Policy Research Working Paper 9976

Roads, Electricity, and Jobs

Evidence of Infrastructure Complementarity in Sub-Saharan Africa

Mansoureh Abbasi
Mathilde Lebrand
Arcady Bluette Mongoue
Roland Pongou
Fan Zhang

WORLD BANK GROUP
Infrastructure Chief Economist Office
March 2022

Policy Research Working Paper 9976

Abstract

Evidence for road expansion and electrification as drivers of job creation is limited and mixed, with most studies having considered either one or the other, and only in isolation. This paper estimates the average and heterogeneous impacts of road and electricity investments and the interaction of the two on job creation over the past two decades in 27 countries of sub-Saharan Africa. Exploiting the exogenous location of ancestral ethnic homelands, a new instrumental variable is created for road accessibility, inspired by post-independence leaders' agenda of building roads to extend authority over the entire expanse of their country, and to promote nation building. Topography and lightning strikes—a key source of damage to electric lines and disruption of service—are used to instrument electricity supply. The paper finds positive and significant effects on employment from enhancing proximity to roads and to electric grids. Moreover, the interaction of the two enhances the effects, making them complementary investments. The impacts of both individual and bundled investments are positive, but with differences between men and women, workers of various ages, and countries at different stages of development. In urban areas, better access to roads and electricity promotes all types of employment. In rural areas, greater access induces a transition from low- to high-skilled occupations. These differential effects suggest that the structural transformation brought about by road and electricity expansion is primarily a rural phenomenon.

This paper is a product of the Infrastructure Chief Economist Office. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The author may be contacted at mlebrand@worldbank.org.

Roads, Electricity, and Jobs: Evidence of Infrastructure Complementarity in Sub-Saharan Africa*

Mansoureh Abbasi
University of Ottawa

Mathilde Lebrand
World Bank

Arcady Bluette Mongoue
University of Ottawa

Roland Pongou
University of Ottawa

Fan Zhang
World Bank

Keywords: Infrastructure complementarity; jobs; impact heterogeneity; structural transformation; Africa

JEL classification: J24, L91, L94, O13, O15, O18

*We thank Moussa Blimpo, Mark Dutz, Vivien Foster, Aart Kraay, Harris Selod, and seminar participants at the World Bank who provided useful comments on the preliminary versions of this paper. Send correspondence to Abbasi at mabba061@uottawa.ca, Lebrand at mlebrand@worldbank.org, Mongoue at bmong077@uottawa.ca, Pongou at rpongou@uottawa.ca, and Zhang at fzhang1@worldbank.org.

1 Introduction

Both roads and electricity play central roles in economic development, yet evidence about whether their expansion is a potential driver of job creation is limited and mixed. Moreover, little is known about the complementary effects that such investments may confer in combination, or the constraints on potential benefits of one kind of infrastructure because of the absence or inadequacy of the other type. For example, greater access to electricity can stimulate local production, but a lack of reliable transport infrastructure can reduce the potential gains due to lack of market access, especially in more isolated areas. On the other hand, greater connections to road networks can increase market access, allowing for better access to customers, but also greater exposure to competition; without access to modern production technology that electricity enables, the competition effect from improved road access may outweigh the benefits of reaching more potential customers, potentially stymieing local economic growth. Empirical evidence on the complementarity between roads and electricity is limited (Moneke, 2020). Most existing studies either analyze the effects of infrastructure investments in isolation, or estimate the aggregate impact of infrastructure in a bundle of many types of infrastructure, calculating the elasticity of output with respect to a synthetic infrastructure index that includes electricity, transport, and telecommunications (Calderon et al., 2015). Thus, questions remain about whether a big push for investments in roads and electricity represents a powerful means of creating more and better jobs.

This paper investigates how infrastructure investments can be coordinated to support economic development by looking at the combined, causal effect of electricity and road expansion on employment in sub-Saharan Africa. The analysis relies on two sets of geo-referenced household survey data: the Living Standards Measurement Study (LSMS) surveys and Demographic and Health Surveys (DHS). We combine these with an extensive array of data on the geo-location of road expansions (Jedwab and Storeygard, 2021) and electric grids in 27 African countries.

The high costs and potentially large benefits of infrastructure investments mean that the placement of electrification projects and new roads typically correlates with both economic and political characteristics of locations (Blimpo et al., 2013; Burgess and Donaldson, 2017; Okoye et al., 2019; Selod and Soumahoro, 2019). To address the potential endogeneity of infrastructure investment, we use two identification strategies: a baseline regression strategy and an instrumental variable (IV) approach. In the baseline model, we control for country and year fixed effects and a wide range of individual and local factors. In the IV model, we instrument electrification with topography data (Dinkelman, 2011) and the density of lightning strikes, which are a key source of damage to electricity lines and a source of disruption in service, particularly in Africa (Manacorda and Tesei, 2020).

We propose a new instrumental variable for the proximity to the road network, inspired by post-independence leaders' idea of constructing roads to govern the entire expanse of their countries from the capital city - the center of political power - and to promote ethnic and regional integration and nation building. One of the main goals of African leaders as their countries' gained independence was to extend the exercise of their authority over all locations. In the wake of the arbitrary partition of Africa over 1884 and 1885, African leaders also sought to integrate different ethnic groups and regions into their countries (Herbst, 2014; Deng, 1997). One way to achieve both policy goals was to construct roads to both facilitate the travel of administration officials and military troops from the capital city to other regions of the country, and the movement of people and goods between different ethnic homelands. Leveraging this premise for our analysis, we construct hypothetical roads linking ancestral ethnic homelands from the capital of each country to instrument for the actual road network. We use a least-cost algorithm, assuming that land altitude is the main geographic determinant of construction costs for roads. The exclusion restriction is likely to be met because these hypothetical roads are conditional only on geographic costs of construction, not demand-side factors. Moreover, the set of ethnic groups and homelands in each country is exogenously determined, given the arbitrary partition of Africa.

Estimates suggest positive and significant employment effects of proximity to roads, proximity to electricity grids, and the interaction of the two. For people in locations sufficiently close to an electric grid, bringing the main road 10 km closer increases the probability of being employed by between 2.5 percentage points (based on the LSMS sample) and 26 percentage points (based on the DHS sample). Greater road access also increases the number of hours worked by 1.2 hours per week (DHS sample). For locations sufficiently close to a main road, bringing an electric grid 10 km closer increases the likelihood of being employed by between 6 percentage points (LSMS sample) and 8.4 percentage points (DHS sample). Greater proximity to an electric grid also raises the number of hours worked by 12.5 hours per week (DHS sample).

Our estimates also reveal complementarity. We show that bringing an electricity grid closer to a location increases the positive marginal impact of bringing a main road closer; and, in turn, bringing a main road closer to a location increases the positive marginal impact of bringing an electric grid closer. Specifically, we find that bringing an electric grid 10 km closer increases the probability of working by more than 8.4 percentage points in locations that have direct road access, but by only 4 percentage points in locations that are more than 10 km away from a main road (DHS sample). Similarly, bringing the main road network 10 km closer increases the probability of working by more than 25 percentage points when that location is near an electric grid, but by only 21 percentage points when it is located more than 10 km away from an electric grid. The results suggest that road and electricity expansions play complementary roles in job creation.

