbone cables whose route was clearly chosen to connect them). In WBES we thus classify firms/cities as connected if the backbone passes through the city limits, as classified in Schneider, A., M. A. Friedl and D. Potere (2009). (This issue is not relevant to our other datasets, where we have much more fine-grained information on individuals and firms' location). Robust standard errors clustered at city level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE X: FAST INTERNET AND INCOMES

Outcome:	**Light density at night (asinh)**	
Unit of analysis:	Point	
Sample:	NOAA	
	(1)	(2)
SubmarineCables × Connected	0.024***	0.033*
	(0.009)	(0.018)
Observations	80360	80360
Country×Time FE	Yes	Yes
Grid-cell×Connected FE	Yes	Yes
Connected×Time FE	No	Yes

The data is yearly and for 2007-2013. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Locations are considered connected if they are closer than 0.5 km to the backbone network. Light density at night proxies for average income at location level. Robust standard errors clustered at grid-cell level in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

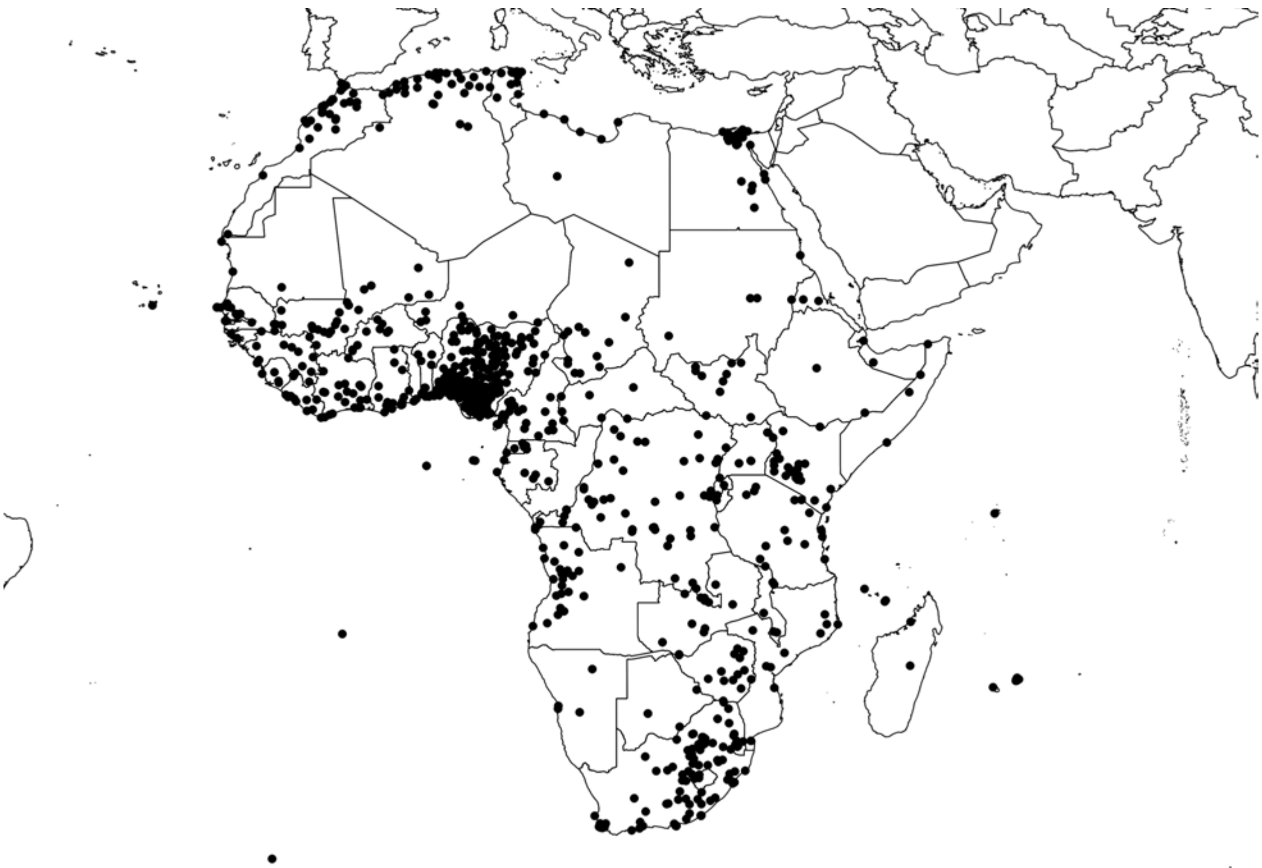
Appendix

The South Africa Companies and Intellectual Property Commission's administrative dataset of firm registrations categorizes firms only as public, private or NGO. To estimate the effect of fast Internet on sector specific firm creation, we