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Does Africa Need More Roads in the Digital Age?

Evidence of Complementarities in Infrastructure

Mathilde Lebrand
Arcady Mongoue
Roland Pongou
Fan Zhang

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Abstract

This paper investigates whether the expansion of fast internet networks complements or substitutes for the development of roads to improve market access and create more and higher-skilled jobs in Africa. The paper combines the geographic locations of households and firms with the locations of main roads and optical-fiber nodes in 25 Sub-Saharan African countries. Using the difference-in-differences and instrumental variables approaches and leveraging the history of post-independence road building and the timing of the arrival of submarine internet, the paper examines the impacts of access to these two types of infrastructure, both in isolation and in combination. The findings show that improving access to both has large and positive complementary effects. On average, the additional impacts on employment from combining access to both types of infrastructure are 22 percent larger than the sum of their isolated effects. The findings suggest that a big push for combined investments in fast internet and road access could enhance economic development in Africa overall. Firms and workers in urban locations, female workers, and workers with higher levels of education gain the most from the complementarities that emerge.

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Does Africa Need More Roads in the Digital Age? Evidence of Complementarities in Infrastructure

Mathilde Lebrand[2], Arcady Mongoue[1], Roland Pongou[1], and Fan Zhang[2]

[1]Ottawa University

[2]World Bank

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1 Introduction

The rapid spread of the internet has been heralded as an opportunity for the economies of low-income countries to "leapfrog into the 21st century" and to create more and better jobs (Hjort and Poulsen, 2019). But it is also argued that unless investments in digital technologies are complemented by policies and measures to improve traditional means of market access, it is unlikely that these new technologies will realize their full potential (Goldberg, 2019). Several papers in the economic literature have examined the role of road on economic growth and job creation, and a few studies have analyzed the impact of internet infrastructure on these outcomes. Among others, Duflo et al. (2015) show that the proximity to road networks has contributed to economic gains within regions in China. Hjort and Poulsen (2019) show that fast internet access has had large, positive effects on employment rates and on groups of workers with lower levels of education. However, most of the literature has studied the employment impacts of different types of infrastructure in isolation, leaving open the question of how they work in combination. Addressing the question of whether internet networks complement or substitute for the development of roads to improve labor market outcomes and economic development is crucial for the optimal design of policies to supply these costly infrastructures.

In this paper, we investigate *complementarities* between the internet and road networks in employment, the structure of the labor market, and firms' operations in Africa. We also analyze how these (complementary) effects vary across gender, skills, occupations, educational levels, rural and urban locations, and levels of economic development. Both roads and internet access provide better market access to firms and consumers. Internet connectivity can substitute for access to roads, for example, by enabling some people to work from home rather than to use roads to commute to an office. Alternatively, roads and internet access can also complement each other. For example, e-commerce in remote areas is likely to develop only if good roads allow for trade to and from these regions. Internet access may reduce information frictions for firms, allowing them to find and use better inputs, to find and employ better workers, and to train their workers on the job; at the same time, good roads may remain necessary to take advantage of these inputs, both to allow workers to easily come to workplaces, and for firms to have incentives to improve production through investments to increase labor productivity. Our paper aims to identify whether roads and internet access are substitutes or complements for job outcomes in Africa. Addressing this question has important implications for optimizing the allocation of infrastructure investments in poor countries.

To examine how the expansion of fast internet networks complements or substitutes for the development of roads to encourage job creation, we combine data on characteristics and geographic locations of households and firms, and on the location of optical-fiber nodes and roads in Sub-Saharan African countries. We draw on detailed demographic data from the Demographic and Health Surveys (DHS) Program, the World Bank Enterprises Surveys (WBES), and the Living Standard Measurement Study (LSMS). Novel data on optical-fiber nodes come from Africa Bandwidth Maps, and submarine cable maps from Mahlknecht (2014). Using a combination of difference-in-differences techniques and instrumental-variable approaches with these varied data, we estimate the join effects on local labor markets and workers that stem from changes in the proximity of major roads and accessibility to high-speed internet infrastructure.

We find large, complementary effects of investing in the two types of infrastructure. For example, combined investments of this kind increase the probability of having been employed in the last year by at least 9 percentage points from the probability that is the case when no investments are made. By contrast, road and internet investments undertaken in isolation have lower impacts. Being 1 kilometer closer to a road in a given location increases the likelihood of employment by 0.8 percentage point, and having fast internet access increases the likelihood of employment by 6.7 percentage points. Thus, the additional impact on employment that arises from the complementarities of combining road and internet investments is, on average, 22 percent higher. Similarly, complementarities that arise from the two investments are 20 percent larger in terms of both the share of a given location's workers who are skilled and the share who work in service-sector jobs. Better access to roads and fast internet in combination leads the share of low-skilled workers to fall.

Investments in both types of infrastructure also have positive impacts on firms. We find that firms' productivity improves and that losses decline. Firms have more opportunities to enter into contracts with the government. This has a positive impact on the labor demand of firms, leading them to operate for more hours and to hire more full-time employees. On average, the combined impact of accessing fast internet and bringing a main road 1 kilometer closer increases firms' hours of operation by 4.4 hours per week and leads them to add one more full-time employee. Combining investments in the two types of infrastructure rather than making isolated investments leads to an increase in firms' hours of operation and in the number of full-time employees.

We study the heterogeneity in impacts of the isolated and combined investments in expanding access to fast internet and main roads. These impacts differ between urban and rural locations, as well as between male and female workers. Isolated investments in fast internet benefit urban locations and female workers the most. Construction that brings a main road 1 kilometer closer to a locality benefits rural locations and female workers the most. The additional impacts from combining road and internet investments are 72 percent larger in urban locations compared to localities that gained better access to only one of the types of infrastructure; by contrast, the additional impacts of such dual investments are far lower, just 5 percent, in rural locations. The additional impacts are around 23 percent larger for both male and female workers than those with access to only one of the types of infrastructure in urban areas.

Contributions to the literature Our paper provides novel findings on how the expansion of internet networks complements important infrastructures such as roads to enhance job creation and employment in developing countries, and documents how the benefits of this complementarity vary across individuals and societies. It does so using both individual and firm-level data from various sources and employing an identification strategy that involves a new instrumental variable based on the arbitrary ethnic composition and political history of African countries. Our analysis adds to the recent literature on the impacts of internet access on economic development. Hjort and Tian (2021) provide an overview of the nascent yet already sizeable empirical body of research on the economic impact of internet connectivity in developing countries. Theoretically, internet access can drive economic development through its impacts on both the supply-side and the demand-side of an economy. In many contexts, internet access appears to improve the productivity of workers and firms (Draca et al., 2006; Khanna and Sharma, 2018; Goldfarb and Tucker, 2019; Houngbonon et al., 2022). Research findings show that labor market outcomes for female workers especially improve when firms use more ICT (Dutz et al., 2017), but the findings are mixed on whether internet connectivity plays a role in building skills. Demand-side forces focus on the expansion of market access for firms, workers, and/or consumers, and the reduction of information frictions (Allen and Arkolakis, 2014; Fan et al., 2018; Couture et al., 2021). Internet access has also been shown to improve health-related human capital by reducing HIV/AIDS prevalence (Abbasi and Pongou, 2022). In contributing to this literature, our work breaks new ground by analyzing not just the effect of the internet in isolation, but also the additional impacts that arise from the complementarity between internet and road infrastructure investments on employment opportunities and outcomes.

Our paper also adds to the literature on the impacts of transport infrastructure expansion on economic growth and development. Several papers have shown that the net welfare gains of highways are large (Aschauer, 1989; Shatz et al., 2011; Duranton and Turner, 2012; Faber, 2013; Allen and Arkolakis, 2014; Ejaz Ghani, 2016; He et al., 2020). Others have focused on the impacts of better accessibility to roads or railroads on GDP per capita (Atack et al., 2009; Donaldson, 2010; Duflo et al., 2015), and on economic development (Okoye et al., 2019). These papers have focused on transport investments only.

Very few papers have looked at *complementarities* in infrastructure, especially in Africa. Analyzing data from Ethiopia, Moneke (2020) examines the impact on employment and welfare that stems from combined investments in road and electrification. Using data from 27 Sub-Saharan African countries, Abbasi et al. (2022) explore the heterogeneous effects of joint investments in road and electrification on employment, finding strong complementarities between these infrastructures. Gebresilasse (2023) documents complementarities between road construction and extension services in agricultural productivity in rural Ethiopia. Our paper adds to this new literature by examining the complementarities of internet and road investments.

Our paper also makes a methodological contribution. It adds to the empirical literature on infrastructure by using two original instrumental variables to address the possible endogeneity of infrastructure locations. We exploit the least-cost-path procedure to construct theoretical road networks connecting the centroids of different ethnic territories in Sub-Saharan Africa. We interact the resulting exogenous distance to the nearest main road with the accessibility of submarine internet.

The remainder of this paper is organized as follows: Section 2 presents the conceptual framework. Section 3 describes the context, data, and our empirical strategy. Sections 4 and 5 present the main findings. Section 6 concludes.

2 The Gains from Internet Connectivity and Roads

Following Hjort and Tian (2021), we present an overview of potential mechanisms driving the job and economic impacts of the combined provision of internet connectivity and road networks. Internet and road access can drive economic development through both supply- and demand-side impacts.

2.1 Supply-Side

The presence or absence of access to the internet and road networks can directly affect the productivity of firms, workers, and other inputs in the production process. Findings from Li et al. (2017) suggest that road investments in China had significant and positive returns, increasing manufacturing firms' productivity. A similar study by Gordon and Li (1995) finds that road investments led to a 4.6 percent increase in the productivity of firms that contract with government and to a 3.6 percent increase in annual total factor productivity (Zhu, 2012). Gibbons et al. (2016) similarly find that new road infrastructure in the UK greatly impacted the productivity of firms there. Access to the internet can also affect firm productivity by directly affecting workers' on-the-job productivity, inducing human capital accumulation, and enhancing firm-worker matching.

Several empirical papers point toward a direct impact of accessibility to roads on wages and employment (Gibbons et al., 2016; Yamauchi, 2016; Matas et al., 2015; Yamauchi et al., 2011; Frish and Tsur, 2010; Reardon et al., 2001); other empirical studies point toward a direct influence of high-speed internet connectivity on wages and employment, too. Chen et al. (2020) document significant increases in workers' wages and firm productivity in response to an internet-upgrading program that increased internet speeds in China. In the context of Brazil, Almeida et al. (2017), Poliquin (2020), and Tian (2021) find that newly established broadband access increased workers' wages on average; by contrast, Dutz et al. (2017) find a negative correlation between increased internet access in Brazil and average wages. In Nigeria, Bahia et al. (2020) examine how the roll out of mobile broadband affected labor-market outcomes, household consumption, and poverty in Nigeria. Using a difference-in-differences approach to track impacts on individual households, they show that internet connectivity increased labor-force participation and employment.

Another strand of the literature points toward a direct impact of internet connectivity on human capital development. Internet connectivity can facilitate on-the-job training. Hjort and Poulsen (2019) find evidence that internet-connected firms in six African countries invested more in their workers' human capital; Mouelhi (2009) also documents an additional human capital investment among internet-connected firms in Tunisia. Internet connectivity can affect human capital development both at home and in school. Bianchi et al. (2020) show that connecting high-quality teachers in urban areas of China with millions of students in rural primary and middle schools improved students' long-run academic achievement, labor-market outcomes, and internet use. However, the overall evidence on the impacts of connected schools on test scores is mixed thus far. Positive impacts have been documented in Peru (Kho et al., 2018) and Malawi (Derksen et al., 2019); by contrast, work in Peru (Malamud et al., 2019) and Brazil (Bessone and Dahis, 2020) has found no impact on test scores.

Internet access can also affect labor productivity by improving firm-worker matching, especially in developing economies where frictions in the labor market are large. Empirical evidence is largely from high-income countries, such as the US (Kuhn and Mansour, 2011) and Norway (Bhuller et al., 2020). Lederman and Zouaidi (2020) find a robust, negative relationship between internet usage and long-term, frictional unemployment across countries. Internet access can also increase firm-level productivity by facilitating the adoption tangible inputs such as machines, new technologies, and intermediate materials, and the adoption of intangible inputs such as management, organizational practices, and services. Evidence on the take-up of tangible inputs in response to internet connectivity is limited, but such high-speed connectivity has been shown to affect the organization of production and trade in developing countries. Houngbonon et al. (2022) find that individual firms in Africa are 20 percentage points more likely to undertake process innovation and 12 percentage points more likely to undertake product innovation when fast internet becomes available. Tian (2021) shows that internet access allows firms in urban areas to reorganize production to enhance collaboration and facilitate the division of labor.

Using enterprise-level panel data, Gibbons et al. (2016) examine the effects of investments in road construction on employment and labor productivity in the

UK. They find that improvements in road access substantially increased workers productivity at the individual level. In China, Li et al. (2017) find that investments in road infrastructure yielded an annual return of 11.6 percent from productivity gains. Li and Li (2013) find that investing in roads in China increased firms' productivity, with an annual rate of return of close to 10 percent.

2.2 Demand Side

Roads can impact employment and firms' expansion through exports and trade (Mbekeani, 2010; Martincus et al., 2017), regional integration (Mbekeani, 2010), and new market-entry enhancement (Melo et al., 2010; Holl, 2004). Internet connectivity can also affect economic activity both by directly expanding market access for firms, workers, and consumers, and by addressing information frictions. For example, e-commerce may allow firms to make their products accessible to more consumers, especially in rural and remote regions. Internet connectivity appears to enable firms to expand their sales between regions within countries (see Fan et al. (2018) for China) and through exporting and importing (see Hjort and Poulsen (2019) for Africa). Internet access appears to lower prices and expand the variety of choices available to consumers (Couture et al. (2021), for China). Internet access can help reduce information frictions that are pervasive in developing countries. Internet access can lead to (1) a reduction in price dispersion, (2) higher local prices when buyers have a degree of monopsony power (see Goyal (2010) for India, and Guerrero Barreto and Ritter Burga (2014) for Peru), (3) a reduction in uncertainty about product quality, and (4) improvement in communication with trade partners (see Leuven et al. (2018) and Fernandes et al. (2019) for China).

2.3 Heterogeneities

The literature has uncovered important heterogeneity in the effects of access to high-speed internet on wages and productivity. Many papers have found that internet connectivity appears to especially benefit female workers. In Vietnam, Chun and Tang (2018) find suggestive evidence that firms that increased their

ICT use also increased the share of female labor. In Brazil, Dutz et al. (2017) find that employment growth from internet access established in different areas of Brazil was greater among low-skilled, female-filled jobs. Similar results have been found in Mexico (Juhn et al., 2013) and Nigeria (Bahia et al., 2020).