We also show that infrastructure investments impact the structure of employment and that they spur structural transformation at the local level. That is, better access to road and electricity networks increases employment in skilled occupations, and decreases employment in unskilled occupations, especially self-employment in agriculture. Roads and electricity again play complementary roles. Together, they raise the probability of being employed with a skilled job and decrease the probability of having an unskilled job.

Taking advantage of the fine granularity of the available data, we analyze the heterogeneous effects of infrastructure investments between more-developed and less-developed countries, between rural and urban areas, and across gender and age groups. We find that expanding access to roads and electricity, both separately and jointly, has a greater positive impact on employment in more-developed African countries than in countries that are less developed. Our comparison of rural and urban locations shows that greater proximity to a main road has a greater effect on rural households, increasing skilled employment and reducing unskilled employment. We find that the employment gains due to infrastructure investment accrue to a greater degree for women than for men (DHS sample). Our results also suggest that younger adults and those in middle age benefit more from infrastructure investments.

By 2035 Africa's working age population is expected to grow by 450 million people, an increase of close to 70 percent. Forecasts indicate that the number of people of working age will grow faster than the number of jobs available for them (World Economic Forum, World Bank, and African Development Bank, 2017). Thus, job creation is a pressing priority for African countries. Our findings suggest that investments in roads and electricity are mutually beneficial drivers of employment and structural transformation in Africa. However, the benefits of infrastructure investment could differ significantly across countries, between rural and urban areas, and across gender and age groups.

This paper adds to a growing body of research examining the impact of various sorts of infrastructure investments on development outcomes. Recent studies have shown that highways and railroads can have substantial impacts on the allocation of economic activity, land use, local economic specialization, and migration (Fajgelbaum and Redding, 2014; Cosar and Fajgelbaum, 2016; Dave Donaldson, 2016; Blankespoor et al., 2017; Berg et al., 2018; Donaldson, 2018; Morten and Oliveira, 2018; Fajgelbaum and Schaal, 2020; Jedwab and Storeygard, 2021). We use the same road panel as used by Berg et al. (2018) and Jedwab and Storeygard (2021). Berg et al. (2018) find a modest impact of improved market accessibility on local cropland expansion, but suggestive evidence of a positive association between improved market accessibility and local GDP growth which could reflect the stimulation of non-agricultural activities. Jedwab and Storeygard (2021) estimates show a positive 30-year elasticity of city population with respect to market access. These are average effects. The importance of heterogeneous effects have been examined by recent papers, examined in the survey of the literature by Berg et al. (2017), but most papers have looked at the spatial heterogeneous impacts. They find that transportation infrastructure increases the access of rural regions to cities, with the agglomeration effects of cities potentially causing productive capital and skilled labor to move from rural regions. Faber (2014) finds that NTHS highway connections in China have led to a reduction in local GDP growth and industrial output among peripheral counties on the way between targeted metropolitan centers relative to non-connected peripheral counties. A few papers have looked at the heterogeneous impacts across industries. Using historical U.S. data, Chandra and Thompson (2000) find that connections to highways have heterogeneous effects across industries. Ghani et al. (2016) find different impacts from the upgrades to India's Golden Quadrilateral highway network on the organization and efficiency of manufacturing activity across districts, depending on their distance to the Golden Quadrilateral roads. Our paper contributes to this literature by looking at the heterogeneous impacts of roads on outcomes at the household level.

There is a lack of consensus on the benefits of electrification. While many studies find substantial benefits from electrification on income, labor supply and education outcomes (Dinkelman, 2011; Van de Walle et al., 2017; Zhang, 2018), others suggest that these benefits may be overstated (Burlig and Preonas, 2016; Aklin et al., 2017). However, a recent paper by Fried and Lagakos (2020) quantifies the long-run, general equilibrium effects of eliminating power outages on firm and aggregate productivity in Nigeria, for which they find much larger estimates than previously estimated in the literature. In line with this paper, our work analyzes the impacts of better access to the national grid for multiple African countries.

In this paper, we investigate how the impacts of infrastructure change when considered in isolation or, instead, when bundled together. Moneke (2020) is one of the few studies to have considered interactions of infrastructure investments. Using data from Ethiopia, he shows that the combination of market access provided by roads and the positive productivity effect of electrification on non-agricultural production is key for the achievement of large effects of infrastructure on economic development. Our paper complements Moneke (2020) by expanding the geographic analysis to 27 countries, and by considering the outcomes at household rather than district level. To the best of our knowledge, our paper is the first to study the impact of roads and electricity and their interaction at the continental level in Africa, and to document significant heterogeneities. We find that the effects of isolated and bundled infrastructure differ significantly - between lagging and more advanced regions, across gender, and among various age groups. We complement the findings from the literature that lagging and leading regions benefit differently by documenting and comparing these impacts when investments are bundled and when they are isolated. For instance, Mu and van de Walle (2011) find that, in Vietnam, benefits from rural road improvements are greater in poor communities, where levels of initial market development are lower. Moreover, we find that improved infrastructure in rural areas induces a shift away from agricultural and other low-skilled jobs into more skilled occupations; and, by contrast, that improved infrastructure in urban areas promotes all types of employment. These differential effects suggest that the structural transformation brought about by road and electricity expansions is primarily a rural phenomenon. These findings are new.

The remainder of this paper is organized as follows: Section 2 describes a simple conceptual framework of infrastructure and job creation, and findings from the related literature. Section 3 presents data sources. Section 4 discusses identification strategies. Sections 5 and 6 present findings on the average and heterogeneous effects of employment outcomes from infrastructure investment, with a special focus on the contrasts between the effects on urban and rural economies. Section 7 concludes.

2 Conceptual framework

Investment in infrastructure could influence employment outcomes through a range of different channels and effects. First, infrastructure programs can lead to direct employment on site for construction, maintenance, and operation. Second, large investments in infrastructure could stimulate short-term growth and indirectly contribute to jobs creation in related industries (Romer and Bernstein, 2009). Third, and perhaps most importantly, infrastructure could induce employment expansion and enhance the quality of employment by boosting productivity, improving competitiveness, and enhancing market access for both households and firms. Jobs created under this category tend to be longer term and broad based. The rest of this section lists the main economic channels through which access to roads and electricity affects long-term employment, the interactions between both types of investments, and their heterogeneous impacts across population groups and locations. While not exhaustive, this discussion seeks to address the main economic channels of interest to set the stage for interpretation of the results of our empirical analysis.

2.1 Different economic channels

Infrastructure and human capital accumulation

Employment is a function of labor supply and demand. Infrastructure affects the quantity and quality of the labor supply through its impact on households' behavior, skills development, and access to the job market. For example, rural electrification increases the productivity of home-production activities, and releases females' time from home- to market-based work (Dinkelman, 2011). Rural electrification is also linked to better health and education outcomes, raising the quality of the labor supply and boosting the employability of workers; see Samad and Zhang (2016) and Samad and Zhang (2018). Better roads are expected to improve households' employment outcomes by reducing the duration of transportation to jobs, by allowing workers to access more potential offers, and by improving the potential to match workers' skills and available jobs.

Infrastructure and market access

Investments in new transport infrastructure may reduce the cost of transportation (Martincus et al., 2017) and improve market access in both rural and urban areas (Hjort and Poulsen, 2019; Aggarwal et al., 2018; Baum-Snow et al., 2016). Many rural locations in poorer countries lack all-weather roads that connect villages to one another, and/or connect villages to market centers in towns and cities. Isolated villages operate in an environment of near autarky, with product markets too thin for farmers to rely on them to diversify production. Farmers adopt subsistence farming, and produce most of what they need for consumption, instead of specializing in few crops, and buying the rest from outside (Kebede, 2020). From a similar reasoning at the national scale, Tombe and Zhu (2019) show that the construction of new highways in China increased domestic market integration and had large impacts on population and local GDP.