thus need to categorize the firms based on their names. We choose a set of sectors that, as far as possible, correspond to the categories of occupations reported in the DHS and QLFS datasets: services, white collar firms, blue collar firms, retail and sales, technology, manufacturing, finance, agriculture, mining, and tourism and foods.

We start by splitting all firm names on the space between the words. For example, "The South African Mining Company" would render five new variables. The first one would be called "name1" and would have the value "The", the second one would be called "name2" and would have the value "South", and so on.

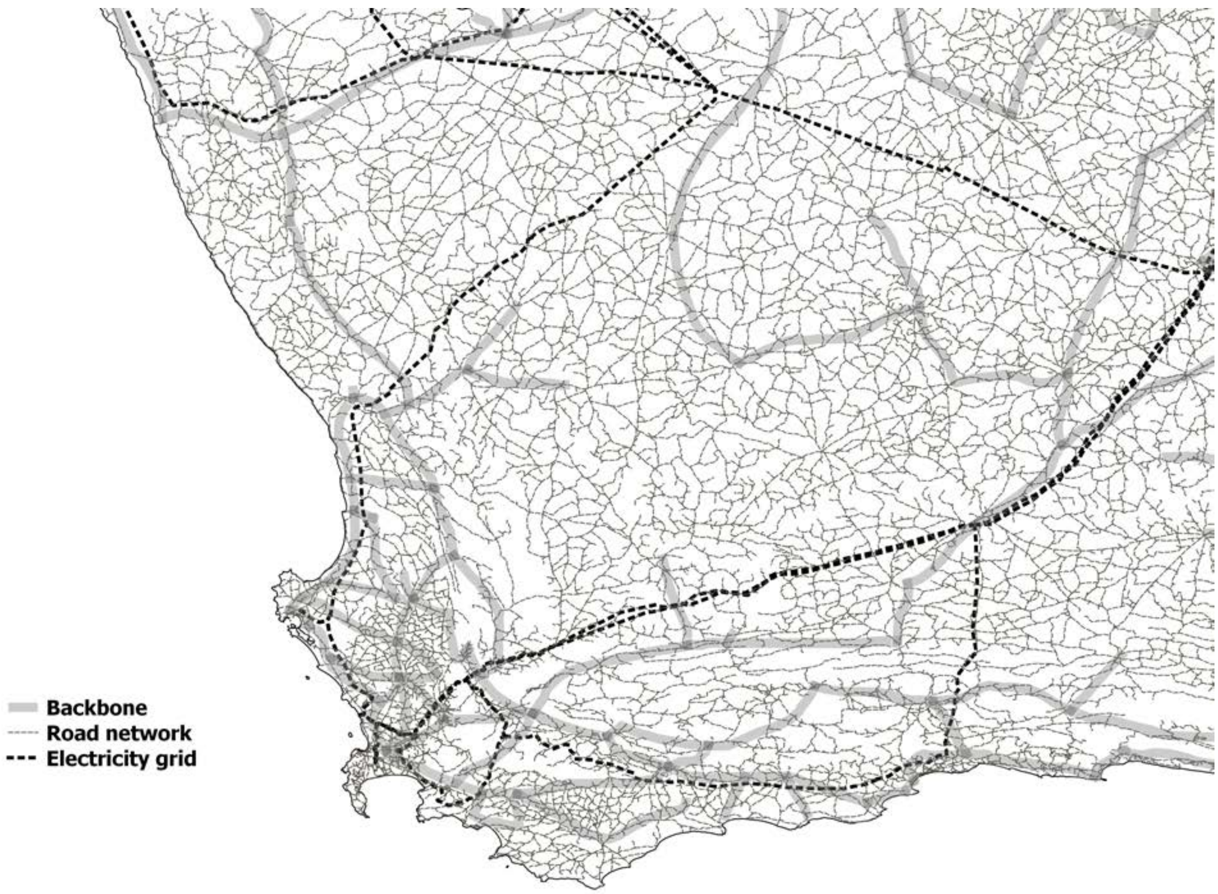
name2, as specified above, usually contains the important key word that makes it possible to categorize a firm, such as "accounting", "trading", "properties", or "catering". We therefore use name2 to manually match key words to the sectors listed above. For example, we categorize firm X as belonging to the technological sector if name2 contains the words "computer", "tech", "telecommunications", and so on. The mapping of words to sectors is provided in Appendix Table AVI. Of course, the key words could have ended up in any of the other name variables. We thus run the exact same iteration for all of those, up to name10. With this method, we are able to categorize 67 percent of the firms in the CIPC sample.