The evidence on internet technology as a source of skill bias in developing countries is mixed. Khanna and Sharma (2018) show descriptive evidence of complementarity between using ICT and undertaking non-routine tasks. Chen et al. (2020) find that the adoption of high-speed internet provided greater benefits to Chinese firms that were in more skill-intensive industries and that had more educated workers. Dutz et al. (2017) also find evidence that, within the manufacturing sector in Brazil, internet access appears to have raised wages in medium- and high-skill jobs, but not in low-skill jobs. In Tanzania, Bahia et al. (2021) show that broadband availability increased both labor force participation and wage employment among young, educated men. Hjort and Poulsen (2019) show that the gradual arrival of fast internet infrastructure in Africa increased employment rates, even for less-educated worker groups, although the estimates are that the effects are considerably larger for more-educated workers.

The evidence on differences across urban and rural areas in developing countries is also mixed. Masaki et al. (2020) find that the labor market impact of fast internet in Senegal is larger for households in urban areas than those in rural areas; by contrast, Bahia et al. (2020) find especially beneficial impacts in rural areas in Nigeria.

The effects of road construction have also been shown to vary, depending on location, industry type, and quality. Baum-Snow et al. (2017) provide evidence that new, regional highways promoted the concentration of outputs but also the concentration of the working-age population into regional prefectures in China. Moneke (2020) find that investments in road expansions that brought the road network closer to isolated areas improved productivity, with some manufacturing sectors growing and expanding to export their products. The study also found that increasing road access alone caused a large shift of employment from the manufacturing sector to sectors involving high-skill activities, and, at the same time, caused service employment to rise, largely in informal, small retail businesses.

3 Data and Empirical Strategy

3.1 Data Description

We combine geo-coded survey data with spatial data on internet and road networks.[1]

3.1.1 Demographic and Health Surveys (DHS)

The DHS are cross-sectional surveys that have been conducted in the majority of developing and middle-income countries since the 1980s. They are representative at the national and subnational levels. They provide information on demographic characteristics and socioeconomic status (e.g., age, gender, education, occupation) of all household members and recent surveys have been georeferenced. Recent studies have used DHS to examine the economic and social impacts of infrastructure in developing countries (Okoye et al., 2019; Hjort and Poulsen, 2019; Moneke, 2020; Canning et al., 2020; Herrera Dappe and Lebrand, 2021; Lebrand, 2022; Abbasi et al., 2022). We rely on data from 56 surveys conducted in 20 Sub-Saharan African countries. The total sample size is 806,378, with 552,022 women and 254,356 men. Grid cells, 20 kilometers by 20 kilometers in area, are constructed around each location to account for any time-invariant factor that might affect our infrastructure location and outcome variables. We group those who are employed into two categories: high-skilled workers and low-skilled workers. We also differentiate between agricultural workers and non-agricultural workers. Skilled workers include employed workers in the following occupation categories: professional, managerial, skilled manual labor, services, or agriculture. In our sample, 67.7 percent of respondents claimed to be employed, while 32.3 reported being

[1] Table (A1) in the Online Appendix provides details on the countries analyzed and years in which the surveys were conducted.

unemployed.[2]

3.1.2 World Bank Enterprise Surveys (WBES)

The WBES are countrywide, representative samples of businesses and firms from all sectors of activity with at least five workers. They include information on enterprises' establishments, assets, operations, sources of funding, structure of the workforce, and type of activities. We exploit data that were collected over the 2005-2018 period for coastal nations that had survey cycles before and after the date when submarine internet was acquired. These countries are Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania. We limit our sample to small- and medium-size enterprises (SMEs) that employ a maximum of 99 individuals. It is also important to note that while digitalized road maps are for the period before 2014, our household and firm-level data extend beyond 2014. Using household and firm-level data that extend beyond 2014 maximizes the number of observations, but this is justified because the African road networks have not changed much in recent years.[3] The WBES provide information on the location of firms that we first match with the location of cities and then from which we compute both the indicator of whether the establishment's location is connected to internet, and the distance to the closest major road. After pooling all observations together, we obtain a sample of 15,033 firms. We define internet connectivity as being within a radius of two kilometers of an optical-fiber node. Firms' hours of operation range between 10 and 84 hours, averaging 35 hours a week. They employ, on average, 16 full-time workers, and an average of 6 female workers. More than a quarter of firms, 26.85 percent, reported that telecommunications limitations are

[2]The characteristics of individuals in the sample are summarized in Table (A2) in the Online Appendix. Skilled occupations are distributed as follows: sales (38 percent); manual labor (18 percent); agricultural employee (16 percent); service sector (22.9 percent); professional, technical, or managerial occupations (10.90 percent); clerical occupations (2 percent). In our data, 80 percent of unskilled workers reported being self-employed in agriculture, with the remaining 20 percent working in domestic work or as unskilled, manual laborers. Among all respondents, 62 percent lived in rural areas, and 38 percent lived in urban areas. The ages of those who responded to the survey were as follows: 25 and under (39 percent), 25 to 50 (57 percent), and over 50 (0.2 percent).

[3]Figure (A1) in the Online Appendix shows the road networks in some West African countries have barely changed between 2008 and 2014.

an important obstacle to their operations.[4]

3.1.3 Living Standards Measurement Study (LSMS)

The LSMS is a household-survey program led by the World Bank. The LSMS project works in partnership with the national statistics offices of its eight affiliated countries in Sub-Saharan Africa using representative panel, household surveys. The sampling procedure applied is a stratified two-stage (two-stage probability sample). In the first stage, an enumeration area (EA) is selected, according to a probability relative to the total number of households in that area.[5] We analyzed the different survey waves for each country as cross-sectional data. This paper considers seven of the eight countries that are part of the LSMS; Côte d'Ivoire is excluded because of a lack of georeferenced data for this country. This sample contains 1,577,278 respondents, with ages ranging from 20 to 65 years old. The average population age is 35.8 years old. About 86.2 percent of the sample lives in rural areas. About 52 percent of the population is female.

3.1.4 The Roads Dataset

We use the road network from Jedwab and Storeygard (2021), who relied on a previous 2004 network by Nelson and Deichmann (2004) and digitized 64 Michelin road maps constructed between 1961 and 2014 to characterize the then-current road outlook.[6] To address the lack of Michelin maps for certain states and periods, we use grid fixed effects. We use georeferenced survey data to estimate the distance between the centroid of each enumeration area and the nearest main road (highway, paved and/or improved road). Throughout the paper, we consider the distance between an individual or a household and the nearest road as the distance between the centroid of the cluster in which that individual or household is located and the nearest road. Similarly, in the WBES, the distance between a firm and the

[4] More details on this sample are displayed in Table (A3) in the Online Appendix.

[5] The LSMS component of our final data set is summarized in the Online Appendix Table (A4).

[6] Figure (A1) in the Online Appendix illustrates the dynamics of the road network of three countries in Sub-Saharan Africa over the period from 1965 to 2014.

nearest road is computed as the distance between the centroid of the city where this firm is located and the nearest road. In our sample, the average distance from a household or a firm to the closest main road differs according to the data set used: 2.31 kilometers (WBES), 9.70 kilometers (DHS),and 15.2 kilometers (LSMS). The average distance from a main road to a household is 13.43 kilometers in rural areas and 3.60 kilometers in urban areas (DHS). There is heterogeneity in terms of households' proximity to a main road by level of development; in less-developed countries, the average distance is 11.46 kilometers; by contrast, the average distance is 7.50 kilometers in more-developed countries.

3.1.5 Internet Data

We use the Hamilton data from Africa Bandwidth Maps on long-distance optical-fiber nodes from 2009 to 2019. The map depicts Africa's terrestrial, satellite, and submarine cable transmission networks in great detail. The Hamilton map includes fiber-optic networks (operational, under construction, planned, and proposed), microwave networks (operational and planned), and submarine cables (operational, under construction, planned, or proposed) for over 300 network operators in more than 50 African countries, and for 72 submarine cable systems. Geographic coordinates of fiber-optic nodes are included in the data set. We have information on the year each fiber node became operational. Figure (A2) in the Online Appendix depicts the evolution of the optical-fiber network over time, showing a significant increase in the number of optical-fiber backbones from the year 2009 (see Figure (A3) too). In fact, by 2009, a large majority of African countries already had their terrestrial internet backbones connected to submarine cables. We also use information from Mahlknecht (2014) on submarine internet-landing points and arrival dates. Figure (A4) shows the gradual arrival of submarine internet on the African coast since 2008, with the East African Marine System (TEAMS) being the first cable that landed and was made operational in Sub-Saharan Africa in October 2009. We combine these data with the location of optical-fiber nodes to determine a location's connectivity to the internet and to submarine (or high-speed) internet.

When the distance between the centroid of a cluster (that is, the enumeration area for the DHS and the LSMS, and the city for the WBES) and the location of the nearest optical-fiber node is less than two kilometers, we consider individuals or firms in that location to be connected to the internet network. Approximately 42 percent and 6 percent of individuals have access to the internet in our DHS and LSMS data, respectively.[7] About 78 percent of the firms in our WBES sample are connected to the internet. An individual (resp. a firm) is connected to submarine internet if that individual (resp. firm) is connected to an optical-fiber node after the arrival of submarine internet. Individuals connected to submarine internet represent 19 percent of the DHS sample and 5.5 percent of the LSMS sample, and firms connected to this technology represent 36 percent of the WBES sample.

3.2 Identification Strategy

To identify the "joint" causal effect of roads and internet infrastructure on the labor market, we compute distances between the nearest infrastructure and the location of the household or firm. In this part, we combine difference-in-differences (DID) and instrumental variables (IV) techniques to answer endogeneity concerns. We rely on: (1) a DID strategy to explore the causal effect of submarine internet access, and (2) an IV approach to examine how the proximity to roads interacts with internet access.

3.2.1 The Model

In the first stage, we estimate the following equation:

$$Dist.Roads_{i,g,t} = \alpha_1 + \alpha_2 HistRoad_{i,g,t} + \alpha_3 Submarine * Internet * HistRoad_{i,g,t} + geography_{i,g,t}\alpha_4 + X_{i,g,t}\alpha_5 + \lambda_t + \gamma_g + \delta_c + \varepsilon_i \quad (1)$$

where $Dist.Roads_{i,g,t}$ is alternatively the measure of the negative distance (or

[7]While the DHS is more geographically representative, the LSMS oversamples individuals in rural areas, which explains the difference in the share of the population connected to the internet across the two samples.

proximity) between location g of individual/firm i and the nearby main road or the interaction between this variable and the submarine Internet treatment indicator. $HistRoad_{i,g,t}$ is the shortest distance to the historical network built from Murdock's 1959 map (see below for the rationale and details on this instrumental variable), and $Submarine * Internet * HistRoad_{i,g,t}$ is its interaction with the treatment variable. As additional instruments, we use geographic characteristics ($geography_{i,g,t}$) including terrain elevation and lightening intensity, which are clearly exogenous. $X_{i,g,t}$ is a vector of control variables including age, gender, education, and place of residence; we also control for year fixed effect, country fixed effect, and grid cell by connectivity fixed effect as in the second stage equation below.

In a second stage, we examine the simultaneous causal impacts of the accessibility to major roads and the availability of Internet on employment status and other labor-market outcomes by estimating equation (2), which combines the two aforementioned strategies:

$$
\begin{aligned}
Y_{i,g,t} = \beta_1 + \beta_2 Submarine * Internet_{i,g,t} + \beta_3 RoadProximity_{i,g,t} + \\
\beta_4 RoadProximity * Submarine * Internet_{i,g,t} + X_{i,g,t}\pi_5 + \lambda_t + \gamma_g + \delta_c + \varepsilon_i
\end{aligned}
\tag{2}
$$

with $Y_{i,g,t}$ being individual i's employment outcome (or firm i's outcome). The variable $RoadProximity_{i,g,t}$ is the proximity to the nearest major road. It is a continuous variable representing the negative distance to the nearest main road. The proximity to the nearest main road is measured by taking the length of the shortest straight line between the place of residence and the closest major road. However, given the fact that roads' networks are probably not randomly built across cities in such direct routes, OLS estimates might be biased. Therefore, we use two instrumental variables, namely the land roughness and the distance obtained from exogenous historical theoretically built networks.

$Submarine_{i,g,t}$ is a dichotomous variable taking the value one when a fiber node in a given area is connected to fast internet (submarine cables). The variable $Internet_{i,g,t}$ takes the value one when the grid in which the individual i is located is connected to an optical fiber node. The interaction between these two variables allows to isolate the impact of fast internet on employment status for areas connected to submarine internet from the variations in employment status in other localities not connected to fast internet. The variable $RoadProximity * Submarine * Internet_{i,g,t}$, which is the interaction term between the road variable and the binary indicator for fast internet access, captures the joint effect of these two infrastructure on employment status (or occupation).

We also control for year and country fixed effects. We further account for local time-invariant, unobserved factors that might bias our estimated effects of infrastructure by controlling for grid-cell by connectivity fixed effects. We cluster the standard errors at the grid-cell level.

3.2.2 Who Is Connected to the Internet?

We define the connectivity to the internet based on the distance to the closest optical-fiber node. The deployment of optical fiber has accelerated considerably in recent years in Sub-Saharan Africa, from a network of fewer than 400,000 kilometers in 2009 to one of more than 1.5 million kilometers in 2019. Optical fiber is a technology with the greatest capacity to transport information quickly and effectively. There are two types of optical-fiber cables. Single-mode optical fiber has very low levels of signal attenuation, which optimizes the signal-transmission speed, and the transmission distance can reach 5 kilometers. However, due to its very high cost, it is mainly used for very long-distance signal transmission. Multimode optical-fiber cable is the most common type of cable and is generally used for short-distance signal transmission such as in concessions, campuses or apartment buildings. It can transmit a signal for distances of up to 2 kilometers â a maximum distance that we took into account to establish 2 kilometers as the threshold distance in our definition of internet connectivity in this study. Thus, we consider locations positioned within 2 kilometers of the closest optical-fiber node as connected locations.