Infrastructure and productivity

Infrastructure could also increase the number and quality of jobs by raising the productivity and competitiveness of businesses and firms. For example, an increase in the adoption and quality of electricity can improve firms' productivity - in turn increasing their net output and demand for labor (Grainger and Zhang, 2019; Hjort and Poulsen, 2019). Investments in roads between rural villages and urban markets can reduce the price for inputs to agricultural production, and incentivize adoption of better technologies that can increase productivity. From work undertaken in rural, northern Tanzania, Aggarwal et al. (2018) estimate that halving travel costs - the approximate effect of paving rural roads - would double adoption of agriculture-improving technologies, and reduce the adoption-remoteness spatial gradient.

However, the effects might be more complicated when considering labor mobility at both rural and urban levels. For example, Asher and Novosad (2018) show that a major road construction program in rural India, rather than facilitating growth of non -farm firms in treated villages, enabled workers to access external labor markets, and supported labor reallocation to (non-farm) wage labor. Moreover, average effects of infrastructure investments have been found to be positive in some cases and negative in others.

Reduced-form estimates of the impacts of new highways in China by Baum-Snow et al. (2016) indicate that the expansions of regional highway networks had negative average effects on local populations and no significant effects on local GDP. A recent strand of the literature has shown that average impacts can be misleading with some groups or regions benefiting more than others, suggesting that economic impacts can differ significantly across locations and groups (Baum-Snow et al., 2016; Lall and Lebrand, 2020).

2.2 The heterogeneous impacts of infrastructure investments

Heterogeneities across gender and age groups

The impacts of infrastructure provision may differ across genders. Electrification has been shown to disproportionally benefit women and girls. In households with electricity, women spend less time on household chores, and they are more likely to participate in income-generating activities; girls have higher educational attainment (see Samad and Zhang (2017) and Samad and Zhang (2018)). On the other hand, gender-based constraints and preferences could limit opportunities and benefits to women from investment in infrastructure. For example, women may play a smaller part in labor-intensive forms of infrastructure construction (which is often linked to employment creation) than their male counterparts. Similarly, the impacts on employment differ across age groups. When investments in infrastructure boost new economic activities at the expense of old activities, older workers are more likely to lose their jobs. Changing sectors may be more difficult for older workers than those in their prime. The employment effects of investment in infrastructure could also differ according to workers' characteristics, such as skill level. Lowering transportation costs and expanding the supply of electricity may speed the structural change of economies, with jobs moving from low-productivity agricultural sectors to manufacturing or service sectors. The relative demand for skilled manufacturing workers may therefore increase, while the relative demand for unskilled workers in the agriculture sector may decrease.

Heterogeneities across locations

Economic impacts of infrastructure investments vary across locations. Investing in rural areas, in nationwide projects, or in urban projects will activate different channels to generate jobs. Rural roads can trigger structural transformation, with workers moving away from subsistence agriculture to services. National roads may support jobs in manufacturing and export-led industries. The potential of roads to match skills and jobs might differ, with different ramifications for isolated areas, the periphery of cities, and urban contexts. For example, improving access to jobs and enhancing skill matching in cities allow the density of population to create positive spillovers from agglomeration large enough to surpass the negative spillovers from congestion. Similarly, the gains from investing in modern energy will differ for firms in large cities, and for small businesses in villages and rural areas. While the type of investments matter, its location will also affect the types of impacts one can expect to occur. The impacts of road construction have been shown to be heterogeneous across locations. Baum-Snow et al. (2016) provide reduced-form estimates of the impacts of new highways in China. While the average impact is negative, they show that it results from a large heterogeneity in the effects of highways on prefectures. Regional highways promote concentration of both output and population into regional prefectures, at the expense of other prefectures. Since there are more small prefectures than large, the average is negative.

2.3 The complementarities between road investments and electrification

Investments in roads or electrifications alone may have limited or even adverse impacts in some contexts, for some locations, and for some groups. On the one hand, electricity can stimulate local production. However, the lack of reliable transport infrastructure will reduce the potential gains, especially in more isolated areas. Electrification alone mostly increases productivity in remote locations that have high transport costs and tend to remain shielded from import competition (Behrens et al., 2006). While some positive effects driven by local demand are predicted from, say, greater access to electricity, these electrified locations may miss out on other regions' increased import demand for their newly electrified goods simply because they lack the transportation connection.

On the other hand, connecting isolated locations may increase import competition and have adverse impacts on local economic activities and jobs. Using the insight from a spatial quantitative model, Moneke (2020) shows that in partial equilibrium, as previously autarkic regions gain access to markets, the pre-existing employment in the manufacturing sector suddenly competes with manufacturing-sector varieties from larger, more productive agglomerations. Unless the initial manufacturing-sector productivity is high, the sectoral-employment share of the manufacturing sector in the location newly connected by roads would be expected to fall. However, as productivity in previously isolated locations improves in the wake of new road connections, the roll-out of electrification can lead some manufacturing sectors to become profitable for exports, and to such a degree that the manufacturing employment share may actually rise. In the context of Ethiopia, reduced-form analysis by Moneke (2020) shows that road access alone causes manufacturing employment to drop largely in skilled activities, and, by contrast, causes service employment to increase, largely in informal, small-scale retail jobs.

The enabling effects of investment in infrastructure on job creation may depend on the interactions of investments. Whether "big push," combined investments deliver higher benefits than isolated investments of only roads or only electrification remains an open empirical question. One of the few attempts to examine the issue is the work in Ethiopia by Moneke (2020), who finds that only the interactions of infrastructure investments - not isolated investments - gave rise to large effects on economic development.

Thus, this paper aims to complement existing empirical studies and to fill a research gap, by looking at both the average and heterogeneous impacts of investment in infrastructure, and by examining the complementarity effects between two types of investments, roads and electricity.

3 Data

To analyze the effects of infrastructure on employment in sub-Saharan Africa, we use two geo-referenced, household surveys: the Living Standards Measurement Study (LSMS) surveys conducted between 2005 and 2019, and the Demographic and Health Surveys (DHS) conducted between 2000 and 2018. Both surveys are merged with spatial information on roads and electricity grids.

3.1 Living Standards Measurement Study (LSMS)

LSMS surveys are conducted by the World Bank in association with country statistical offices. We use 26 LSMS surveys from 7 sub-Saharan African countries: Ethiopia, Côte d'Ivoire, Malawi, Mali, Niger, Tanzania, and Uganda. All the surveys and their corresponding years are listed in Table 9. The collection of information and follow-up across subsequent surveys vary across countries. In our sample, 54 percent of respondents are women, and 86 percent of respondents reside in rural areas. Roughly 55 percent of individuals who responded to the survey were working at that time. Among these individuals, around 44 percent were working in the agricultural sector. Over 50 percent of individuals have at least a secondary level education.[1] The average age of a respondent is 36. Around 78 percent of sampled individuals are between 20 and 45; around 22 percent of individuals are between 46 and 66.