FIGURE AI: LOCATIONS INCLUDED IN DATASET ON INTERNET SPEEDS



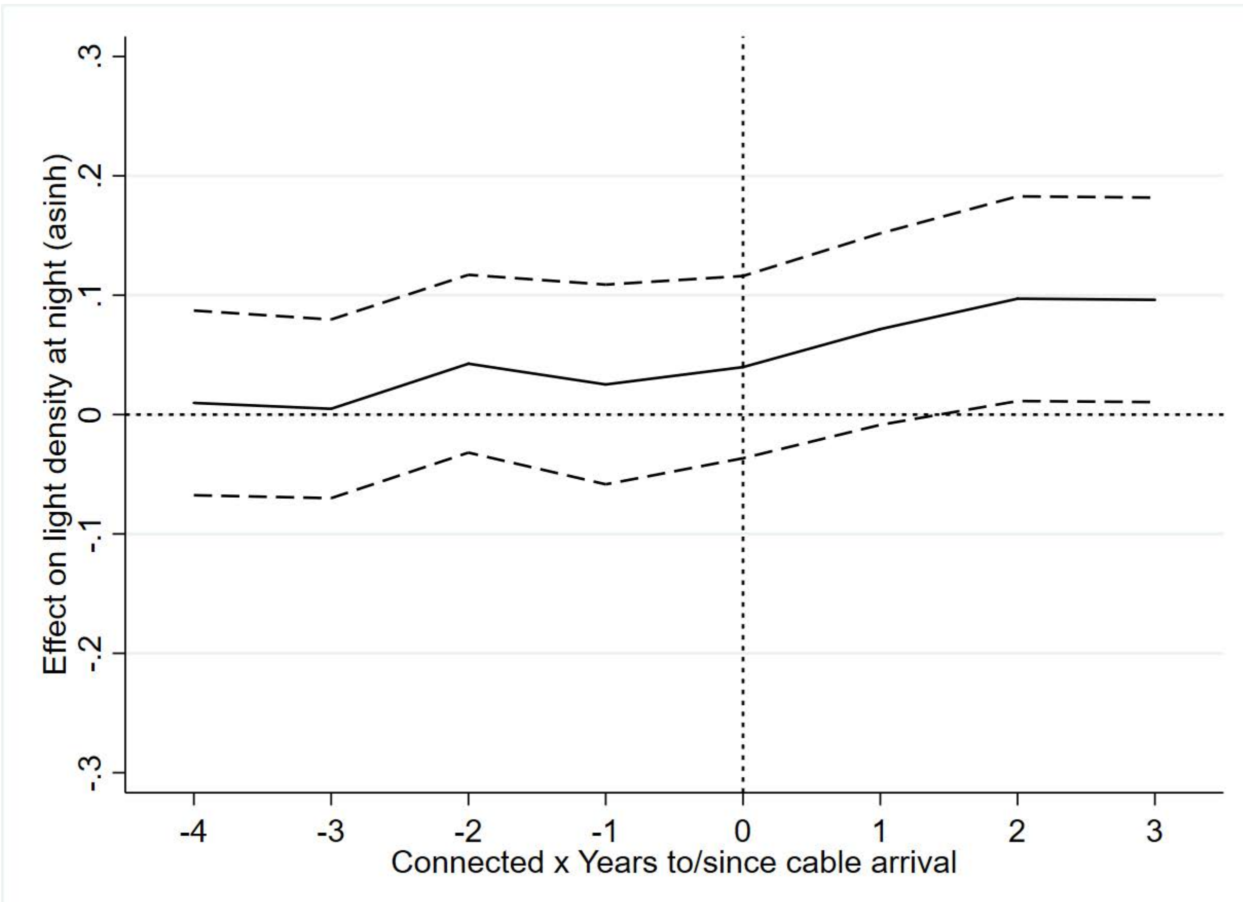
This graph plots the locations for which Akamai has information on Internet speed between 2007 and 2014. There are around 920 locations in this sample. We use data for the countries listed in Table AI.