We compute the probability of employment for each given distance (measured in bins of 10 kilometers) to an infrastructure location, and then fit the prediction of employment on distances.[8] We find that as the distance to a main road increases, the proportion of the economically active population decreases. For example, those living within 10 kilometers of a main road are about 20 percentage points more likely to participate in the labor force than those living 100 to 110 kilometers away from a main road. A similar pattern is observed with the distance to the closest fiber-optic node. For example, individuals living within 10 kilometers of the closest fiber-optic node are about 12 percentage points more likely to work than those living 90 to 100 kilometers away from the closest optical-fiber node.

3.2.3 The Causal Effect of Roads: IV Approach

We generate a new instrumental variable for proximity to road networks, based on the rationale that post-independence African leaders promoted the construction of transportation infrastructure to bolster national integration and govern the entirety of their respective territories from the capital city where political institutions were based. For this variable, we rely on an extensive literature outlined here.

To move agricultural products and mineral resources from the interior of countries to export ports, colonial rulers in Africa created transportation infrastructure (Okoye et al., 2019). These improvements in infrastructure also served an administrative purpose; better roads and trains allowed colonial authorities to travel to most sections of the country to exert control. In the post-independence period, country leaders expanded these networks, constructing transportation that enabled them to expand the exercise of their authority from the country's political center across their whole territory, including rural locations and all ethnic homelands (Herbst, 2014; Muller-Crepon et al., 2020). Since the colonial era, construction of transportation infrastructure, particularly roads and trains, in Africa, has been driven by economic, social, and administrative (political or military) mo-

[8] Figure (A7) in the Online Appendix shows how employment relates to proximity to main road networks and access to the internet.

tives (Taaffe et al., 1963; Okoye et al., 2019).[9] To promote country building and national unity, these leaders used a variety of techniques. These measures included promoting the use of a single national language, prohibiting political organizations formed around ethnic groups, and distributing ministerial offices and other public positions among different ethnic groups.

Almost all African countries used infrastructure development as a strategy for national integration. Infrastructure development as a means of integrating different ethnic groups is not a phenomenon exclusive to African countries. For example, in their study on the relationship between ethnicity and economic development in China, Han and Paik (2017) write: "The state has pursued provision of necessary infrastructure such as roads, railways, and airports as means to promote local economic growth and, in turn, integrate ethnic minorities with the Han majority"(p. 33).

Herbst (2014) claims that the difficulties that African political leaders met in governing countries divided into multiple ethnic groups, combined with the separation of ownership and control of land, drove them to develop infrastructure that would allow them to extend their authority as far as possible (see also Herbst (2000)). Herbst (2000) argues that, with the bulk of rural people in Sub-Saharan Africa cut off from political power centers due to the inadequate or non-existence of road networks in most nations, African governments have been expanding their authority by developing highways connecting political centers to formerly unreachable locations. The investigations of Muller-Crepon et al. (2020) are based on the thesis that public officials' access to ethnic homelands is a requirement for political leaders to extend their dominance over remote areas (Herbst, 2000; Fearon and Laitin, 2003; Buhaug and Rod, 2006; Raleigh and Hegre, 2009; Tollefsen and Buhaug, 2015). Certainly, Muller-Crepon et al. (2020) claim that political instability is more prevalent in areas where those with political power have little control over the population; the authors contend that ethnic group homelands

[9] Indeed, the arbitrary partition of Africa by European colonizers at the Berlin Conference in 1884 and 1885 resulted in varied levels of ethnic diversity among the countries that arose from this experiment. In most of these countries, leaders faced the difficult task of administering a diverse ethnic population while also unifying and integrating them (Deng, 1997).

that are difficult to reach from the national capital are also hotbeds of rebellion and political conflict. Using a map of African road networks to calculate access to ethnic homelands from national capitals and ethnic group interconnectivity, they estimate the effects of these two variables on political conflicts, showing that political conflicts occurred in areas where the state had a weak physical presence. To demonstrate the robustness of this finding, they created a theoretical network comprised of hypothetical road segments that ensure the shortest travel time between the busiest ethnic groups; using these hypothetical road networks, they build instrumental variables estimating the accessibility of ethnic homelands from political centers, and the degree of interconnectivity of ethnic groups that would occur if these networks were to exist. Their findings are robust to the use of these instruments, confirming the role of road networks in both extending political control and reducing political instability; they show that political authority and stability are strengthened in ethnic groups that are accessible from political capital.

Thus, to construct our instrumental variables to examine the interaction of the proximity to main roads and high-speed internet, we rely on this historical literature, which highlights political leaders' motivation to build roads to expand their capacity to govern. In doing so, we follow a large body of literature that shows that non-economic factors influence African governments' willingness to invest in public infrastructure (Herbst, 2014; Burgess et al., 2015; Bonfatti et al., 2019). We assume that African leaders build roads to facilitate territorial administration by easing the movement of administration officials and military troops from the capital city to the rest of the country (Herbst, 2014; Muller-Crepon et al., 2020).

Following these assumptions, we use a map of African ethnolinguistic divisions created by an American anthropologist in 1959 (Murdock, 1959) to identify the ethnic homelands within all countries of our sample. For all purposes, these ethnic homelands are generally regarded as being exogenous. Using the least-cost-path algorithm, we create hypothetical roads that connect the centroids of different ethnic homelands to the capital city of each country. We exploit the assumption that the social planner's goal is to keep the construction costs of these roads as low as possible.[10]

We use the proximity to these hypothetical road networks to compute instrumental variables for the proximity to the actual road networks, and for its interaction with internet access. The validity of these instrumental variables relies on the fact that the hypothetical road networks must be close enough to the actual networks and must be orthogonal to the economic activity and job creation by completely ignoring demand-side factors and local labor market conditions. In our analysis, the two conditions are most likely to be met.[11] Moreover, the fact that ethnic homelands are exogenously located makes it likely that the hypothetical road network is exogenous to local economic development. In addition, the fact that we control for the 20x20-kilometer grid-cell fixed effect means that we are comparing the outcomes of individuals and firms that are located in places that are homogeneous with respect to a wide range of geographical, cultural and historical factors (such as the slave trade and the presence of ancient cities).

3.2.4 The Causal Effect of the Internet: DID Approach

Connectivity to the internet may differ in various aspects, all correlated to the development and growth processes within countries and technological advances. The first internet access in Sub-Saharan Africa in the early 2000s was initially transmitted through telephone cables. Submarine cables began to arrive in Sub-Saharan Africa in 2009. Submarine cables are cheaper to install and maintain, and they are able to transport data faster and over longer distances. The arrival of the submarine internet in Sub-Saharan Africa allowed Africa to better communicate

[10] The hypothetical and actual road networks of Ethiopia represented in Figures (A5) and (A6) in the Online Appendix show how such a network would evolve to connect ethnic homelands with the capital city if one were to consider only the accumulated geographical costs of networks' construction between two locations, and to ignore all other economic factors (including demand-side factors).

[11] Figure (A6) in the Online Appendix, for instance, compares the dynamic of the hypothetical road networks to that of the actual road networks in Ethiopia. As illustrated by the map, these two networks are close enough to satisfy the latter conditions.

with the rest of the world.[12]

We exploit the exogenous nature of the different arrival dates of submarine cables on the coast of African countries south of the Sahara to establish the causal effect of the internet on labor-market outcomes. The first submarine cables arrived and were connected to the land network of the countries in our data on specific dates; this makes it possible to hypothesize an absence of spillovers between countries. We thus define two groups: 1) The group of treated individuals is made up of those who have access to high-speed internet (defined as access to submarine-cable-accessed internet). That is, they are the group of individuals who are located within a 2 kilometer radius of the nearest submarine-cable network. 2) The control group consists of those people or firms who did not receive the treatment. That is, this group is composed of people and firms located more than 2 kilometers from the nearest submarine optical-fiber network. This control group includes those who had no internet connection, and those who were connected to the internet network via the old telephone cable technology that predated the arrival of the submarine cables. For this identification strategy to be valid, the characteristics of those in the treatment and control groups must be the same (i.e., present statistically zero differences in the main variables that are the subject of study).[13]

4 Findings

4.1 First-Stage Results

The results of the estimation of equation (1) show a positive and very significant relationship between the distance to the actual road network and the distance to our hypothetical road network (Table (2)). The results also show a statistically non-zero relationship between the distance to a road network and the topography

[12]Figure (A2) in the Online Appendix shows how the terrestrial communications network has evolved over time.

[13]Table (A5) in the Online Appendix shows that the differences between those who have high-speed internet and those who lack such access is statistically nil.

of the land. These results are consistent across the three databases we use in this work. Similarly, we find that the interaction term between the distance to the hypothetical road network and connection to submarine internet positively correlates with the interaction term between the distance to the real road network and connection to submarine internet, and we also find that lightning intensity negatively correlates with the latter variable.

For our three samples, a strong and significant correlation is demonstrated between the instruments used and the endogenous variables of our model. The Cragg-Donald Wald and Anderson-Rubin Wald statistical tests show that the chosen instruments are strong enough. Certainly, the results of these tests allow us to reject the null hypothesis of weak identification. Also, results of the Kleibergen-Paap test allow us to reject the null hypothesis of under-identification. Our first stage is, therefore, robust across the three samples used, with the theoretical model well fitted to the data.

4.2 Average Complementary Effect of Roads and Internet

This subsection presents the average, complementary effect of access to submarine internet and road networks on employment and occupation types.

4.2.1 Employment

Table (3) displays the coefficients resulting from the estimation of equation (2). In columns (1) and (2), using the DHS sample, we regress two measures of the odds that an individual is employed on the infrastructure variables and on all our controls including year, country and grid-cell fixed effects. In the third column, we use the LSMS data to compute the effect of infrastructure on the number of hours worked, using the same identification strategy as in the first two columns.[14] The last three columns display the estimations computed from the WBES, with the dependent variables being the number of hours of operation per week in the last fiscal year; the number of permanent, full-time employees at the end of the

[14] Information on the number of hours worked is not collected in the DHS.

Table 1: Average and heterogenous marginal impacts

	One more km closer, without internet	Internet access without road access improvement	Combined impacts of one more km closer and internet access
DHS			
Employed last year (in p.p.)	0.8	6.7	9.1
Currently working (in p.p.)	0.8	4.5	6.5
Low skilled worker (in p.p.)	0.5	-11.2	-12.6
Services (in p.p.)	0.1	13.9	16.9
Skilled worker (in p.p.)	0.1	10.7	13.0
High skilled worker (in p.p.)	0.1	8.1	9.7
LSMS			
Hours worked last week	0.5	-4.4	0.1
WBES			
Hours of operation per week	3.8	0.5	4.4
Number of full time employees	0.7	2.02	2.9
Full time skilled employee	1.0	1.0	2.07
Full time unskilled employee	0.4	1.1	1.6
Telecommunications as an obstacle (in p.p.)	3.6	-6.4	-3.2
Percentage of losses (in p.p.)	-0.7	-2.1	-3.0
Government ownership share (in p.p.)	-0.3	1.2	1
Contract with government (in p.p.)	0.2	16.1	17.1
DHS			
Employed last year (in p.p.)			
Average	0.8	6.7	9.1
Urban	0.6	12.0	21.6
Rural	0.8	3.5	4.5
Male	0.4	4.7	6.3
Female	0.9	7.7	10.5
Currently working (in p.p.)			
Average	0.8	4.5	6.5
Urban	0.7	11.0	19.7
Rural	0.8	1.7	2.4
Male	0.5	3.9	4.4
Female	0.9	6.7	9.2
LSMS			
Hours worked last week (in p.p.)			
Average	0.5	-4.4	0.1
Urban	4.8	-2.7	6.8
Rural	0.3	-3.6	-0.1
Male	0.0	-5.0	-0.5
Female	0.0	-4.0	-0.3

Note: Summary of average and heterogeneous impacts based on tables of results in the Appendix. All results are calculated for a distance to main road equal to 1km. In that case, the road variable takes the value -1 when calculating the interaction effect using the regression tables in the Appendix.

three prior fiscal years; and the number of full-time employees in the previous fiscal year, respectively.

The complementary impacts of road and internet access are large for employment. When located 1 kilometer away from a main road, an individual connected to fast internet is 6.7 percentage points more likely to have been employed during the 12 months preceding the interview.[15] Likewise, when individuals without access to the internet are 1 kilometer closer to a major road, the likelihood that they have worked in the year preceding the survey increases by 0.8 percentage points. In addition, Table (3) shows a positive interaction coefficient. When the effects of both improvements are combined, the probability of having been employed in the previous year increases by more than 9 percentage points compared to the situation in which no investments have been made. The additional impacts on employment that accrue from combining road and internet investments are, on average, 22 percent larger.

Similarly, when investments in both types of infrastructure have been made the probability of being in work increases by at least 6.5 percentage points compared to the likelihood of being in work in locations where no investments have been made. By contrast, investment solely in road access or internet access has a smaller effect. Being one kilometer closer to a road network increases the likelihood of working by 0.8 percentage point; having access to fast internet increases the likelihood of working by only 4.5 percentage points. The additional impacts from combining road and internet investments are, on average, 22 percent larger for both employment and the probability of being currently in work.

The marginal impact on employment from bringing a main road closer is much larger when the same location also has access to fast internet. At equal proximity to the nearest major road, the gap between the two is of about 1.3 percentage points between the two groups, with the probability of being employed at 2.1 percentage points for those with internet access, and 0.8 of a percentage point for those who are unconnected. This result is consistent with the coefficient of

[15] Table 1 summarizes the average and heterogeneous effects of the internet and road access based on most of the analyses conducted in this paper.

the interaction between road and internet access, and validates the hypothesis according to which, gaining access to the internet reinforces the positive effect of roads on employment.

The complementary impact on hours worked is strong. Proximity to roads reverses the negative impact of the internet. As indicated by column (3), individuals connected to fast internet work approximately 23 fewer minutes a week than those not connected. This negative sign could be explained by either fewer work opportunities or the increase in the productivity generated by the internet (Rollo and Paunov, 2015; Hjort and Poulsen, 2019). However, when the distance to the closest road decreases by a kilometer, the number of hours of work per week for individuals connected to submarine internet increases to four hours. As for the isolated effect of the road, the number of hours worked per week increases by about 32 minutes as main roads become one kilometer closer to the location of the household/firm. Indeed, with better proximity to a main road, the travel time to work certainly decreases, which could explain the positive effect of improved road access on the number of hours worked per week. The addition of the accessibility to high-speed internet to a location that has better accessibility to main roads boosts the number of hours worked per week by four hours. So, roads and internet complement each other, leading to at least 3.5 extra hours of work.