We primarily use data on respondents' occupation. Following Hjort and Poulsen (2019), we categorize employed individuals as being either high-skilled or low-skilled workers. Also, given the importance of agriculture in African economies, agricultural employment is distinguished from other types of employment in part of the analysis. Respondents were classified as low-skilled workers if they worked in any of the following occupation types: farming, fishing, domestic employment. At the time of the survey, 55 percent of the sample reported being employed. Among employed individuals, 26 percent are classified as high-skilled workers, and 74 percent are classified as low-skilled workers. Farmers represented 42 percent of workers.

Using the geo-referenced information (latitude and longitude) associated with these surveys, we combine them with the roads and electricity datasets. An average household is located 14.6 km away from a main road and 7.9 km away from an electric grid.

3.2 Demographic and Health Surveys (DHS)

Demographic and Health Surveys are repeated, cross-section surveys that have been conducted in most developing and middle-income countries since the mid-1980s. These surveys are representative at the national and subnational levels. Information on demographic and socioeconomic status (e.g., age, education, occupation) is collected for all household members. In addition, selected women and men provide information on a wide range of other variables, including matters concerning health status, fertility history, migration, and children. The DHS Program routinely collects geo-reference data (longitude and latitude) in selected surveyed countries, making it possible to combine these surveys with a wide range of external data and information. DHS have been used in recent studies to analyze 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).

We use data from 73 surveys that cover 29 countries in sub-Saharan Africa. The combined sample includes 900,229 women and 405,142 men.[2] We look at the DHS data in 20km-by-20km grill-cell panels. Table 2 summarizes the characteristics of the individuals in the sample.

We categorize employed individuals as being either high-skilled or low-skilled workers. We also distin-

[1] Details are displayed in Table 2.
[2] The number of observations is greater for women than for men because women are oversampled in the DHS.

guish agricultural workers in parts of our analysis. Employed individuals are considered to be high-skilled workers if at the time of the survey they worked in any of the following occupation types: professional, clerical, skilled manual labor, sales, services, or agriculture (employee). Individuals were considered to be low-skilled workers if they worked in any of the following occupation types: domestic, unskilled manual labor, or agriculture (self-employed). Among the respondents in our data, 69.03 percent reported being employed, and 30.97 percent reported that they were not employed. Among skilled workers who in our data, the occupations were in the following categories: sales (38 percent); manual labor (18 percent) agricultural employee (16 percent); service-sector (12 percent); professional, technical or managerial occupations (12 percent); clerical occupations (2 percent). Among unskilled workers, 80 percent reported being self-employed in agriculture, and the remaining 20 percent were in either in domestic work or as unskilled manual laborers. Among respondents, 63 percent resided in rural areas, and 39 percent resided in urban areas. The ages of survey respondents were as follows: 25 or younger (39 percent), 25 to 50 (57 percent), over 50 (0.2 percent).

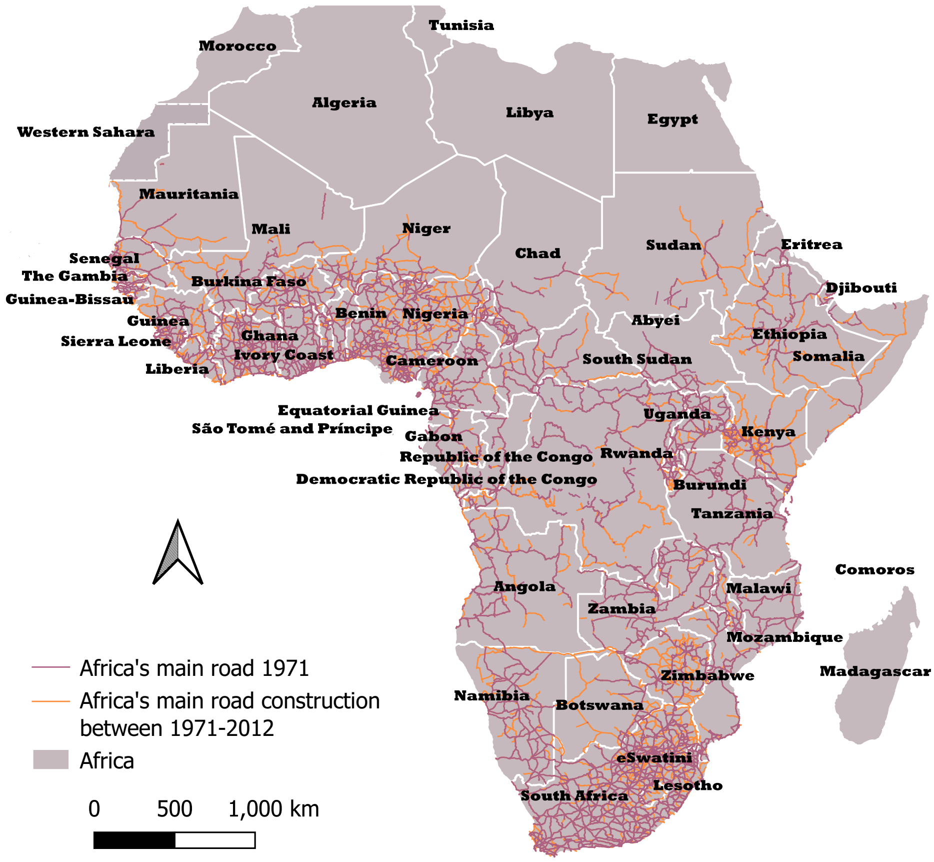
To look at the differential effects of investment in infrastructure across countries at different stages of development, we group the survey data into two categories of development. Using PPP-adjusted GDP per capita, we classify countries as less developed or more developed. A country is less developed if its PPP-adjusted GDP per capita falls below 2017 USD 3,400. In the LSMS, 97.37 percent are categorized as less developed. In the DHS, 64 percent of the countries are categorized as less developed.

3.3 Roads

We combine geo-referenced household survey data with spatial data on road expansions as used by Berg et al. (2018) and Jedwab and Storeygard (2021).[3] The development of road infrastructure is tracked over 40 years from 1971 to 2014. Data on both the layout and road type are included, relying on layouts from Nelson and Deichmann (2004) and completed with information extracted from Michelin maps. The road-layout information used by Nelson and Deichmann (2004) was primarily constructed using information from the U.S. Digital Chart of the World database, originally constructed by the U.S. Defense Mapping Agency. Road surface information was obtained using 64 Michelin road maps for the northeast, northwest, and central-south regions of mainland sub-Saharan Africa. Roads are divided into the following categories: earth/dirt, paved, improved, or highway. We combine the last three of these categories into one ”main road” category. Michelin also collects statistics on road development projects, and its maps are meant to specify the year during which a specific road was made operational. However, Michelin maps for some states and time periods do not exist. Overall, the road network in Africa has steadily expanded from 239,018 km in 1971 to 334,391 km in 2014. Figure 1 depicts the evolution of main roads from 1971 to 2012. We combine the road network information with the geo-referenced households from the DHS. Overall, the mean distance of households from the main roads is 66 km in the DHS and 14.6 km in LSMS surveys.

[3]The roads digitization effort of Jedwab and Storeygard (2021) benefited from funding under the DFID/World Bank's Strategic Research Program on Transport Policies for Sustainable and Inclusive Growth.