FIGURE AII: ROAD NETWORKS AND ELECTRICITY GRID (SOUTHWESTERN SOUTH AFRICA AS EXAMPLE)



This graph plots the road networks and electricity grid used in the placebo "treatment" estimations. Road data comes from SEDAC and electricity data from AICD.

FIGURE AIII: FAST INTERNET AND INCOMES OVER TIME



This graph plots the coefficients from the interaction terms between the connected status and event-time indicators. The event time is calculated as the year of light measurement net the year of first cable connection. A dummy variable is created for each event time and is subsequently interacted with the connected indicator. Country×year FE's are included in the regression, but the results are virtually unchanged using year FE's solely.

Table AI: Included Countries, Survey Rounds, and Cable Connection

Country	Survey	First connected
Benin	Afrobarometer (2008, 2011); DHS (2001, 2012)	2010/Q3
D.R. Congo	DHS (2007, 2013)	2012/Q2
Ghana	Afrobarometer (2008, 2012); DHS (2008, 2014)	2010/Q3
Kenya	Afrobarometer (2008, 2011); DHS (2008, 2014)	2009/Q3
Madagascar	Afrobarometer (2008, 2013)	2010/Q3
Mozambique	Afrobarometer (2008, 2012)	2009/Q3
Namibia	DHS (2006, 2013)	2012/Q2
Nigeria	Afrobarometer (2008, 2012); DHS (2008, 2013)	2010/Q3
Senegal	Afrobarometer (2008, 2013)	2010/Q3
South Africa	Afrobarometer (2008, 2011); SA-QLFS (2008/Q1 - 2010/Q2)	2009/Q3
Tanzania	Afrobarometer (2008, 2012); DHS (1999, 2010)	2009/Q3
Togo	DHS (1998, 2013)	2010/Q3

This table shows the survey rounds and connection quarters for countries included in our main analysis. Included countries (1) have surveys conducted both before and after cable arrival; (2) have detailed geographical markers; (3) have employment status for individuals; and (4) are not landlocked. We only make use of *Standard DHS* surveys.