Both investments benefit firms that tend to have longer hours of operation and more full-time employees, but the complementary impacts are small. The impact of internet access on hours of operation is relatively small. From the WBES, we find that, in the absence of internet access, an increase in the proximity to the closest main road increases a firm's operation hours by 3 hours and 46 minutes. By contrast, bringing a main road one kilometer closer leads connected firms to operate approximately only 6 minutes more than non-connected ones. Similarly, firms connected to the internet operate approximately half an hour more than non-connected ones. On average, the combined impact of bringing a main road 1 kilometer closer and having fast internet access increases a firm's hours of operations per week by 4.4 hours and leads it to add one more full-time employee

(Table (1)). The impacts from combining road and internet investments are 2 percent larger in terms of the hours of operation and 7 percent larger in terms of the number of full-time employees.

Those results suggest a positive, complementary effect of road and internet access on employment. When proximity to main roads and the availability of internet access increase they support one other, resulting in job creation. This complementarity holds across all employment variables we examine and among all the data sources.

For the rest of the results, the coefficients are summarized in Table 1, and the full regressions tables can be found in the Online Appendix.

4.2.2 Skilled and Unskilled Employment and Occupational Sectors

Connectivity to high-speed internet when coupled with a better proximity to major roads increases employment in professions requiring high levels of qualifications, and diminishes employment in unskilled occupations; this favors a transition from low-skilled employment to higher-skilled professions. Workers in services and skilled workers benefit the most from the investments, with the share of low-skilled workers falling in locations with better access to roads and fast internet. Our findings indicate that the marginal effect of supplying high-speed internet in locations located within one kilometer of a main road lowers the probability of being in a low-skilled profession by 11 percentage points, but increases the probability of working in the services sector by 14 percentage points and the probability of being in a skilled profession by 11 percentage points (Table (3)). The additional impacts on employment in services and skilled-worker professions are on average, 20 percent larger. For an equal change in the proximity to the road, there is a far greater likelihood of being a skilled worker in an internet-connect location (1.86 percentage points) than in an unconnected location (0.01 percentage points). Clearly, road and internet access complement each other, boosting the increase in the demand for skilled labor by roughly 2 percentage points.

For highly skilled jobs, we find a statistically null effect of the presence of road access in isolation. However, for localities connected to fast internet, individuals who are in locations in which a main road becomes one kilometer closer are 1.6 percentage points more likely to work in very highly skilled professions. It is very interesting to note that, while road and internet accessibility complement each other to further reduce the creation of unskilled jobs by about 2 percentage points, they further increase the creation of skilled jobs by an average of 2 percentage points. This makes it possible to conclude unequivocally that road and digital communication infrastructure investments act as complements to allow migration of employment from unskilled sectors of activity to those requiring a certain level of qualifications.

These results are consistent with those obtained when using the WBES data relating to the number of full-time employees with a high level of qualifications. Roads and the internet play complementary roles in increasing the number of qualified full-time workers in companies. Internet-connected firms that moved 10 kilometers closer to the nearest main road had 0.980 more high-skilled, full-time employees at the end of the last fiscal year compared to firms that had experienced an improvement in their accessibility to only one of the two types of infrastructure. The results also show that the combination of the two infrastructures additionally improves employment, even for the suppliers of low-skilled labor. Indeed, we show that firms in the second group have 0.447 more unskilled workers than those in the first group. The combination of these two results (means that the firms in the first group have a statistically higher demand for labor, both for high-skilled and low-skilled workers, compared to the second group of firms, which demands fewer workers of either skill level. Roads and the internet together enhance job creation; at the same time, the results do not contradict the result of labor migration from unskilled to higher-skilled employment. Unfortunately, because of the significant difference in the number of responses, it is difficult to determine whether, among the WBES responding firms, the joint effect of the presence of these two types of infrastructure is greater on skilled or unskilled employment.

4.2.3 Agricultural Employment

Estimating equation (2) with agricultural employment as the outcome variable shows that enhanced access to road and internet networks increases the prospect of employment and stimulates labor reallocation, with labor force activities shifting from farming and other low-skilled occupations to skilled professions.[16]

We distinguish between self-employed farmers and farmers in general. Overall, we find that in locations connected to submarine internet, when sited within a fixed distance of the closest main road, individuals are 14.7 percent less likely to be self-employed farmers, in comparison to their counterparts located in locations that lack internet connections but are within an equal distance to the closest main road. Moreover, when roads bring them one kilometer closer to the main road, the probability of being self-employed farmers in connected localities falls by an extra 2.8 percentage points. Even though having better proximity to road networks in the absence of having internet connectivity increases the odds of being a self-employed farmer, when both types of infrastructure are made available the prospect of individuals operating as autonomous farmers declines. We obtain similar results for agricultural employment overall. Indeed, the marginal effect of an increase in the proximity to the nearest major road for locations connected to submarine internet decreases the probability of individuals working in the agricultural sector by 2.6 percentage points.

Given the critical role that agricultural activity plays in rural localities, we closely examine the impacts of access to road and internet networks, both together and in isolation. Better access to roads and the internet reduces agricultural employment in rural areas significantly. Being one kilometer closer to the nearest main road in a location with fast internet access reduces the probability of working in agriculture by 2.97 percentage points. Likewise, access to submarine internet in a location along a road reduces agricultural employment by nearly 1.1 percentage points. Hence, the marginal impact of being one kilometer closer to the nearest main road is 1.7 percentage points smaller for individuals in internet-connected

[16] See table (3) and tables (A6) and (A7) in the Online Appendix.

locations.

Finally, the two types of infrastructure have greater effects in combination, on employment and job creation overall and on migration of the labor force.

4.3 Heterogeneous Complementary Effects of Roads and Internet on Employment

This section investigates heterogeneities in the complementary effects of being both closer to roadways and having access to internet. Our findings also provide some insights regarding the channels through which infrastructure investment influences employment.

4.3.1 Economic Development

We study how the employment impacts of roads and fast internet vary across levels of economic development. Different professional choices among countries with different levels of economic development could cause mixed outcomes. Developing economies may have a greater share of the labor force working in agriculture, for example; and developed countries, by contrast, may have a greater share of people working in the service sector. Mindful of the potential for such differences in the labor forces of countries at various stages of development, we categorize development levels based on the 2019 GDP classification of countries. Using purchasing power parity (PPP)-adjusted GDP per capita, we categorize countries as less developed or more developed. A country is considered less developed if its PPP-adjusted GDP per capita was below USD 3,400 in 2019.[17]

The effects of road expansion on employment differ by a country's level of economic development. In areas with access to the internet, increasing the proximity to the road network by 1 kilometer does not statistically increase the probability of having offered their labor force during the 12 months preceding the interview in more developed. In less-developed countries, the corresponding effect is 1.2 per-

[17] The results of the regression of equation (2), distinguishing between countries of different development levels are reported in columns 3, 4, 7, 8 11, and 12 of Table (A8) in the Online Appendix.

centage points, and it is highly statistically significant. We have similar findings regarding the probability of being employed. In areas where the road network extends 10 kilometers closer to a community, being connected to submarine internet increases the probability of working by 9 percentage points in less-developed countries but has only a statistically insignificant effect in more-developed countries.

Clearly, there is a positive and significant complementary effect of road and internet access on employment in less-developed countries, and that effect does not emerge in developed economies. In locations that are far enough from roads and lack internet access, gaining access to both types of infrastructure has a positive effect, but this effect is strongly statistically significant only in less-developed countries. These findings imply that the complementary role of road and internet access is stronger in economies at lower levels of development. The findings regarding the number of hours worked over the seven days prior to an interview are similar. Though there is no significant effect across developed countries, the marginal effect of the road and internet results in six additional hours of work per week for individuals in less-developed economies.

In summary, the isolated effect of access to high-speed internet is non-zero only in poorly developed countries; the isolated effect of access to roads is non-zero in countries of both development levels, but higher in more-developed countries. However, when better proximity to the road is combined with access to high-speed internet, the joint effect increases employment only in poorer countries.

4.3.2 Place of Residence

The isolated and combined marginal impacts of investments in road and internet access differ between urban and rural locations. Isolated investments in fast internet benefit urban locations the most, but bringing a main road 1 kilometer closer to a given location benefits rural locations the most. The additional impacts from combining road and internet investments are 72 percent in urban locations and 5 percent in rural locations.[18] In both urban and rural areas, road expansions

[18] Table (A8) in the Online Appendix shows the results in columns 1, 2, 5, 6, 9, and 10.

have a positive impact on employment, but there are key differences: the impact is larger in rural locations that lack internet, and much larger in urban locations that have access to fast internet. While the complementary impact is 22 percent on average, the additional impact from combining road and internet investments is 72 percent in urban locations and 5 percent in rural locations. We find no evidence of significant differential effects between urban and rural areas regarding the combined investments in both types of infrastructure on the number of hours worked.

We also analyze the differential effects of road and internet access on low-skilled and high-skilled employment in urban and rural areas. The results show that both low- and high-skilled employment responds consistently to the joint expansion of these types of infrastructure, but in different ways.[19] Expansion of both roads and internet services increases high-skilled employment in rural areas, but has a null impact in urban areas. Similarly, joint expansion of the two types of infrastructure leads to a decrease in low-skilled employment in rural areas, and has a null effect in urban areas. In urban areas connected to high-speed internet, bringing road networks 1 kilometer closer to a given location increases the likelihood of working in a high-skilled job by 8.1 percentage points; in rural areas with internet access, bringing road networks 1 kilometer closer to a given location increases the likelihood of working in a high-skilled occupation by 6.9 percentage points. While the joint effect of both types of infrastructure is positive in rural areas, making them complementary investments in these areas, it is null in urban areas. Thus, we conclude that the presence of roads and internet access complement each other to bring an extra increase in high-skilled labor-force demand only in rural areas.

Similarly, in rural internet-connected areas, bringing a main road 1 kilometer closer to a location decreases low-skilled employment by 11.34 percentage points; by contrast, in urban internet-connected areas, bringing a main road 1 kilometer closer to a location increases low-skilled employment by 0.3 percentage points. In fact, the isolated effect of expanding road networks in this respect is negative in both urban and rural areas. However, the addition of internet access to road access

[19]The results are reported in Table (A13) in the Online Appendix.

is beneficial in that it decreases the share of people working in low-skilled occupations in rural areas; in these areas, gaining internet access marginally decreases the likelihood of working in a low-skilled occupation by 1.1 percentage points, but the effect is not statistically significant in urban areas.

In the service sector, we can observe that the two infrastructure types complement each other to increase employment, but with a statistically higher effect in urban areas. While roads and internet access complement each other to bring an additional boost to the demand for labor in the services sector in both locations, the boost amounts to 6.3 percentage points in urban areas but only 1.2 percentage points in rural areas.

To summarize, in rural areas, investing in both road and internet infrastructure promotes job migration from low-skilled to high-skilled occupations. In urban areas, bringing the road network closer to communities and also investing in the development of internet infrastructure essentially promotes job creation in the service sector.

4.3.3 Gender

The isolated and combined effects on employment from improvements in roads and internet access differ across genders.[20] Isolated investments in either fast internet or better proximity to a main road benefit female workers the most. The additional impacts from combining road and internet investments are around 23 percent for both male and female workers.

Internet and road investments complement each other, boosting demand for high-skilled labor for both men and women. But the effects are greater for women.[21] However, these two types of infrastructure work together to decrease low-skilled employment, leading to greater impacts on men. In areas with internet access, bringing a main road 1 kilometer closer decreases the probability of having low-skilled employment by 26.1 percentage points for men and by 10.1 percentage

[20] Table (A9) displays the results of regressions undertaken to examine the effect on each gender group.

[21] See table A13 in the Online Appendix.

points for women.

The findings imply that employment gains from investment in roads and internet in Sub-Saharan Africa are more beneficial for women than for men. However, for some employment outcomes, the effects are larger for men. For instance, the joint effect of investment in these two infrastructure types favors the sectoral migration of the labor force from the low-skilled sector to the high-skilled sector to a greater degree for males than for females. Also, in the WBES, the joint effect of these two types of infrastructure is statistically null for women. In fact, in isolation, internet access has a greater impact on the labor demand for males; by contrast, in isolation, road access has a greater impact on the labor demand for women. However, their joint effect significantly increases the demand for labor only for men.

4.3.4 Age Group

It is possible that the joint investment in the development of road networks and internet infrastructure affects individuals differently depending on the age group to which they belong. To examine whether there is any differential effect by age, we divide our sample into three distinct age groups: 20-34, 35-44 and 45-64 years old.[22] For the outcome variable indicating whether individuals had worked during the year preceding the survey, the results show better net-employment gains for the 20-34 age group than for the two other age groups; this finding holds across all three samples. Indeed in internet-connected locations that were in effect brought 1 kilometer closer to main roads, individuals ages 20 to 34 were 2 percentage points more likely to have worked in the year preceding their interview compared to their same-age counterparts located to an equal distance to the closest main road, but who had no internet access. The joint effect of both types of infrastructure leads to 1.1 percentage point greater likelihood of employment for those ages 35 to 44, and 1.4 percentage point greater likelihood of employment for those ages 45 to 64.

We find great similarities between these effects on all our outcome variables

[22] The results of the regressions are reported in Table (A11).

capturing employment. As with the first outcome, the effect of the two types of infrastructure on whether an individual is currently employed is greatest in the 20-34 age group; by contrast, the combination of the two types of infrastructure does not increase employment significantly for the other age groups. Only isolated effects are significant. As for the number of hours worked in the last seven days, the joint effect of the two infrastructure types increases the number of hours worked much more in the 45-64 age group; by contrast, separately or jointly, road access and infrastructure access do not significantly affect the number of hours worked among people aged 35 to 44 . We find that the two types of infrastructure jointly exert a positive effect on high-skilled employment and a negative effect on low-skilled employment.[23] However, the effects are greatest for the youngest age group that we evaluate. In other words, the roads and the internet act as complements to shift employment from low-skilled to higher-skilled jobs, but with a greater magnitude among the youngest adults.

Summarily, these results imply that the youngest adults in the labor force are more likely to benefit from the simultaneous expansion of roads and ICT infrastructure, presumably as workers in this age group are more adaptable to technological change.

4.3.5 Education

We also investigate how the effects of road and internet access on employment differ by the level of educational achievement of individuals. For this, we create four educational groups: (1) individuals who have no education; (2) individuals who attended only primary school; (3) individuals who did not go further than primary school (including non-educated individuals); and (4) individuals who have at least a secondary education.[24] The prospect of employment tends to be higher among less educated individuals under the joint influence of road and internet access. Indeed, simultaneous investment in both types of infrastructure increases

[23]Tables (A13), (A14) and (A15) show how the effects of road and internet access on low-skilled and high-skilled employment vary by age.