Figure 1: Change in Sub-Saharan Africa's Main Roads between 1971-2012



3.4 Electricity

Information on the expansion of the electricity grids is obtained from World Bank/Energy Sector Management Assistance Program (ESMAP) data sources. Arderne et al. (2020) present the first composite map of the global power grid using publicly available open data. The map was generated using data obtained through Gridfinder and OpenStreetMap data. Gridfinder is an open-source tool used for predicting the location of electricity network lines using satellite imagery of nighttime light use. Combined with OpenSreetMap data, multiple filtering algorithms are applied to nighttime light imagery to identify locations most likely to produce light from electricity. These light sources (target-locations) are then connected to known electricity networks through a least-cost routing algorithm following roads and known distribution lines (adopted from OpenStreetMap). This results in connected networks at two voltage levels: high voltage and medium voltage. The data we use are for the year 2010. Time variation in connectivity to electricity within a country therefore stems from the use of multiple rounds of surveys for each country and survey samples that vary across years. Hjort and Poulsen (2019) follow a similar design. The OpenStreetMap data show that 97 percent of the global population lives within 10 km of electricity lines. Globally, an estimated 2 percent of the population does not live within 10 km of electricity lines; the vast majority of them live in sub-Saharan Africa. In our data set, the mean distance of households to the closest electricity grid is 32 km; the maximum is 80 km.

Figures 2 and 3 show how employment relates to proximity to a main road and proximity to an electricity grid. To generate these figures, we compute the probability of employment for each given distance to an infrastructure point, where distance is measured in bins of 10 km. We then fit the prediction of employment on distance. We find that as the distance to a main road increases, the proportion of active population decreases. This is true for both LSMS and DHS samples. In the LSMS sample, for example, those living within 10 km of a main road were 2.4 times more likely to be in work than those living within 90 to 100 km of a main road. A similar pattern is observed in the DHS sample in Figure 3. The patterns are similar with regard to the relationship between employment and distance to an electricity grid. We also note that the proximity to roads and electricity positively affects the probability of working in a high-skilled occupation and negatively affects the probability of working in a low-skilled occupation.

Figure 2: Employment Pattern and Proximity to Infrastructure (based on LSMS)

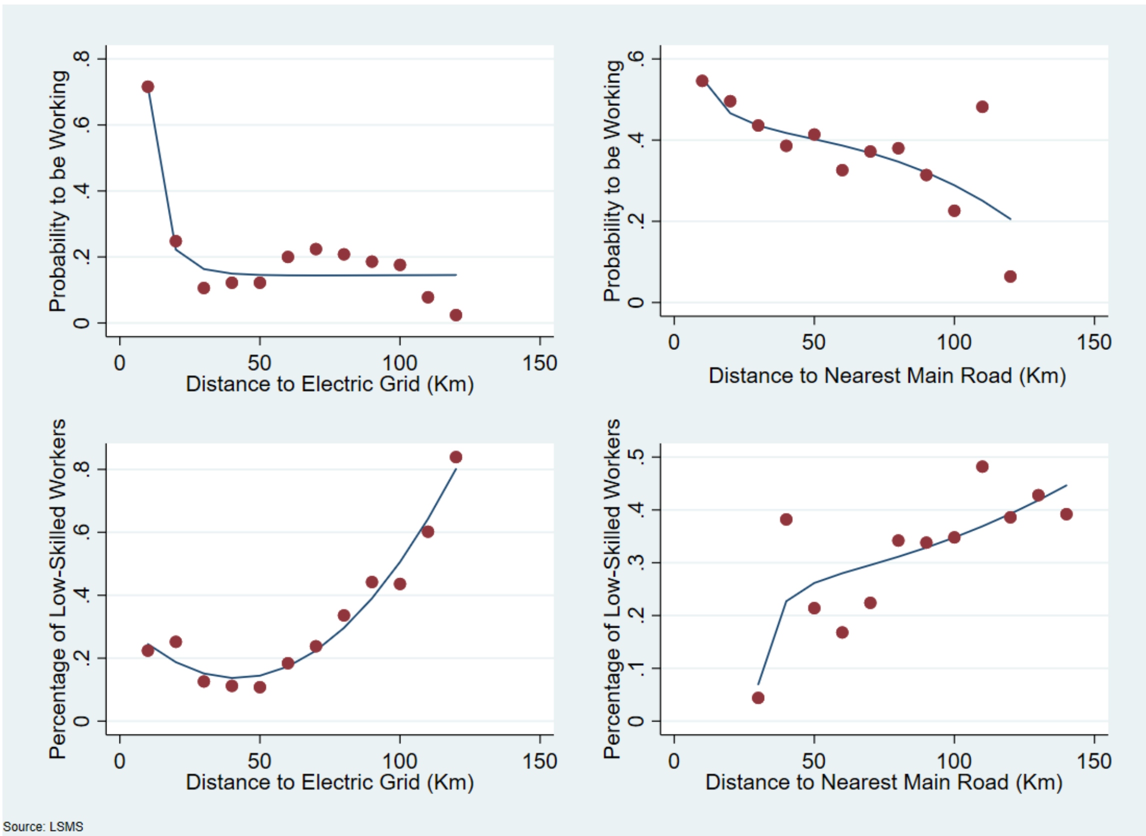
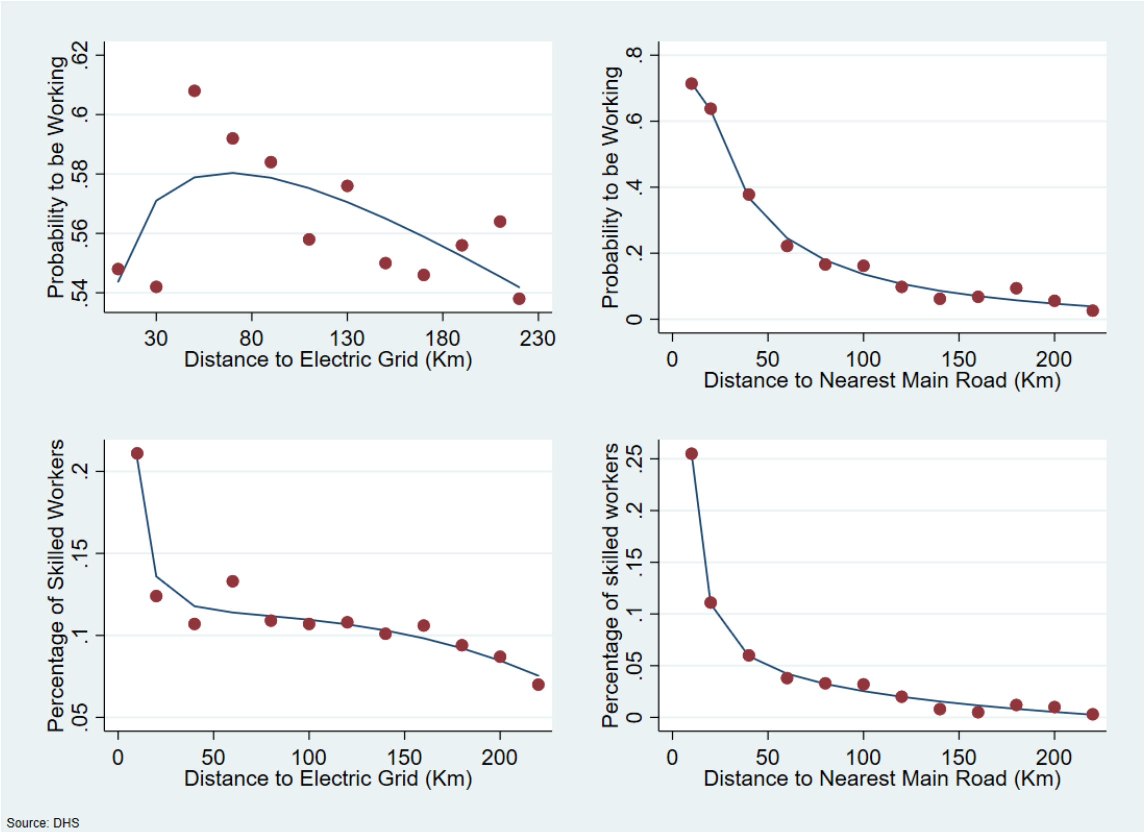