Table AII: Fast internet and employment, Varying Grid-Cell Size

Outcome:	**Employment (0/1)**						
Unit of analysis:	Individual						
Grid-cell size:	**10 km**	**15 km**	**20 km**	**25 km**	**30 km**	**35 km**	**40 km**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
DHS:							
SubmarineCables × Connected	0.046***	0.047***	0.051***	0.044**	0.052***	0.049***	0.060***
	(0.014)	(0.016)	(0.018)	(0.019)	(0.014)	(0.016)	(0.018)
Observations	59914	59914	59914	59914	59914	59914	59914
Mean of Outcome	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Afrobarometer:							
SubmarineCables × Connected	0.077**	0.076**	0.080**	0.076**	0.069**	0.071**	0.073**
	(0.037)	(0.038)	(0.036)	(0.037)	(0.034)	(0.035)	(0.034)
Observations	7918	7918	7918	7918	7918	7918	7918
Mean of Outcome	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Country×Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Grid-cell×Connected FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. Survey years for each DHS and Afrobarometer country are reported in Table AI. Grid-cells range from 10×10 km to 40×40 km. Time is years in both datasets. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. Robust standard errors clustered at grid-cell level in parentheses, using the same grid-cell size as stated in the column headers. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

TABLE AIII: EMPLOYMENT AND SKILLED EMPLOYMENT BY EDUCATIONAL ATTAINMENT, BEFORE SUBMARINE CABLE ARRIVAL

Outcome:	**Employed (0/1)**			**Skilled (0/1)**		
	Connected	**Un-connected**	**All**	**Connected**	**Un-connected**	**All**
DHS						
Not primary	0.78	0.80	0.80	0.66	0.61	0.62
	[0.41]	[0.40]	[0.40]	[0.47]	[0.49]	[0.48]
Primary	0.69	0.72	0.72	0.53	0.56	0.55
	[0.46]	[0.45]	[0.45]	[0.50]	[0.50]	[0.50]
Secondary	0.60	0.61	0.61	0.55	0.56	0.56
	[0.49]	[0.49]	[0.49]	[0.50]	[0.50]	[0.50]
Higher	0.69	0.70	0.70	0.66	0.69	0.68
	[0.46]	[0.46]	[0.46]	[0.48]	[0.46]	[0.47]
Afrobarometer						
Not primary	0.42	0.44	0.43			
	[0.49]	[0.50]	[0.50]			
Primary	0.52	0.54	0.53			
	[0.50]	[0.50]	[0.50]			
Secondary	0.60	0.68	0.66			
	[0.49]	[0.47]	[0.47]			
Higher	0.79	0.79	0.79			
	[0.41]	[0.41]	[0.41]			
SA-QLFS						
Not primary	0.74	0.73	0.73	0.28	0.28	0.28
	[0.44]	[0.44]	[0.44]	[0.45]	[0.45]	[0.45]
Primary	0.73	0.65	0.66	0.44	0.38	0.39
	[0.45]	[0.48]	[0.47]	[0.50]	[0.49]	[0.49]
Secondary	0.76	0.71	0.72	0.65	0.60	0.60
	[0.43]	[0.45]	[0.45]	[0.48]	[0.49]	[0.49]
Higher	0.91	0.90	0.90	0.88	0.88	0.88
	[0.29]	[0.30]	[0.29]	[0.32]	[0.33]	[0.33]

All measures displayed are from the period before submarine cable arrival. Employment rates are from Demographic Health Surveys (DHS), Afrobarometer, and South African Quarterly Labor Force Surveys (QLFS). Occupational skill levels in DHS and QLFS are defined according to ILO ISCO standards. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. Standard deviations are shown in square brackets.