[24]The results are presented in Tables (A10) and Tables (A13), (A14) and (A15) in the Online Appendix.

employment opportunities to a far greater degree for the least-educated group. This could be explained by the fact that the marginal benefits of investment in these two infrastructures on knowledge acquisition are likely to be greater for individuals in need of education. We show that the joint effect of the two types of infrastructure further increases the probability of working in a high-skilled profession by 2.18 percentage points for the least-educated individuals, compared to an additional increase of 0.7 points for those with primary education, and 1.4 for those with at least a secondary education. Similarly, in localities connected to fast internet, bringing the main road one kilometer closer decreases the probability of working in a low-skilled job to a greater degree for less-educated workers, with a nil effect among the most-educated people; however, the number of hours worked increases only among more-educated workers. Thus, with the exception of the effect on the number of hours worked, the joint effect of road and internet expansion is more beneficial for less-educated individuals because it helps their migration to more skilled jobs.

5 Complementary Effect on Firms' Operations and Productivity

To assess the complementarities in the effect of road and internet access on the operations and productivity of firms that responded to the WBES, we use four variables: (1) a dichotomous variable taking the value one if the firm indicates that access to telecommunication infrastructure hampers its operations, and zero otherwise; (2) a variable for the percentage of annual losses in annual sales volume; (3) a variable for the percentage of the firm owned by the government; and (4) an indicator for whether the company had secured at least one contract with the government during the previous fiscal year.[25]

We show that access to the internet reduces the probability of telecommunications being an obstacle to the smooth running of a firm's operations by 6

[25] The results are detailed in Table (A12) in the Online Appendix

percentage points. This finding suggests that internet access alone can improve the productivity of firms by promoting the smooth running of their operations. In the absence of internet connectivity, a reduction in the distance to the nearest main road increases the probability of telecommunications being an obstacle by 3 percentage points. The combined impact of the two types of infrastructure lowers the probability of telecommunications being an obstacle, indicating that both roads and internet access play complementary roles in reducing barriers to productivity.

We then examine the effect of infrastructure on annual losses as a percentage of total sales in the fiscal year prior to the survey response. Access to the internet reduces losses, measured as a percentage of total sales, by 2.1 percentage points. These losses fall by an additional 0.7 of a percentage point for unconnected firms whose proximity to a main road increases by 1 kilometer. The combined impact of the two types of infrastructure lowers the share of losses, indicating that road and internet access play a complementary role for firms.

We focus on the complementary effect of road and internet access on private and governmental entrepreneurial initiatives. We present the effects of the two types of infrastructure on the propensity of firms to obtain a government contract. Access to high-speed internet increases the probability of securing a contract with the government by 16.1 percentage points. The marginal impact of increasing proximity to a main road is also positive. The combined impact of the two types of infrastructure increases the propensity to sign a contract with the government to an even greater degree. Thus, the two infrastructure types play complementary roles in enhancing productivity, particularly by reducing obstacles to the smooth running of firms' operations.

6 Conclusion

We study the effects of increasing road and internet access alone and in combination on employment outcomes in Sub-Saharan Africa. Such investments have large, positive, and complementary effects. The additional impacts on employment from combining road and internet investments are, on average, 22 percent larger than the sum of the isolated effects. The positive effects vary by country, gender, age group, education level, and location. In more advanced economies, the benefits of investing jointly in internet and roads tend to be greater. Within countries, roads benefit rural areas more than urban areas in terms of job creation. Furthermore, due to the greater influence of high-speed internet in urban occupations, the complementarity between the two types of infrastructure is significantly stronger in these areas. Combining internet and road investments generates an impact that is 72 percent greater in urban locations, but only 5 percent greater in rural locations. The simultaneous expansion of road and internet access leads to a decrease in low-skilled employment, particularly in agricultural employment. The combination of both types of infrastructure also increases firms' demands for skilled workers and firms' productivity, reducing firms' losses and increasing the opportunity for firms to enter into government-contracted work. Although both men and women profit from having access to improved roads and faster internet connections, women benefit more. Our findings suggest that the joint expansion of roads and internet is a major factor in Sub-Saharan Africa's structural development and transformation. Therefore, we argue that development policy measures that target job creation should integrate the simultaneous development of both of these types of infrastructure to achieve optimal impacts.

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7 Tables

Table 2: First Stage

	(1)	(2)	(3)	(4)	(5)	(6)
	DHS		WBES		LSMS	
	Proximity to road (Km)	Submarine internet * road	Proximity to road (Km)	Submarine internet * road	Proximity to road (Km)	Submarine internet * road
Proxymity to hyp. roads	0.0369***	0.0123	0.154***	-5.86e-13	0.000992***	-0.0000353***
	(0.00929)	(0.0546)	(0.00371)	(4.20e-13)	(0.0000554)	(0.00000630)
Submarine * hyp. roads	0.000693*	0.0580***	0.0319	3.815***	-0.00111***	0.000546***
	(0.000409)	(0.00524)	(0.0243)	(3.23e-08)	(0.000161)	(0.000107)
Lightning	0.109	-0.00853***	0.731***	-0.0691***	-0.190***	-0.0132***
	(0.398)	(0.000921)	(0.174)	(7.70e-10)	(0.0300)	(0.00321)
Terrain elevation	-0.0149*	0.0000475	-0.00242***	-0.0428***	-0.00106***	-0.00000592***
	(0.00860)	(0.0000686)	(0.000397)	(9.41e-11)	(0.0000262)	(0.000000467)
N	780422	780422	5902	15028	1336608	1336608
ymean	-9.445	-0.882	-0.441	-0.214	-8.162	-0.068
r2	0.275	0.171	0.992	1	0.858	0.720
r2_a	0.275	0.171	0.992	1	0.858	0.720
Kleibergen-Paap F-statistic	46.03	46.03	33.83	33.83	60.15	60.15
$P > F$	0	0	0.2747	0.2747	2.70e-12	2.70e-12
Cragg-Donald Wald F-statistic	792.3	792.3	218.478	218.478	57.57	57.57
Windmeijer F-statistic	33.37	33.37	30.43	30.43	36.29	36.29
Kleibergen-Paap Wald F-statistic	7.875	7.875	33.831	33.831	18.94	18.94
Anderson-Rubin Wald F-statistic	6.673	6.673	41.81	41.81	37.41	37.41
Age	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✓	✓	✓
Place of residence	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 ** p < .05 *** p < 0.01$.

Table 3: The Effect of Internet and Roads on Employment

	(1)	(2)	(3)	(4)	(5)	(6)
	DHS		LSMS		WBES	
Variables	Worked during last year	currently working	Hours Worked last week	Hours of operation per week in last year	Number of permanent full time employees 3 fiscal years ago	Number of full time employee last year
Submarine internet	0.0833***	0.0568**	-0.386**	0.575**	0.602***	2.166***
	(0.0236)	(0.0219)	(0.192)	(0.240)	(0.111)	(0.183)
Proximity to road (Km)	0.00779***	0.00787***	0.532**	3.782***	1.415***	0.665*
	(0.000478)	(0.000470)	(0.216)	(0.0602)	(0.403)	(0.352)
Submarine internet * road	0.0167**	0.0116*	4.042**	0.0934***	0.0238***	0.143***
	(0.00522)	(0.00475)	(1.624)	(0.0246)	(0.00597)	(0.0154)
N	756335	696417	471182	14526	11294	6633
ymean	0.744	0.680	1.30	35.28	12.00	15.235
R-sq	0.0343	0.0654	-0.339	0.331	0.158	0.0346
R-sq_a	0.0342	0.0653	-0.339	0.327	0.153	0.0246
Kleibergen-Paap F-statistic	79.65	81.52	10.79	1.094	1.178	1.463
$P > F$	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	848.5	791.4	1050.8	1282.5	1051.4	484.3
Windmeijer F-statistic	28.8	25.32	26.58	25.39	38.93	51.5
Kleibergen-Paap Wald F-statistic	18.72	19.21	2.658	25.39	51.50	4279.6
Age	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✗	✗	✗
Place of residence	✓	✓	✓	✗	✗	✗
Education	✓	✓	✓	✗	✗	✗
Year FE	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 ** p < .05 *** p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

A Online Appendix

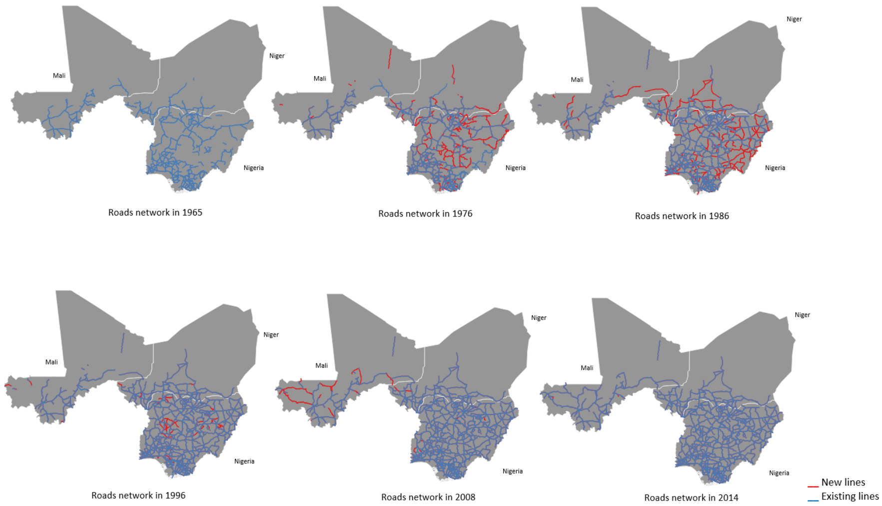

Figure A1: Dynamic in North-West Africa's roads network between 1965 and 2014.

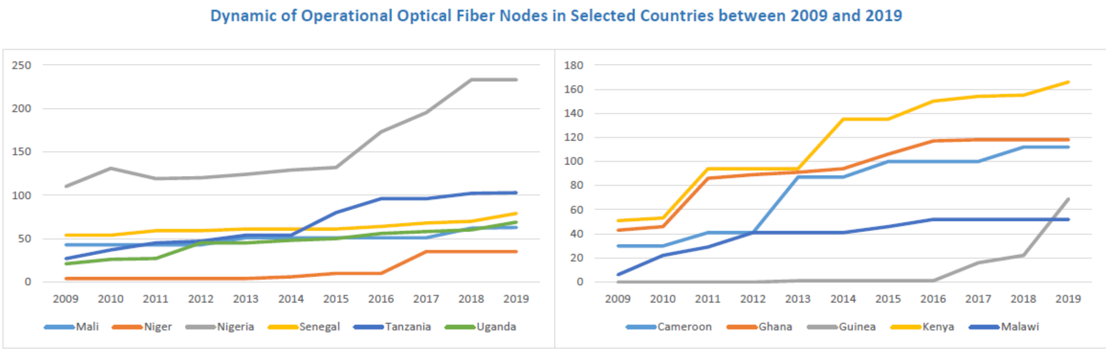

Figure A2: Dynamic of fiber optic network between 2009 and 2019.

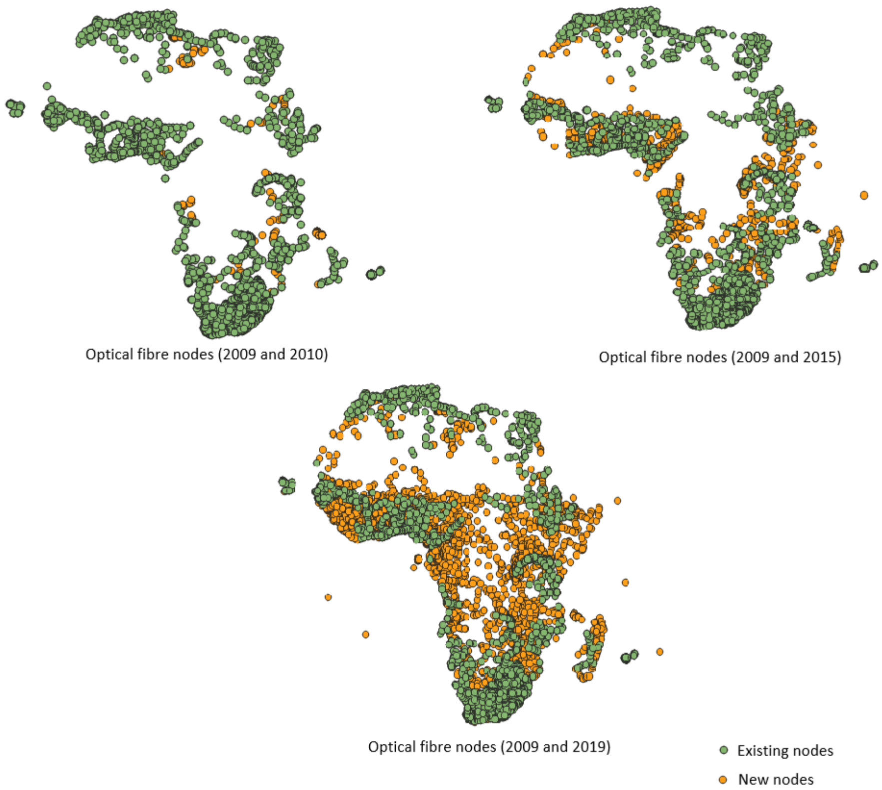

Figure A3: Coverage of optical fiber nodes between 2009 and 2019.