Figure 3: Employment Pattern and Proximity to Infrastructure (based on DHS)



4 Identification strategies

We use two main identification strategies to analyze the causal effects of access to main roads, access to electricity, and the interaction of the two on job creation in sub-Saharan Africa. The first and baseline strategy is ordinary least squares (OLS) with individual-level controls and, country and year fixed effects. The second strategy develops an instrumental variables approach.

Dependent variables. We analyze five main dependent variables. The first measures whether an individual (in a specific location and time period) is employed. The second accounts for the number of hours worked during the last seven days. The third variable measures whether an employed individual is a farmer. The fourth variable measures whether a worker is unskilled, and the fifth one focuses on higher-skilled employment categories. We follow Hjort and Poulsen (2019) to create an intermediate employment category between being high-skilled and unskilled.

Independent variables. We analyze the effects of three main independent variables - proximity to a main road, proximity of an electricity grid and the interaction of the two - on the dependent variables. Proximity to a given infrastructure is measured by taking the negative value of the distance between the centroid of an individual's cluster and the closest location of the corresponding infrastructure.

4.1 Baseline strategy: OLS with fixed effects

For our baseline strategy, we estimate the following equation using OLS:

$$Emp_{ict} = \alpha_0 + \alpha_1 Road_{ict} + \alpha_2 Elect_{ict} + \beta(Road_{ict} \times Elect_{ict}) + X'_{ict}\delta + \mu_c + \theta_t + \epsilon_{ict} \quad (1)$$

Where Emp_{ijct} is the outcome variable, measuring whether individual i in country c and at time t is employed. In regressions using skilled/unskilled worker as the dependent variable, Emp_{ict} measures whether individual i in country c and time t is a skilled or unskilled worker. $Road_{ict}$ measures proximity of individual i in country c at time t to the road networks, and $Elect_{ict}$ measures proximity of individual i in country c at time t to the electricity grids. $Road_{ict} \times Elect_{ict}$ measures the interaction between proximity to road and proximity to electricity grid. [4]

In our main specification, the parameters α_1 measure the marginal effect on employment of moving 1 km closer to the road networks in locations within zero km to an electricity grid, and α_2 measure the marginal effect on employment of moving 1 km closer to the electricity grids in locations within zero km to a main road.[5] The parameter β measures the incremental effect of moving closer to both the road networks and the electricity grids. If all these parameters are positive, then roads and electricity are complements in the process of job creation. If on the contrary, β is negative while both α_1 and α_2 are positive, then the two types of infrastructure are substitutes. Being complements (substitutes) means that one type of infrastructure is more (less) useful when the other type is supplied.

Our identification strategy exploits both spatial and temporal variation in the expansion of the road networks, and mostly spatial variation in the expansion of the electricity grids.[6] The term μ_c captures country fixed effects; and θ_t captures survey year fixed effects. Controlling for year fixed effects accounts for all the time-variant factors common to all grid cells, and that may affect infrastructure and job creation. X'_{ict} is a vector of individual-level controls including age, gender, residence in a urban or rural location, education, and average temperature computed at the grid cell level. The identifying assumption is that the error term, ϵ_{ict}, is uncorrelated with each of the variables measuring proximity to infrastructure given all the aforementioned controls.

4.2 Instrumental variables approach

For our second identification strategy, we use an instrumental variables approach. In fact, inferring causation from the OLS regression requires that proximity to the road networks and the electricity grid be uncorrelated with the error term of equation (1) given individuals' characteristics, and the country

[4] Electricity grids are often located along main roads, which can make the identification of having access to the grid alone difficult (Moneke, 2020). In this paper, we keep all three variables, proximity to road, proximity to electricity grid and their interaction term of the following reasons. First, we consider the distance to the closest road, which might be different from the distance to the road along which the closest electricity grid point can be found. This analysis differs from Moneke (2020) which uses binary access variables and finds that all districts with access to the electric grid have a main road, which makes the identification of access to the grid alone impossible. Second, the correlations between our three variables are positive but not very high. For example, the correlation between proximity to road and proximity to electricity grid is 0.38 in the LSMS sample and 0.34 in the DHS sample.

[5] This interpretation stems from the fact that each variable that measures proximity to a given infrastructure takes only "negative" values, with greater values implying greater access; the highest access is therefore achieved when the value of the variable is zero.

[6] We follow a research design similar to that of Hjort and Poulsen (2019), in which temporal variation in connectivity to the electricity grid comes from the fact that survey samples vary across years in the DHS and the LSMS for each country.

and year fixed effects. This would indeed be the case if within each country in a given year, roads and electricity grids were randomly assigned. However, owing to their high costs, road construction and electrification are likely to be determined by the location of mineral resources, local labor market conditions, and trade demand. In the African context, the placement of such infrastructure might be also determined by colonial history and other political factors (Okoye et al., 2019). It is therefore reasonable to assume that locations that receive these infrastructure investments have specific characteristics that determine employment and occupational sectors. To the extent that these local characteristics are time invariant, our baseline strategy, which controls for country fixed effects, accounts for them. However, if some of these characteristics change over time, then this can lead to an endogeneity problem that is unlikely to be completely solved by controlling country and year fixed effects. To account for this possibility, we instrument for proximity to roads using a new instrumental variable, and instrument for proximity to electric grids using existing instrumental variables.[7]

4.2.1 Instrumental variable for proximity to road

We generate a new instrumental variable for proximity to the road networks based on the rationale that post-independence African leaders promoted the construction of transportation infrastructure to allow them to govern the entirety of their respective territories from the capital city - the center of political institutions - and to bolster national integration. Starting from the colonial era, the construction of transportation infrastructure, consisting mainly of roads and railways, has primarily been motivated by economic, social, and administrative (political or military) reasons in Africa (Taaffe et al. (1963), Okoye et al. (2019), and several references therein). Colonial powers developed transportation infrastructure to move agricultural products and mineral resources from the interior of countries to ports of exports (Okoye et al., 2019). In each country, such infrastructure also served an administrative purpose; better roads and railroads made it possible for colonial officials to travel to most parts of the country. Though the same reasons motivated the construction of transportation networks in the post-independence period, country leaders followed a different strategy in expanding these networks. They instead built transportation networks in a way that would allow them to extend the exercise of their authority from the ”political center” of the country to their entire territory (Herbst, 2014), including remote areas and all ethnic homelands (Muller-Crepon et al., 2020). Indeed, the arbitrary partition of Africa by European leaders at the Berlin Conference in 1884 and 1885 endowed the countries that emerged from this experiment with different levels of ethnic heterogeneity. In most of these countries, independence leaders faced the daunting task of governing a multitude of disparate ethnic groups, and of unifying and integrating them (Deng, 1997). These leaders used a number of different strategies to promote nation building and national unity. These strategies included promoting the use of one national language, outlawing political parties organized around ethnic groups, and distributing ministerial posts and other official positions among different ethnic groups to foster national pride (Deng, 1997). Interestingly, building infrastructure such as roads was also a strategy for national integration used in all African countries.[8]

[7]Importantly, in results not shown here but available upon request, we control for grid cell fixed effects, which controls for all time-invariant characteristics at the grid cell level; the findings we present in this paper are robust to the inclusion of these controls.