TABLE AIV: FAST INTERNET AND EMPLOYMENT, VARYING THE SAMPLE AND TERRESTRIAL CABLES CONSIDERED

Outcome:	**Employment (0/1)**		
Unit of analysis:	Individual		
Sample:	**DHS**	**Afro-barometer**	**SA-QLFS**
	(1)	(2)	(3)
Panel A: Backbone cables reported in 2 maps			
SubmarineCables × Connected	0.048***	0.045	0.024***
	(0.015)	(0.040)	(0.009)
Observations	59914	7900	280641
Mean of Outcome	0.67	0.58	0.71
Panel B: Excluding obs. close to landing station			
SubmarineCables × Connected	0.054***	0.086**	0.025***
	(0.016)	(0.042)	(0.008)
Observations	51129	5871	259177
Mean of Outcome	0.67	0.58	0.71
Panel C: Excluding obs. with distance to backbone >5 km			
SubmarineCables × Connected	0.040***	0.079**	0.022***
	(0.015)	(0.038)	(0.008)
Observations	49982	7062	231242
Mean of Outcome	0.67	0.58	0.72
Country×Time FE	Yes	Yes	No
Grid-cell×Connected FE	Yes	Yes	No
Time FE	No	No	Yes
Location FE	No	No	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. The QLFS survey is from South Africa. Survey years for each DHS and Afrobarometer country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time FEs are quarters in QLFS and years in DHS and Afrobarometer. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. Panel A defines the backbone network as the intersection of AfTerFibre (2014)'s map and www.africabandwidthmaps.com map from 2013/Q2. Panel B excludes observations that are closer than 20 km to a landing station. Robust standard errors clustered at the level of location FEs in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

TABLE AV: ALTERNATIVE STANDARD ERRORS

Outcome:	**Employment (0/1)**		
Unit of analysis:	Individual		
Sample:	**DHS**	**Afro-barometer**	**SA-QLFS**
	(1)	(2)	(3)
Panel A: Fast Internet and Employment Standard errors accounting for spatial correlation			
SubmarineCables × Connected	0.046***	0.077**	0.022***
	[0.014]	[0.029]	[0.005]
Observations	59914	7918	280641
Mean of Outcome	0.68	0.58	0.72
Country×Time FE	Yes	Yes	No
Grid-cell×Connected FE	Yes	Yes	No
Time FE	No	No	Yes
Location FE	No	No	Yes
Panel B: Fast Internet and Employment Standard errors clustered on administrative area			
SubmarineCables × Connected	0.032*	0.077*	0.022***
	[0.017]	[0.045]	[0.008]
Observations	40798	7918	280641
Mean of Outcome	0.63	0.58	0.72
Country×Time FE	Yes	Yes	No
Grid-cell×Connected FE	Yes	Yes	No
Time FE	No	No	Yes
Location FE	No	No	Yes

Outcome:	**Productivity**
Unit of analysis:	Firm
Sample:	**Ethiopian LMMIS**
	(1)
Panel C: Fast Internet and Firm Productivity Bootstrapped Standard Errors	
SubmarineCables × Connected	0.127*
	[0.068]
Observations	4321
Grid-cell×Connected FE	Yes
Industry×Time FE	Yes

The DHS sample includes Benin, D.R. Congo, Ghana, Kenya, Namibia, Nigeria, Tanzania, and Togo. The Afrobarometer sample includes Benin, Ghana, Kenya, Madagascar, Mozambique, Nigeria, Senegal, South Africa, and Tanzania. The QLFS survey is from South Africa. Survey years for each DHS and Afrobarometer country are reported in Table AI. QLFS data are 2008/Q1-2010/Q2. Ethiopian LMMIS manufacturing firm census for 2006-2013. Grid-cells are 0.1×0.1 decimal degrees, which is roughly 10×10 km. Location FEs are enumeration areas in South Africa QLFS. Time is quarters in QLFS and years in DHS, Afrobarometer, and Ethiopian LMMIS. Individuals (locations) are considered connected if they are closer than 0.5 km to the backbone network. This table presents the precision of our main results using Conley standard errors that accounts for spatial auto-correlation in Panel A (Conley, 1999).The cut-off window is 100 km, but the results are virtually unchanged for 50 km, 500 km, and 1,000 km. Panel B clusters the standard errors on a region (DHS and Afrobarometer) and municipality (SA-QLFS, since South Africa does not formally have regions, and there are only nine provinces) level. The estimates and number of observations differ somewhat due to missing information on regions in the DHS data. There are 95 distinct regions in the DHS sample, 154 distinct regions in the Afrobarometer sample, and 341 distinct municipalities in the SA-QLFS sample. Panel C bootstraps the standard error in the last procedure described in Section 6.2.2. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$