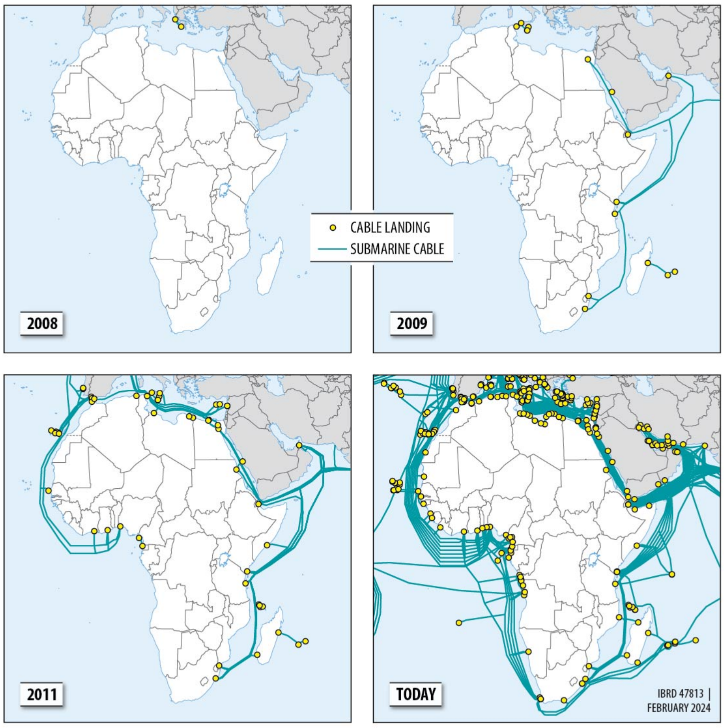

Figure A4: Gradual Arrival of Submarine Cables in Africa.

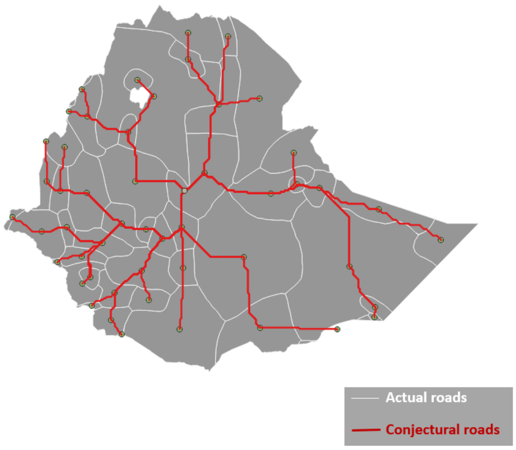

Figure A5: Least Cost Path based on Murdock 1959's Map for Ethiopia.

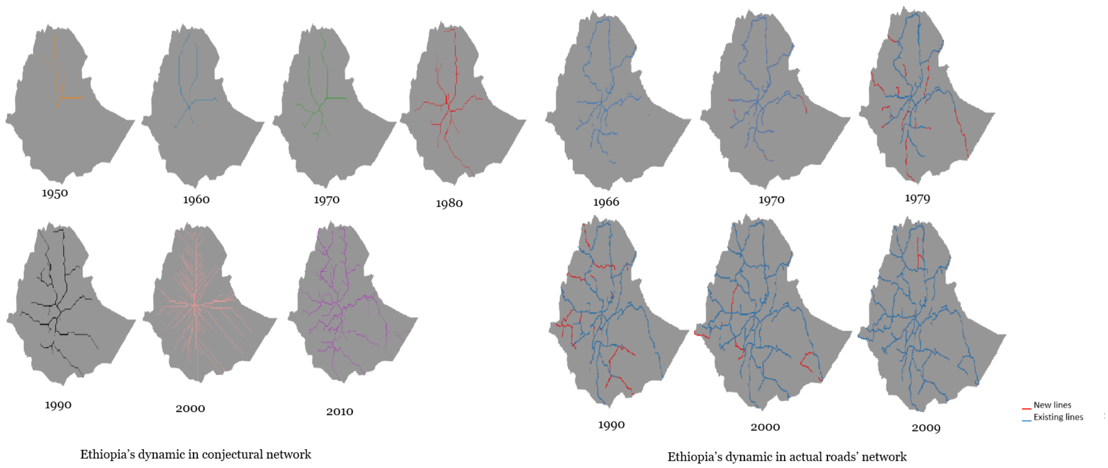

Figure A6: Conjectural (left) vs actual (right) road networks for Ethiopia.

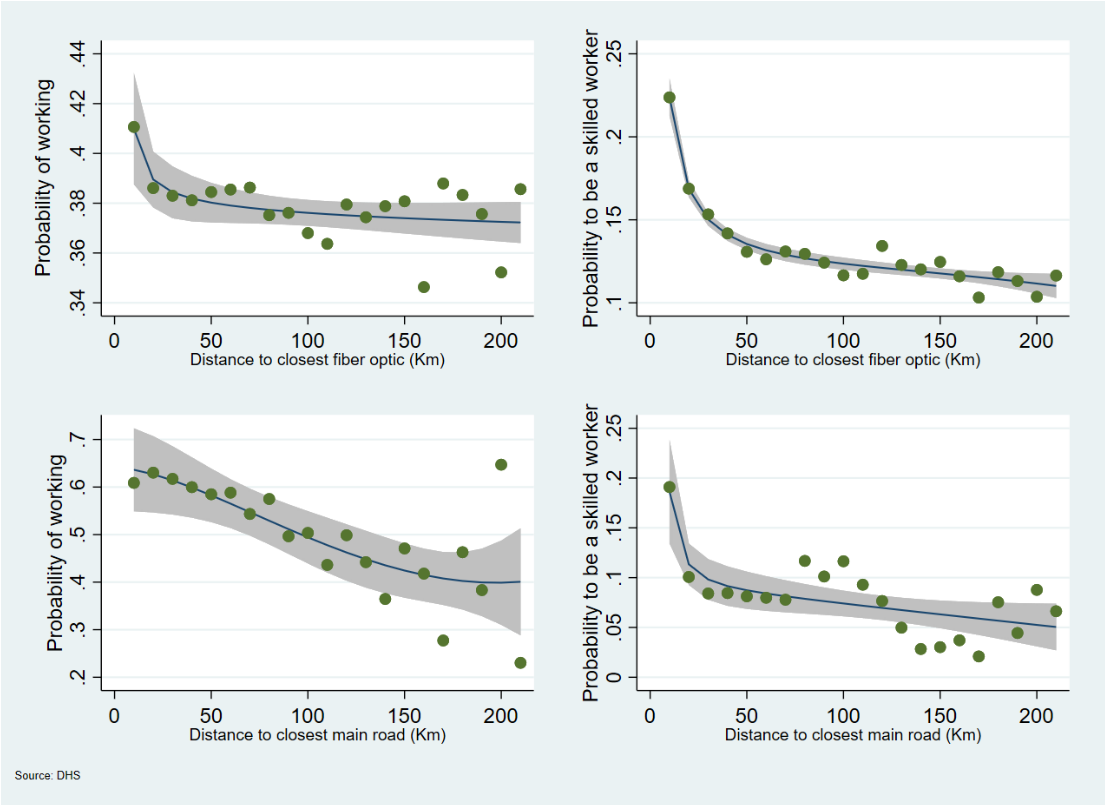

Figure A7: Employment Pattern and infrastructure.

Table A1: Surveys summary

Countries	WBES Years					
Ghana					2007	2013
Kenya				2007	2013	2018
Mauritania				2006	2014	2015
Nigeria				2007	2009	2014
Senegal				2003	2007	2014
Tanzania				2006	2013	2015

Countries	LSMS Surveys Years					
Ethiopia				2011	2014	2015
Malawi		2005	2010	2013	2017	2019
Mali					2014	2017
Niger					2011	2014
Nigeria			2010	2012	2015	2018
Tanzania	2008	2010	2011	2012	2014	2016
Uganda		2005	2009	2010	2011	2013

Countries	DHS Years					
Angola					2006/2007	2015/2016
Burkina Faso					2003	2011
Benin				2001	2011	2017
Burundi					2010	2016
Ethiopia				2005	2011	2016
Ghana				2003	2008	2014
Guinea				2005	2012	2018
Kenya				2003	2008	2014
Liberia					2007	2013
Lesotho				2004	2009	2014
Mali			2001	2006	2013	2018
Mozambique					2011	2015
Nigeria			2003	2008	2013	2018
Namibia				2000	2006	2013
Sierra Leone					2008	2013
Senegal			2005	2010	2015	2016
Togo					1998	2013
Tanzania				1999	2010	2016
Zambia				2007	2014	2018
Zimbabwe				2006/2006	2010/2011	2015

Table A2: Descriptive statistics: DHS Sample

DHS					
Variables	Observation	Mean	Std.Dev	Min	Max
Submarine cables have arrived	806,378	0.415852	0.492868	0	1
Proximity to road (KM)	805,199	-9.702026	17.28903	-221.4656	-.0000708
Submarine (2 km) * proximity to road (KM)	805,199	-.8802237	4.396371	-192.9587	0
Proximity to Hypothetical road (KM)	806,378	-34.45176	34.22753	-273.9815	-.0010025
Submarine (2 km) * proximity to hypothetical road (KM)	806,378	-6.145832	18.4237	-221.7079	0
lightening	803,469	.498743	.3286748	0	2.120674
Terrain elevation	784,523	679.2284	668.5519	-92	3979
slope	774,937	1.264677	1.726249	0	15.9138
Internet connected (0.5 m)	806,378	.0084253	.0914022	0	1
Internet connected (1 km)	806,378	.0244637	.1544839	0	1
Internet connected (1.5 km)	806,378	.0451314	.2075925	0	1
Internet connected (2 km)	806,378	.4184353	.4933026	0	1
Submarine Internet (0.5 km)	806,378	.0026824	.0517221	0	1
Submarine Internet (1 km)	297,612	.0143845	.1190699	0	1
Submarine Internet (1.5 km)	806,378	.02007	.1402398	0	1
Submarine Internet (2 km)	806,378	.1937032	.3951993	0	1
Currently working	717,077	.6770207	.4676152	0	1
Worked in the past year	781,920	.738738	.4393227	0	1
Low skilled worker	747,665	.4597527	.4983779	0	1
Services	740,750	.2290327	.4202106	0	1
Skilled worker	775,839	.1896076	.3919908	0	1
High skilled worker	793,272	.1090647	.3117206	0	1
Self-employed farmer	775,839	.208417	.4061767	0	1
Farmer (employee and self-employed)	775,839	.2830561	.4504838	0	1
More developed country	806,378	.388675	.4874495	0	1
age	806,378	32.65295	9.142657	20	64
Female individual	806,378	.6845698	.4646873	0	1
Rural residence	806,378	.6210524	.4851254	0	1
No Education	806,365	.3828874	.4860915	0	1
Primary education	806,365	.2653091	.4414979	0	1
No education up to primary education	806,365	.6481965	.4775333	0	1
Secondary education and more	806,365	.3518035	.4775333	0	1
20-34 age group	806,378	.6001949	.4898584	0	1
35 to 44 age group	806,378	.2650221	.4413453	0	1
45 to 64 age group	806,378	.1347829	.3414918	0	1

Table A3: Descriptive statistics: WBES Sample

WBES					
Variables	Observation	Mean	Std.Dev	Min	Max
Submarine has arrived	15,057	.9443448	.2292622	0	1
Proximity to road (KM)	15,028	-2.308359	4.602616	-55.85029	-.0005369
Submarine (2 km) * proximity to road (KM)	15,028	-.2960252	1.253145	-15.97813	0
Proximity to Hypothetical road (KM)	15,028	-30.82412	30.14145	-146.8549	-.3167718
Submarine (2 km) * proximity to hypothetical road (KM)	15,028	-11.3393	23.00974	-104.9434	0
lightening	15,028	.4507335	.3021412	.0098068	1.687402
Terrain elevation	15,028	417.6429	556.265	1	2098
slope	15,028	0.598076	0.743425	0	4.41208
Internet connected (0.5 m)	15,028	.1458611	.3529786	0	1
Internet connected (1 km)	15,057	.257289	.4371545	0	1
Internet connected (1.5 km)	15,028	.318938	.4660805	0	1
Internet connected (2 km)	15,028	.783737	.4117093	0	1
Submarine Internet (0.5 km)	4,433	0.10413	0.30545	0	1
Submarine Internet (1 km)	15,057	.1778014	.4371545	0	1
Submarine Internet (1.5 km)	15,028	.257289	.3823582	0	1
Submarine Internet (2 km)	15,057	.3645481	.4813192	0	1
Establishment's age	14,531	15.00399	12.77004	0	168
Telecommunication is an obstacle to operation	13,929	0.2685046	0.4431974	0	1
Losses as percentage of annual sales	12,139	9.22746	13.49414	0	160
Percentage owned by the government	15,032	0.8455628	6.968249	0	100
Secured a contract with government in last fiscal year	7,181	0.2041498	0.4031071	0	1
Hours of operation per week last year	15,057	35.48174	26.1427	10	84
Number of permanent full time employees 3 fiscal years ago	14,411	32.44917	178.1041	0	89
Number of full time skilled employees at the end of last fiscal year	13,653	15.731	26.506766	0	28
Number of full time male employees at the end of last fiscal year	6,730	16.171	29.117	0	67
Number of full time female employees at the end of last fiscal year	6,730	5.8948	20.82994	0	43
Number of full time employees last year	8,080	16.435712	40.70892	0	99
Number of full time unskilled employee at the end of last fiscal years ago	6,613	10.548468	36.523924	0	67

Table A4: Descriptive statistics: LSMS Sample

LSMS					
Variables	Observation	Mean	Std.Dev	Min	Max
Submarine has arrived	1,577,278	.9095562	.2868166	0	1
Proximity to road (KM)	1,577,197	-15.19746	22.41966	-192.6164	-.0035672
Submarine (2 km) * proximity to road (KM)	1,577,197	-.0561241	1.235172	-81.78571	0
Proximity to Hypothetical road (KM)	1,304,065	-36.49485	41.12254	-988.8704	-.0205457
Submarine (2 km) * proximity to hypothetical road (KM)	1,304,065	-2.393068	15.42633	-942.7307	0
lightening	1,577,263	.4222894	.2858886	.0003547	2.120674
Terrain elevation	1,571,687	1008.529	739.0523	0	3451
slope	1,471,186	6.73157	10.05156	0	110.6
Internet connected (0.5 m)	1,577,278	.040698	.1975896	0	1
Internet connected (1 km)	1,577,278	.0389519	.1934805	0	1
Internet connected (1.5 km)	1,577,278	.0455462	.2084988	0	1
Internet connected (2 km)	1,577,278	.0575821	.2329516	0	1
Submarine Internet (0.5 km)	1,577,278	.0019369	.0439674	0	1
Submarine Internet (1 km)	1,577,278	0.038409	0.192182	0	1
Submarine Internet (1.5 km)	1,577,278	.0447321	.2067152	0	1
Submarine Internet (2 km)	1,577,278	.0555742	.2290977	0	1
age	1,577,278	35.80227	12.12185	20	65
Female individual	1,577,278	.5190537	.499637	0	1
Rural residence	1,187,700	.8615879	.3453321	0	1
No Education	1,577,276	.1970784	.3977921	0	1
Primary Education	1,516,855	.1375227	.3443984	0	1
Secondary Education	1,522,283	.2634103	.4404832	0	1
Higher Education	1,522,284	.5259735	.4993251	0	1
Hours worked in the last seven days	590,010	2.946079	11.94734	0	120
Is a government employee	125,047	.2060025	.4044339	0	1
Owns a business	978,380	.286588	.4521676	0	1
Plans to open non-agricultural business in the next 12 months	772,956	.1417183	.3487612	0	1
Survey years	1,577,278			2005	2019