[8]Building infrastructure as a means to integrate different ethnic groups is not a phenomenon unique to African countries. In their study on the relationship between ethnicity and economic development in China, (Han and Paik, 2017) argue, “The

Herbst (2014) argues that the difficulty African political leaders faced in governing countries divided into multiple ethnic groups, coupled with the dissociation of ownership and control of land, motivated them to develop infrastructure that would extend their authority as far as possible, see also Herbst (2000). The poor or absent state of road networks in most countries in sub-Saharan-Africa leaves a majority of rural people cut off from the centers of political power. Herbst (2000) argues that African governments have been building roads that connect political centers to previously inaccessible areas to expand their power.

Work by Muller-Crepon et al. (2020) relies on a theory according to which the accessibility of ethnic homelands by public authorities is a prerequisite for political leaders to extend their domination over remote areas (Tollefsen and Buhaug, 2015; Raleigh and Hegre, 2009; Buhaug and Rod, 2006; Herbst, 2000; Fearon and Laitin, 2003). Indeed Muller-Crepon et al. (2020) argue that political instability is predominant in areas where political power has very little control over the inhabitants; more specifically, they establish that the ethnic groups' homelands that are difficult to reach from the national capital are also sites of rebellion and political conflicts. The authors use the map of road networks in African countries to measure access to ethnic homelands from national capitals, and the interconnectivity of ethnic groups. Estimating the effects of these two variables on the occurrence of political conflicts, they show that political conflicts reoccur in areas where there is a weak physical presence of the state. To demonstrate the robustness of this finding, they construct a theoretical network composed of hypothetical road segments that ensure the lowest travel time between the busiest ethnic groups; using these hypothetical networks, they construct instrumental variables estimating what the accessibility of ethnic homelands from political centers as well as the inter-connectivity of ethnic groups would be if these networks existed. .

Their results are robust to the use of these instruments, thus confirming the twofold role of road networks in extending the control of political powers and reducing political instability; political authority and stability are reinforced in ethnic groups that are accessible from the political capital.

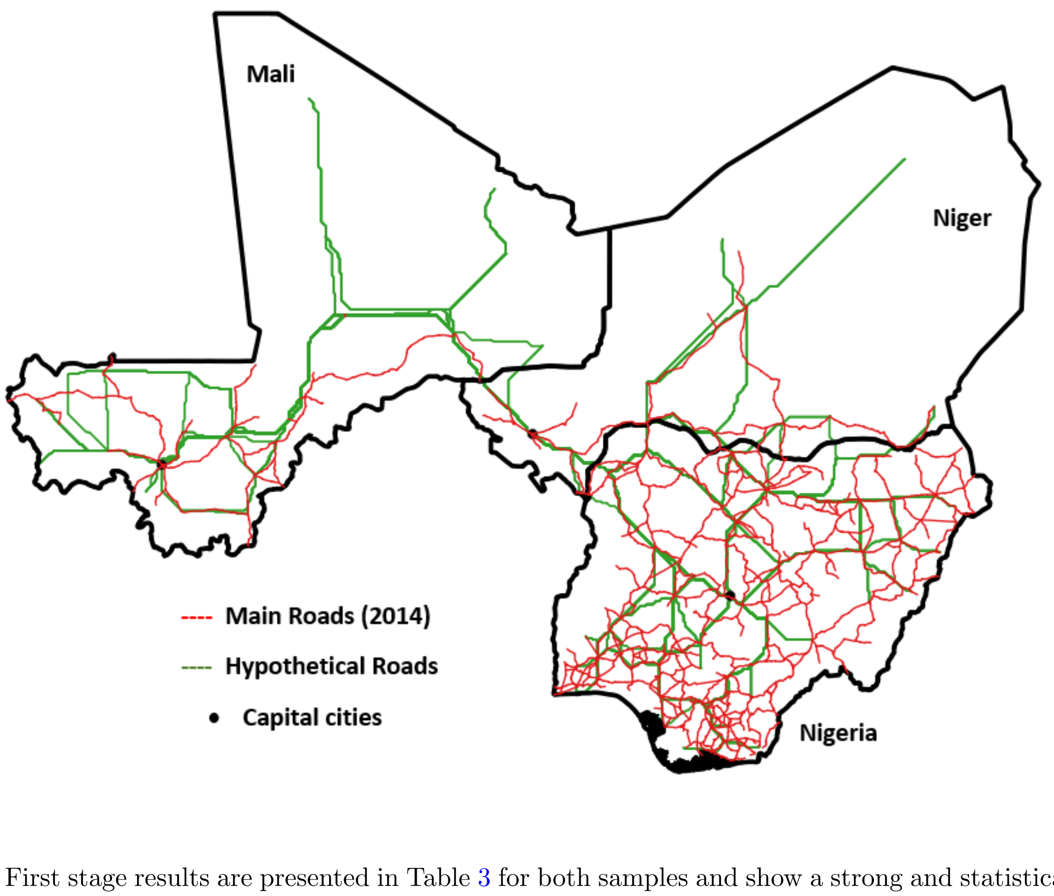
We rely on this literature, which highlights the motivation of political leaders to build roads to extend their capacity to govern, to construct our instrumental variable for proximity to the road networks. In so doing, we follow a large literature that shows that non-economic factors play determining roles in the propensity of African governments to invest in the construction of public infrastructure (Bonfatti et al., 2019; Jedwab and Storeygard, 2021; Burgess et al., 2015; Herbst, 2014). In constructing our instrumental variable, we assume that African leaders would built roads to facilitate territorial administration by easing the movement of administration officials and military troops from the capital power center to the rest of the country, and from one location to another (Herbst, 2014; Muller-Crepon et al., 2020). Following these assumptions, we use the map of African ethnolinguistic divisions produced by the American anthropologist George Peter Murdoch in 1959 (Murdock, 1959) to identify the ethnic homelands of each country in our sample. These ethnic homelands are regarded as being exogenous. Using the least-cost path algorithm, we "construct" hypothetical roads that would link the centroids of different ethnic homelands to each country's capital city. We proceed under the assumption that the social planner's goal would be to minimize the construction costs of these roads if they were to be built. We assume that land altitude

state has pursued provisions 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).

is the main geographic determinant of the construction cost. For each country, this hypothetical road network therefore intends to show how such a network would evolve to connect different ethnic homelands with the capital city if only geographic costs of construction were considered and all demand-side factors were ignored.

We use proximity to these hypothetical road networks as an instrument for proximity to the road networks that exist. For this variable to be a valid instrumental variable, the hypothetical road networks should be close enough to the actual networks, and these hypothetical networks should be exogenous with respect to job creation. The two conditions are likely to be satisfied in our analysis. For example, Figure 4 compares the hypothetical road networks to the 2014 actual road networks in a few countries. As this map shows, these two networks are close enough to satisfy this condition. Moreover, the first and fourth columns of Table (3), containing the first-stage diagnosis, clearly show a positive and statistically significant correlation between proximity to a main road and proximity to our hypothetical road (using both the DHS and the LSMS samples).