TABLE AVI: CATEGORIZATION OF SOUTH AFRICAN FIRMS' SECTOR BASED ON KEYWORDS FROM FIRM NAMES

Services:									
abbatoir	accommodation	acquisitions	advertising	air-conditioning	aircon	airconditioning	airlines	airport	answers
apartments	art	arts	assessing	assessment	assessments	assist	assistance	aviation	baby
bakery	bar	bars	bay	bistro	block	booking	boxing	burial	cafe
care	carriers	carwash	caterers	catering	caterings	chauffeur	child	children	childrens
christian	church	clinic	clinical	clinics	club	coaches	coaching	coffee	coffees
college	commercial	communication	communications	compliance	concerts	conditioning	conference	conferences	consultation
cooking	cosmetics	cottages	council	counsellors	courier	couriers	couture	creche	cuisine
cure	dance	daycare	deliveries	design	designs	destination	destinations	dienste	driver
driving	drycleaners	eatery	eats	educare	education	empowerment	entertainment	estate	estates
event	events	exhibitions	export	exporters	exporting	exports	facilitators	fashion	fast
feed	fellowship	fencing	fitness	flats	food	football	franchising	funeral	funerals
games	gaming	gardening	god	gourmet	guest	guesthouse	gym	habitat	hair
hairdresser	haven	healing	health	healthcare	hire	hiring	homecare	homecleaners	homes
homestead	hospital	hospitality	host	hosting	hotel	hotels	house	housing	immobiliare
implementation	import	importers	imports	information	innovations	inspections	installations	intelligence	islam
kafee	karate	kontrakteurs	laundry	leadership	learning	leasing	leisure	living	lodge
logistic	logistics	logistix	mail	makelaars	mansions	meals	memorials	migration	ministries
ministry	mission	missions	monitoring	motel	networking	nominees	nursery	nursing	orchards
outsource	paintball	park	parking	payment	payments	pet	planning	pools	pre-school
procurement	promotions	properties	property	protection	realty	recruit	recruiting	recruitment	recruits
recycling	rent	rental	rentals	residence	residential	residentials	resourcing	restaurant	restaurants
resturant	resturants	retirement	retreat	rugby	safety	salon	sanctuary	school	security
seminars	service	services	servicing	shaving	shipping	shuttle	shuttles	spa	sport
sports	sportsbar	staffing	storage	strategies	strategy	supervision	surgical	swimming	tavern
tax	taxi	theatre	theatres	tourism	tours	training	tranport	transformation	transformers
transport	transportation	transporters	transporting	travel	traveling	travelling	travels	treats	trucking
tutoring	undertakers	venue	villa	village	villages	villas	wash	waste	wedding
weddings	wellbeing	wellness							
White collar:									
academy	admin	administrasie	administration	administrators	advisors	advisory	akademie	analytics	architechts
architects	architectura	architectural	architecture	assurance	attorneys	biometrics	branding	chemical	chemicals
consult	consultancies	consultancy	consultant	consultants	consulting	data	decor	dental	designers
directors	editing	entrepreneurs	fashions	forensic	forensics	geoconsultants	ideas	institute	insurance
interior	interiors	konsultante	landscaping	legal	management	managers	managing	marketing	media
optometrist	optometrists	petrochemicals	publication	publishers	publishing	publishings	radiology	research	risk
translation									
Blue collar:									
autobody	automobile	baking	blocks	brick	brickforce	bricks	build	builders	building
butchery	car	carpenter	carpentry	clean	cleaners	cleaning	coaters	coating	coatings
concrete	construction	constructions	constructors	contracting	contractors	deco	distribution	distributions	distributor
distributors	drilling	equipment	fabrics	filtration	fishing	flooring	forestry	foundry	freight
fuel	gas	hunters	hunting	installation	installations	irrigation	knitting	konstruksie	laminations
lawns	maintenance	mechanics	metal	metals	movers	packaging	packing	paint	painters