Table A5: Balance Check: Differences in Employment Outcomes Before Submarine Internet Arrival Between Connected and non-Connected Observations

	Connected **Std.Dev**	**Not connected** **Std.Dev**	**Difference** **t-stat**
DHS			
Currently working	0.57 0.5	0.57 0.5	0 1.54
Worked during last year	0.71 0.45	0.72 0.45	0.01 1.41
Low skilled worker	0.63 0.48	0.56 0.50	-0.07 -3.95
Skilled worker	0.24 0.42	0.15 0.34	-0.09 -9.31
High skilled worker	0.14 0.27	0.08 0.35	-0.06 -8.25
Farming is main employment	0.15 0.36	0.29 0.45	0.15 1.27
Services	0.27 0.44	0.18 0.39	-0.09 -8.54
WBES			
Number of full time employee at business start	10.65 12.65	12.04 13.81	1.38 1.79
Number of full time employee last fiscal year	14.91 31.58	17.29 37.45	2.38 0.61
Number of female full time employee last fiscal year	5.39 23.03	6.26 22.03	0.87 0.45
Number of skilled full time employee last fiscal year	13.84 22.66	19.93 29.24	6.09 0.64
Telecommunication is an obstacle to operations	0.29 0.44	0.27 0.46	-0.02 -2.71
Losses as percentage of annual sales	8.95 14.15	8.58 14.68	-0.37 -1.38
Percentage own by the government	0.73 7.32	0.75 6.98	0.02 0.12
Secured a contract with government in last fiscal year	0.20 0.40	0.14 0.35	-0.06 -5.57
Hours of operations per week in last fiscal year	25.67 29.35	32.23 34.49	6.56 12.01
LSMS			
Hours worked in last 7 days	6.15 17.06	10.03 23.64	3.88 4.05

Table A6: The Complementary Effect of Internet and Roads by Sector of Occupation

	(1)	(2)	(3)	(4)	(5)	(6)
	DHS				WBES	
	Low skilled worker	**Services**	**Skilled worker**	**High skilled worker**	**Number of full time skilled employee at end of last fiscal year**	**Number of full time unskilled employee at end of last fiscal year**
Submarine internet	-0.131***	0.168***	0.129***	0.0962***	1.070***	1.201***
	(0.0195)	(0.0236)	(0.0189)	(0.0143)	(0.268)	(0.3430)
Proximity to road (KM)	0.00524***	0.00126***	0.000939***	0.000988	0.980***	0.447***
	(0.000411)	(0.000283)	(0.000233)	(0.00176)	(0.250)	(0.227)
Submarine internet * road	-0.0194***	0.0294***	0.0218***	0.0156***	0.0629***	0.1010***
	(0.00422)	(0.00529)	(0.00417)	(0.00314)	(0.0201)	(0.0382)
N	724778	717891	752131	767327	12276	3306
ymean	0.528	0.226	0.187	0.121	15.731	8.584
R-sq	0.139	0.0956	0.0734	0.0471	0.145	0.1360
R-sq_a	0.139	0.0955	0.0733	0.0471	0.140	0.1190
Kleibergen-Paap F-statistic	81.24	81.55	80.89	81.15	1.103	1.1300
$P > F$	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	811.4	808.3	885.1	850.6	1202.1	227.6
Windmeijer F-statistic	17.52	20.01	26.87	16.71	29.11	21.14
Kleibergen-Paap Wald F-statistic	19.18	19.23	18.99	19.14	25.88	66.88
Age	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✓	✗	✗
Place of residence	✓	✓	✓	✓	✗	✗
Education	✓	✓	✓	✓	✗	✗
Year FE	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A7: The Complementary Effect of Internet and Roads on Agricultural Employment

	(1)	(2)	(3)	(4)
	All sample		**Rural sample**	
	Farming self-employed	**Farming employee and self-employed**	**Farming self-employed**	**Farming employee and self-employed**
Submarine internet	-0.147***	-0.112***	-0.104***	-0.128***
	(0.0395)	(0.0363)	(0.0327)	(0.0353)
Proximity to road (KM)	0.00209**	0.00270***	0.00312***	0.00601***
	(0.000842)	(0.000802)	(0.000610)	(0.000710)
Submarine internet * road	-0.0284***	-0.0263***	-0.0133***	-0.0169***
	(0.00804)	(0.00779)	(0.00397)	(0.00424)
N	752131	752131	465918	465918
ymean	0.208	0.284	0.304	0.415
r2	0.253	0.220	0.332	0.165
r2_a	0.253	0.220	0.331	0.164
Kleibergen-Paap F-statistic	45.74	45.74	64.41	64.41
$P > F$	0	0	0	0
Cragg-Donald Wald F-statistic	885.1	885.1	1219.3	1219.3
Windmeijer F-statistic	35.21	41.74	30.01	31.85
Kleibergen-Paap Wald F-statistic	7.590	7.590	12.39	12.39
Age	✓	✓	✓	✓
Gender	✓	✓	✓	✓
Place of residence	✓	✓	✗	✗
Education	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A8: Heterogeneity in the Joint Effect of Internet and Roads on Employment: Place of Residence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Worked during past year				Currently working				Hours worked			
	Urban Sample	Rural Sample	high developed Sample	Low developed Sample	Urban Sample	Rural Sample	high developed Sample	Low developed Sample	Urban Sample	Rural Sample	high developed Sample	Low developed Sample
	DHS								LSMS			
Submarine internet	0.210*	0.0369	0.0891	0.0603**	0.190*	0.0165	0.0419	0.0514*	2.005	-0.390**	-0.0893	-1.002***
	(0.101)	(0.0239)	(0.0516)	(0.0209)	(0.0920)	(0.0240)	(0.0443)	(0.0209)	(2.464)	(0.189)	(0.0590)	(0.349)
Proximity to road (KM)	0.00622***	0.00822***	0.00962***	0.00689***	0.00709***	0.00758***	0.00938***	0.00725***	4.782	0.327	-20.84	1.188***
	(0.00118)	(0.000613)	(0.00101)	(0.000515)	(0.00119)	(0.000581)	(0.00104)	(0.000509)	(8.135)	(0.320)	(50.56)	(0.341)
Submarine internet * road	0.0905*	0.00228	0.0152	0.0122**	0.0797*	-0.000414	0.00702	0.00926*	4.691	3.246	-15.84	6.745***
	(0.0442)	(0.00312)	(0.0123)	(0.00425)	(0.0400)	(0.00306)	(0.0104)	(0.00416)	(8.322)	(2.920)	(43.33)	(2.356)
N	287502	468833	295535	460800	265370	431047	263715	432702	31001	440181	285733	185449
ymean	0.734	0.752	0.764	0.733	0.682	0.696	0.671	0.671	4.709	0.750	4.981	1.295
r2	-0.318	0.0754	0.0151	0.0675	-0.239	0.117	0.0767	0.0816	-1.010	-0.408	-0.0356	-0.817
r2_a	-0.318	0.0753	0.0150	0.0675	-0.240	0.117	0.0767	0.0816	-1.011	-0.408	-0.0356	-0.817
Kleibergen-Paap F-statistic	25.81	67.77	21.60	73.31	24.89	69.03	22.38	74.27	4.116	10.04	2.660	5.403
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	47.89	1146.8	125.3	1050.5	45.69	1048.4	114.9	1002.2	57.64	1064.3	62.03	363.2
Windmeijer F-statistic	12.11	16.02	29.89	32.08	13.57	12.04	11.84	16.73	4.12	10.04	12.66	15.40
Kleibergen-Paap Wald F-statistic	5.120	15.50	4.382	17.27	4.940	15.79	4.532	17.54	1.226	1.983	0.555	3.652
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✗	✗	✓	✓	✗	✗	✓	✓	✗	✗	✓	✓
Education	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A9: Heterogeneity in the Complementary Effect of Internet and Roads on Employment: Gender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	DHS				LSMS		WBES	
	Worked during past year		Currently working		Hours worked		Number of full time employee at end of last fiscal year	
	Male Sample	Female Sample	Male Sample	Female Sample	Male Sample	Female Sample	Male Sample	Female Sample
Submarine internet	0.0589**	0.0964***	0.0393	0.0830**	-0.473**	-0.275*	1.078***	0.131***
	(0.0209)	(0.0287)	(0.0205)	(0.0275)	(0.240)	(0.150)	(0.327)	(0.0478)
Proximity to road (KM)	0.00410***	0.00899***	0.00462***	0.00879***	0.401	0.964	0.448***	1.004***
	(0.000467)	(0.000574)	(0.000597)	(0.000551)	(0.253)	(0.663)	(0.0392)	(0.165)
Submarine internet * road	0.0118*	0.0193**	0.00527	0.0163**	4.545**	3.713**	0.0916***	0.00157
	(0.00489)	(0.00610)	(0.00459)	(0.00582)	(2.044)	(1.867)	(0.0337)	(0.00273)
N	245289	511046	176813	519604	231770	239412	5882	5043
ymean	0.898	0.673	0.856	0.620	1.328	1.267	13.332	5.326
r2	0.0161	-0.0155	0.0317	0.0234	-0.600	-0.115	0.0426	0.0278
r2_a	0.0159	-0.0156	0.0315	0.0233	-0.600	-0.115	0.0311	0.0141
Kleibergen-Paap F-statistic	58.36	83.40	60.52	85.79	9.708	11.54	1.485	0.963
$P > F$	0.00000144	0.0000106	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	290.0	558.1	230.5	560.2	476.2	597.1	391.7	321.0
Windmeijer F-statistic	15.01	12.11	12.04	7.54	9.71	11.54	14.85	15.99
Kleibergen-Paap Wald F-statistic	13.09	19.77	13.41	20.44	2.642	2.629	3000.9	5.997
Age	✓	✓	✓	✓	✓	✓	✓	✓
Gender	✗	✗	✗	✗	✗	✗	✗	✗
Place of residence	✓	✓	✓	✓	✓	✓	✗	✗
Education	✓	✓	✓	✓	✓	✓	✗	✗
Year FE	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 * *p < .05 * * * p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A10: Heterogeneity in the Complementary Effect of Internet and Roads on Employment: Education

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Worked during past year				Currently working				Hours worked			
	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample
	DHS								LSMS			
Submarine internet	0.181**	0.0677**	0.106***	0.0629*	0.146**	0.0510*	0.0846**	0.0566*	0.0682	-0.207	-0.0774	-0.561**
	(0.0599)	(0.0248)	(0.0302)	(0.0279)	(0.0542)	(0.0256)	(0.0288)	(0.0272)	(0.138)	(0.130)	(0.0994)	(0.256)
Proximity to road (KM)	0.00649***	0.00939***	0.00770***	0.00701***	0.00619***	0.00985***	0.00749***	0.00784***	2.245	0.393	0.282	0.877***
	(0.000475)	(0.000963)	(0.000473)	(0.00105)	(0.000468)	(0.00101)	(0.000460)	(0.00115)	(2.124)	(0.475)	(0.789)	(0.243)
Submarine internet * road	0.0281**	0.0101*	0.0157**	0.0206*	0.0223*	0.00849	0.0125*	0.0168*	2.870	6.304**	1.863	6.982**
	(0.00992)	(0.00468)	(0.00537)	(0.00846)	(0.00889)	(0.00474)	(0.00506)	(0.00808)	(2.808)	(2.583)	(1.646)	(3.332)
N	295558	196514	492072	264263	278239	180856	459095	237322	160837	91574	252405	161285
ymean	0.740	0.769	0.752	0.732	0.671	0.703	0.683	0.675	1.090	1.435	1.907	18.72
r2	0.0421	0.0362	0.0461	0.0811	0.0914	0.0572	0.0832	0.0914	0.00360	-0.100	0.00356	-0.585
r2_a	0.0419	0.0359	0.0460	0.0809	0.0912	0.0570	0.0831	0.0912	0.00351	-0.100	0.00348	-0.585
Kleibergen-Paap F-statistic	73.58	51.84	75.90	56.00	73.87	53.23	77.11	53.32	3.161	10.71	9.055	9.315
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	213.5	345.9	595.0	228.5	204.3	323.8	561.9	205.6	235.0	436.4	704.0	425.0
Windmeijer F-statistic	9.56	12.63	15.50	6.43	8.31	6.94	9.31	3.80	10.16	10.71	9.05	9.32
Kleibergen-Paap Wald F-statistic	17.43	11.21	17.94	11.90	17.56	11.58	18.28	11.25	0.491	1.662	1.612	3.061
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 * *p < .05 * * * p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A11: Heterogeneity in the Complementary Effect of Internet and Roads on Employment: Age

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Worked during past year			Currently working			Hours worked	
	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample
			DHS					LSMS	
Submarine internet	0.0923**	0.0608*	0.0808**	0.0560*	0.0492*	0.0584*	-0.331*	-0.241	-0.607**
	(0.0283)	(0.0240)	(0.0288)	(0.0252)	(0.0242)	(0.0291)	(0.170)	(0.162)	(0.292)
Proximity to road (KM)	0.00799***	0.00796***	0.00638***	0.00794***	0.00810***	0.00706***	0.761**	0.111	0.797***
	(0.000520)	(0.000521)	(0.000623)	(0.000496)	(0.000537)	(0.000695)	(0.371)	(2.579)	(0.296)
Submarine internet * road	0.0201**	0.0107*	0.0141*	0.0128*	0.00880	0.0107	4.862**	1.901	5.125***
	(0.00646)	(0.00491)	(0.00606)	(0.00565)	(0.00489)	(0.00598)	(2.415)	(4.434)	(1.868)
N	451922	201169	103244	420560	186046	89811	242117	118111	104618
ymean	0.692	0.813	0.844	0.626	0.753	0.785	1.537	1.155	1.228
r2	0.0253	0.0308	0.0484	0.0601	0.0626	0.0686	-0.268	-0.0907	-0.628
r2_a	0.0251	0.0306	0.0480	0.0600	0.0623	0.0681	-0.268	-0.0909	-0.628
Kleibergen-Paap F-statistic	77.79	76.70	50.13	79.84	78.45	50.85	7.427	7.935	6.247
$P > F$	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	445.4	283.5	119.0	419.2	264.0	107.6	505.1	233.7	301.1
Windmeijer F-statistic	26.02	28.51	15.81	24.45	26.28	14.45	7.42	7.94	6.25
Kleibergen-Paap Wald F-statistic	18.19	18.10	11.03	18.70	18.55	11.22	1.422	1.322	4.995
Age	✗	✗	✗	✗	✗	✗	✗	✗	✗
Gender	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 * *p < .05 * * * p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A12: The Complementary Effect of Internet and Roads on Firms Operations and Productivity

	(1)	(2)	(3)	(4)
			WBES	
Variables	**Telecommunication is an obstacle to operation**	**Losses as percentage of annual sales**	**percentage owned by the governemnt**	**Secured a contract with governemnt in the last fiscal year**
Submarine internet	-0.0678***	-2.293***	1.268***	0.172***
	(0.00976)	(0.267)	(0.0477)	(0.0152)
Proximity to road (KM)	0.0362***	-0.712***	-0.295***	-0.00146
	(0.00115)	(0.0248)	(0.00792)	(0.00421)
Submarine internet * road	-0.00361***	-0.146***	0.0847***	0.0111***
	(0.00129)	(0.0451)	(0.00254)	(0.00365)
N	13473	11742	14525	6768
ymean	0.270	9.322	0.757	0.183
r2	0.139	0.0949	0.0301	0.167
r2_a	0.135	0.0892	0.0252	0.160
Kleibergen-Paap F-statistic	1.096	1.059	1.094	1.362
$P > F$	0	0	0	0
Cragg-Donald Wald F-statistic	1181.8	1051.7	1282.4	394.2
Windmeijer F-statistic	25.59	18.95	25.39	12.39
Kleibergen-Paap Wald F-statistic	25.99	18.95	25.39	183.9
Age of the firm	✓	✓	✓	✓
Year FE	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 ** p < .05 *** p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A13: Heterogeneity in the Complementary Effect of Internet and Roads on Skilled Employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							High skilled worker							
	All Sample	Urban Sample	Rural Sample	Male Sample	Female Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	More developed Sample	Less developed Sample
Submarine Internet	0.0962***	0.0807*	0.0612***	0.0669***	0.114***	0.152***	0.0517***	0.0970***	0.0516**	0.111***	0.0817***	0.0611**	0.200**	0.0620***
	(0.0143)	(0.0359)	(0.0126)	(0.0176)	(0.0165)	(0.0324)	(0.0112)	(0.0149)	(0.0189)	(0.0175)	(0.0166)	(0.0230)	(0.0612)	(0.0111)
Proximity to road (KM)	0.0000988	0.00128**	-0.000410*	0.000206	0.0000295	0.0000358	-0.000593*	-0.0000632	-0.0000256	0.000250	-0.0000404	-0.0000714	-0.00107	0.000377*
	(0.000176)	(0.000474)	(0.000164)	(0.000318)	(0.000180)	(0.000137)	(0.000289)	(0.000117)	(0.000734)	(0.000197)	(0.000257)	(0.000362)	(0.000556)	(0.000191)
Submarine Internet * road	0.0156***	0.0203	0.00609***	0.0115**	0.0183***	0.0218***	0.00735***	0.0137***	0.00924	0.0189***	0.0112***	0.0118*	0.0426**	0.00784***
	(0.00314)	(0.0153)	(0.00160)	(0.00404)	(0.00349)	(0.00535)	(0.00198)	(0.00264)	(0.00543)	(0.00402)	(0.00320)	(0.00472)	(0.0148)	(0.00216)
N	767327	291558	475769	245304	522023	300363	199363	499726	267601	459291	203919	104117	300383	466944
ymean	0.121	0.209	0.067	0.166	0.100	0.034	0.070	0.048	0.257	0.115	0.129	0.133	0.140	0.109
r2	0.0471	0.0352	0.0449	0.0801	0.0114	-0.140	0.0332	-0.0176	0.0550	0.0174	0.0878	0.0960	-0.220	0.0810
r2_a	0.0471	0.0350	0.0448	0.0799	0.0113	-0.140	0.0329	-0.0177	0.0548	0.0173	0.0876	0.0956	-0.220	0.0810
Kleibergen-Paap F-statistic	81.15	25.38	68.70	58.25	85.42	73.52	51.83	75.86	56.02	79.25	78.44	51.29	22.25	74.15
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	850.6	48.40	1142.5	290.5	559.9	213.6	346.5	595.8	229.0	447.1	282.4	120.4	124.6	1058.4
Windmeijer F-statistic	16.71	11.97	6.50	7.77	8.05	6.40	9.00	13.75	6.93	8.80	6.75	18.91	6.50	7.54
Kleibergen-Paap Wald F-statistic	19.14	5.036	15.73	13.06	20.34	17.41	11.21	17.93	11.91	18.57	18.57	11.31	4.513	17.52
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓
Gender	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A14: Heterogeneity in the Complementary Effect of Internet and Roads on Skilled jobs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							Skilled worker							
	All Sample	Urban Sample	Rural Sample	Male Sample	Female Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	More developed Sample	Less developed Sample
Submarine internet	0.129***	0.138*	0.0991***	0.171***	0.109***	0.199***	0.0862***	0.146***	0.0607**	0.133***	0.123***	0.116***	0.230**	0.100***
	(0.0189)	(0.0571)	(0.0179)	(0.0341)	(0.0161)	(0.0419)	(0.0185)	(0.0226)	(0.0214)	(0.0218)	(0.0209)	(0.0301)	(0.0715)	(0.0155)
Proximity to road (KM)	0.000939***	0.00296***	-0.000293	0.00286***	0.000141	0.000338	0.00146**	0.000484*	0.00234**	0.00106***	0.000929**	0.000699	-0.0000496	0.00114***
	(0.000233)	(0.000676)	(0.000230)	(0.000477)	(0.000216)	(0.000197)	(0.000474)	(0.000192)	(0.000801)	(0.000261)	(0.000300)	(0.000456)	(0.000664)	(0.000251)
Submarine internet * road	0.0218***	0.0429	0.00985***	0.0352***	0.0165***	0.0280***	0.0139***	0.0211***	0.0128*	0.0234***	0.0185***	0.0224***	0.0495**	0.0131***
	(0.00417)	(0.0244)	(0.00230)	(0.00818)	(0.00336)	(0.00690)	(0.00347)	(0.00405)	(0.00619)	(0.00495)	(0.00418)	(0.00624)	(0.0172)	(0.00310)
N	752131	286213	465918	244272	507859	295085	195580	490665	261466	448254	201003	102874	292000	460131
ymean	0.187	0.297	0.121	0.295	0.136	0.085	0.155	0.113	0.329	0.184	0.194	0.194	0.216	0.170
r2	0.0734	0.0278	0.0589	0.0533	0.0430	-0.0758	0.0703	0.00778	0.0793	0.0561	0.115	0.108	-0.170	0.122
r2_a	0.0733	0.0276	0.0588	0.0531	0.0429	-0.0760	0.0700	0.00768	0.0791	0.0560	0.115	0.108	-0.170	0.122
Kleibergen-Paap F-statistic	80.89	23.87	70.07	58.19	85.11	74.85	52.47	76.84	54.43	78.63	77.85	51.02	21.37	74.14
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	885.1	45.01	1219.3	288.8	596.1	247.4	347.0	632.1	229.5	471.4	289.5	121.8	134.8	1043.2
Windmeijer F-statistic	26.87	8.43	16.15	14.95	19.81	21.51	7.26	18.00	3.20	15.77	11.16	5.67	7.95	13.65
Kleibergen-Paap Wald F-statistic	18.99	4.748	16.04	13.04	20.12	17.78	11.34	18.10	11.56	18.33	18.39	11.24	4.320	17.49
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓
Gender	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A15: Heterogeneity in the Complementary Effect of Internet and Roads on Unskilled Employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							Low skilled worker							
	All Sample	Urban Sample	Rural Sample	Male Sample	Female Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	More developed Sample	Less developed Sample
Submarine internet	-0.131***	0.0779	-0.102***	-0.225***	-0.0888***	-0.211***	-0.0565**	-0.132***	0.00154	-0.129***	-0.133***	-0.134***	-0.243***	-0.0562**
	(0.0195)	(0.0629)	(0.0244)	(0.0301)	(0.0213)	(0.0531)	(0.0217)	(0.0251)	(0.0203)	(0.0212)	(0.0243)	(0.0329)	(0.0606)	(0.0182)
Proximity to road (KM)	0.00524***	0.00310***	0.00479***	0.000397	0.00695***	0.00409***	0.00645***	0.00541***	0.000561	0.00545***	0.00530***	0.00388***	0.00520***	0.00475***
	(0.000411)	(0.000839)	(0.000497)	(0.000603)	(0.000482)	(0.000426)	(0.000915)	(0.000426)	(0.000823)	(0.000437)	(0.000508)	(0.000604)	(0.000937)	(0.000443)
Submarine internet * road	-0.0194***	0.0455	-0.0114***	-0.0356***	-0.0121**	-0.0270**	-0.00622	-0.0162***	0.00241	-0.0196***	-0.0187***	-0.0192**	-0.0419**	-0.00476
	(0.00422)	(0.0270)	(0.00316)	(0.00719)	(0.00439)	(0.00887)	(0.00381)	(0.00440)	(0.00578)	(0.00471)	(0.00479)	(0.00680)	(0.0144)	(0.00348)
N	724778	273255	451523	203643	521135	289648	189254	478902	245876	435086	193759	95933	277048	447730
ymean	0.529	0.640	0.462	0.659	0.473	0.408	0.495	0.443	0.692	0.567	0.469	0.476	0.583	0.495
r2	0.139	-0.0236	0.232	0.256	0.125	0.216	0.133	0.180	0.0676	0.123	0.143	0.202	0.0260	0.167
r2_a	0.139	-0.0238	0.232	0.256	0.125	0.216	0.133	0.180	0.0674	0.122	0.143	0.202	0.0259	0.167
Kleibergen-Paap F-statistic	81.24	25.13	68.91	59.07	85.55	73.85	52.38	76.55	54.16	79.46	78.55	50.98	21.96	74.50
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	811.4	46.51	1091.3	249.6	559.5	208.3	332.6	576.7	211.6	427.3	271.2	112.7	116.3	1027.9
Windmeijer F-statistic	17.52	11.09	14.60	7.04	14.48	16.04	6.00	15.97	2.30	10.94	10.78	6.37	10.46	9.10
Kleibergen-Paap Wald F-statistic	19.18	4.987	15.81	13.23	20.38	17.55	11.37	18.18	11.46	18.62	18.63	11.27	4.448	17.62
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓
Gender	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*

Table A16: Heterogeneity in the Complementary Effect of Internet and Roads on Services jobs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
							Services							
	All Sample	Urban Sample	Rural Sample	Male Sample	Female Sample	Not educated Sample	Low educated Sample (Primary)	Not more than primary Sample	higher educated Sample	20-34 groupe age Sample	35 -44 groupe age Sample	45-64 groupe age Sample	More developed Sample	Less developed Sample
Submarine internet	0.168***	0.195**	0.121***	0.207***	0.156***	0.235***	0.141***	0.198***	0.0979***	0.177***	0.155***	0.144***	0.273**	0.121***
	(0.0236)	(0.0711)	(0.0207)	(0.0327)	(0.0227)	(0.0490)	(0.0245)	(0.0288)	(0.0259)	(0.0282)	(0.0242)	(0.0314)	(0.0839)	(0.0183)
Proximity to road (KM)	0.00126***	0.00359***	-0.000300	0.00298***	0.000664*	0.000426	0.00161**	0.000718**	0.00424***	0.00140***	0.00139***	0.000627	0.000622	0.00131***
	(0.000283)	(0.000862)	(0.000264)	(0.000522)	(0.000266)	(0.000235)	(0.000554)	(0.000236)	(0.000969)	(0.000316)	(0.000342)	(0.000505)	(0.000806)	(0.000284)
Submarine internet * road	0.0294***	0.0627*	0.0124***	0.0348***	0.0268***	0.0331***	0.0217***	0.0284***	0.0198**	0.0331***	0.0233***	0.0262***	0.0603**	0.0172***
	(0.00529)	(0.0307)	(0.00272)	(0.00772)	(0.00487)	(0.00815)	(0.00467)	(0.00521)	(0.00763)	(0.00651)	(0.00493)	(0.00655)	(0.0206)	(0.00370)
N	717891	278417	439474	197714	520177	281217	185596	466813	251078	431907	191991	93993	274836	443055
ymean	0.226	0.356	0.144	0.401	0.160	0.097	0.197	0.136	0.397	0.221	0.230	0.241	0.267	0.202
r2	0.0956	-0.00814	0.0935	0.205	0.0137	-0.0978	0.0789	0.00246	0.113	0.0595	0.156	0.166	-0.219	0.156
r2_a	0.0955	-0.00832	0.0934	0.204	0.0136	-0.0979	0.0787	0.00235	0.113	0.0594	0.156	0.166	-0.219	0.156
Kleibergen-Paap F-statistic	81.55	25.20	69.03	59.68	85.73	73.73	53.06	76.77	55.55	79.75	78.44	51.45	22.63	74.05
$P > F$	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cragg-Donald Wald F-statistic	808.3	47.13	1065.5	246.9	559.2	205.3	327.8	567.1	216.4	426.7	269.3	111.8	118.4	1018.2
Windmeijer F-statistic	20.01	11.52	12.23	14.42	12.87	8.09	18.85	19.42	10.79	19.79	12.87	10.15	10.92	11.44
Kleibergen-Paap Wald F-statistic	19.23	5.006	15.81	13.30	20.42	17.50	11.52	18.19	11.77	18.69	18.52	11.38	4.581	17.48
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓
Gender	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
Place of residence	✓	✗	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Grid (20*20) connectivity FE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Robust standard errors in parentheses clustered at the grid level. $*p < .10 **p < .05 ***p < 0.01$. *We use a strategy that combines difference-in-differences and instrumental variables techniques. The causal effect of Internet is estimated using difference-in-differences, while the effects of the road and its interaction with the Internet are estimated using an instrumental variables approach. Our instruments are: the distance to the hypothetical road, the interaction between the distance to the hypothetical road and an indicator for whether an individual (or a firm) is connected to submarine Internet, lightning, and terrain elevation.*