painting	paints	pavers	paving	plastering	plumbers	plumbing	recyclers	refrigiration	refurbishing
renovations	repair	repairs	roofing	scaffolding	textiles	towing	truck	woodwork	
Retail and sales:									
accessories	aesthetics	affairs	alarms	apparel	appliances	auction	auctioneers	auctions	auto
bags	bathrooms	beads	beautique	beauty	bedding	beverages	books	booksellers	bookshop
boutique	brand	brands	bread	canopies	cement	ceramics	cheese	clothing	commerce
commodities	components	condoms	confectionary	confectionery	consumables	cooling	cosmetic	cosmetics	covers
crafts	creations	cupboards	curtain	curtains	dealer	dealers	deals	delights	detailing
diary	discounters	elegance	enterprise	enterprises	fertilisers	films	flowers	foods	footwear
fuels	furnishers	furniture	furnitures	garden	garments	gift	gifting	gifts	glass
goodies	goods	groceries	grocery	handelaars	hardware	heating	herbs	hygiene	images
ingredients	instruments	jewellers	jewellery	juice	kiosk	kitchen	kitchens	kitchenware	leather
lifestyle	lighting	lights	linen	liquor	liquors	lubricants	machinery	machines	mall
market	markets	mart	materials	meat	meats	medical	medicine	merchandise	merchandising
merchant	mini-supermarket	motor	motorcycles	motors	movies	music	newspaper	noodles	nutrition
oil	oils	optical	opticals	outdoor	outfitter	outfitters	parts	patisserie	pawn
pearls	perfumes	petroleum	pharmaceutica	pharmaceutical	pharmaceuticals	pharmacy	photography	photos	pictures
plant	plants	plates	print	printers	printing	printings	prints	produce	pumps
refrigeration	remedies	resale	retail	retailers	retailing	sales	sewing	shoes	shop
shopfitters	shopping	signs	snacks	spices	sportswear	stationary	stationers	stationery	store
style	suit	superette	supermarket	superstore	supplements	supplier	suppliers	supplies	supply
sweets	telesales	things	timber	timbers	toiletries	tools	towels	toys	trailers
tyre	tyres	upholsterers	upholstery	vehicle	vehicles	vending	wear	wholesailers	wholesale
wholesaler	wholesalers	windscreen	windscreens	wine	wines				
Technology:									
3d	apps	audio	cable	cables	cabling	cellular	computer	computers	computing
digital	electrical	electricals	electrician	electricians	electronics	energy	engeneering	engineering	engineers
fibre	hydraulics	infrastructure	internet	it	mechanical	mobile	multimedia	online	software
solar	tech	technical	technicians	technics	technik	technique	techniques	technological	technologies
technology	telecommunication	telecommunications	telecoms	web	website				
Manufacturing:									
brewery	brewing	fabrication	factory	manufacturer	manufacturers	manufactures	manufacturing	plastic	plastics
production	productions	products	refineries	refiners	refinery	refining			
Financial:									
accountant	accountants	accounting	asset	audit	auditors	beleggings	bonds	bookkeeping	brokers
capital	cash	clearing	credit	credits	debt	equities	equity	finance	finances
financial	finans	finansiele	fund	funding	futures	holding	holdings	invest	investements
investing	investment	investments	investors	lending	loan	loans	money	mortgage	mortgages
portfolio	portfolios	savings	securities	trade	traders	trading	tradings	trust	wealth
Agriculture:									
agri	agri-business	agribusiness	agricultural	agriculture	boerdery	boerderye	farm	farmers	farming
farms	fisheries	growers	horticultural	horticulture	livestock	poultry			
Mining:									
alu	aluminium	aluminum	coal	copper	diamond	diamonds	gold	iron	mine
mineral	minerals	mines	mining	platinum	steel	steelworks	uranium		
Tourism and foods:									
bagel	burgers	cakes	chicken	chickens	cookies	fish	fruit	fruits	pizza
resort	resorts	safari	safari's	safaris	tour	vacations			

This table displays the key words used when assigning firms observed in the CIPC data to a sector. See the Appendix for details on the procedure.