Figure 4: Networks of hypothetical roads (green) and of the main roads that existed (as of 2014) (red) in three countries in west Africa



First stage results are presented in Table 3 for both samples and show a strong and statistically significant relationship between instrumental variables and endogenous regressors. Cragg-Donald, Sanderson-Windmeijer and classic F-test statistics all indicate non-weak instruments. Given that we have multiple endogeneous regressors, Sanderson and Windmeijer (2016) provide the most relevant weak instrument F-test statistic. Following the authors, we report in Table 3 classical F-test and Cragg-Donald test statistics along the Sanderson-Windmeijer statistic for comparative purposes and robustness. It follows that our first stage is strong.

4.2.2 Instrumental variable for electricity

We exploit terrain topography and lightning intensity to generate two instruments for electricity. The use of geographical instruments such as weather variations, terrain roughness, slope, or land elevation is common in existing empirical work. Indeed, the random nature of these geographical instruments gives them the same properties as those of exogenous variables. For example, previous research has used exogenous changes in rainfall as an instrument for economic growth (Edward Miguel and Sergenti, 2004; Miguel, 2005; Paxson, 1992). Other research has relied on terrain elevation as a proxy for the cost of constructing electric grids (Amorim et al., 2018; Durante, 2009; Dinkelman, 2011; Ostrom, 1990).

To construct the instrument for access to electricity grids, we exploit the fact that lightning is a significant contributor to power disruptions in most sub-Saharan African countries (Alvehag and Soder, 2010; Minnaar et al., 2012), which is strictly exogenous. For example, in South Africa, lightning damage accounts for about 65 percent of all over-voltage damage to electrical distribution networks, and is believed to account for one-third of all outages. More than 50% of power outages on transmission lines in Eswatini are attributed to lightning. In Africa, every year lightning strikes and thunderstorms damage circuits and knock out electric power lines, crippling coverage (Minnaar et al., 2012). The recovery time depends on the extent of damage; in some cases changing the route of electricity lines is necessary. The recovery period is generally long (Karagiannis et al., 2017); maintenance is costly. Hence, frequent lightning strikes in a location negatively affect the electric-energy supply and household access to the electricity by damaging electricity grids. Following Andersen and Pablo (2012); Andersen et al. (2011); Andersen and Dalgaard (2013); Agrawal (2021), we use lightning density as an exogenous determinant of power disturbances and disruption to access to electricity that can affect the individuals' location "proximity" to the electricity grids. Note that while some of these papers have used lightning intensity as an instrument for the penetration of the Internet (Agrawal, 2021), the main argument in those papers is that lightning strikes damage electrical infrastructure useful to the functioning of the Internet.

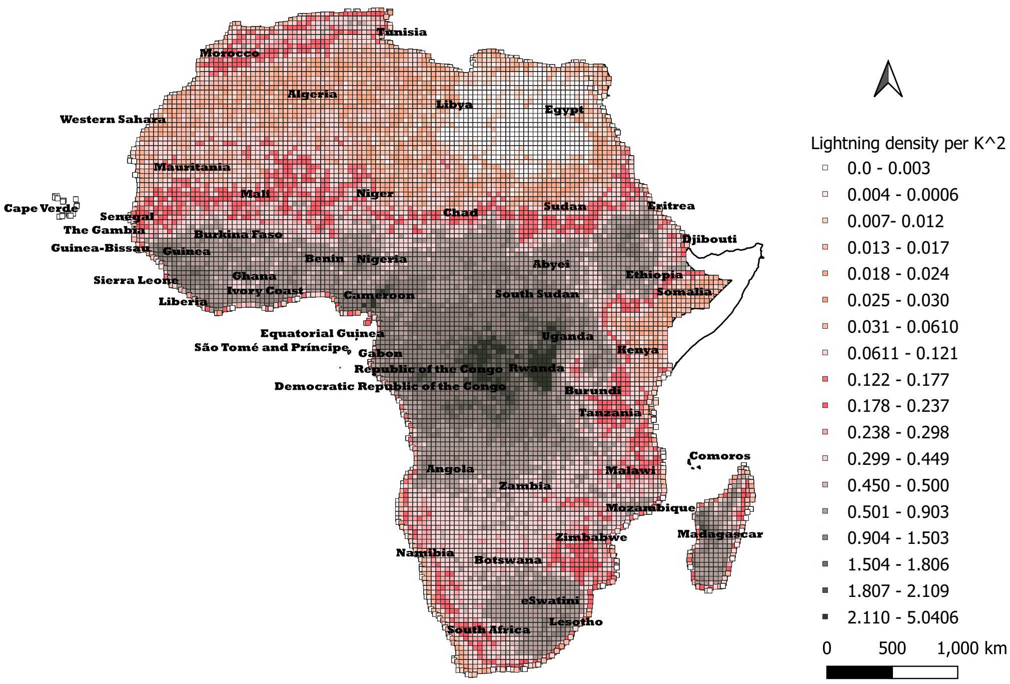
In addition, bearing in mind that topography can be viewed as a geographic obstacle that makes infrastructure construction more expensive (Ostrom, 1990; Durante, 2009; Amorim et al., 2018; Dinkelman, 2011), we add terrain elevation to the exogenous variables that we consider as a determinant of the proximity to electrification grids. Therefore, in our empirical model, the proximity to the electrification grids is partly explained by the topography of the land on which the households are located, and the lightning intensity in that area defined by the mean of lightning strikes per square km each year.

We use satellite data generated by the National Aeronautics and Space Administration (NASA) on lightning strike intensity and aggregated by Manacorda and Tesei (2020); Cecil et al. (2014). They compute average lightning strike intensity between 1995 and 2010 in $0.5° \times 0.5°$ for Africa. In the DHS, we matched the closest location mean lightning density for a specific year with an individual's location. As reported in Manacorda and Tesei (2020), with an average of 17.3 lightning strikes per square km per year, Africa has the highest lightning density on earth. The world average is 2.9 lightning strikes per square km per year. With almost half a million lightning strikes per year in each cell, the Democratic Republic of the Congo has the highest annual number of lightning strikes globally. Importantly, as Figure 5 shows, lightning intensity varies greatly within African countries, implying that this instrument can generate meaningful variation in electricity access. Data on land elevation are provided in the geo-referenced component of the DHS datasets.

Columns 2 and 5 of Table 3 confirm the significant and negative relationships between the proximity to electrification grids on the one hand, and both the elevation of the land and lightning on the other. These negative correlations are found in both the LSMS and DHS samples. In addition, the high values of Cragg-Donald Wald F-statistics and the Windmeijer F-statistics show that our instruments are strong.

Given that proximity to the road networks and the electricity grids are two potentially endogenous variables, their interaction is likely to be endogenous as well. To instrument this interaction term, we use the interaction term between proximity to our hypothetical road networks (the instrumental variable used for proximity to the road networks) and terrain elevation (one of the instrumental variables used for proximity to the electricity grids). Column 3 of Table 3 shows a positive correlation between the instrument and the outcome in both the LSMS and DHS samples. Here the high values of the Wald and Windmeijer statistics also demonstrate the strength of this instruments.

Figure 5: Lightning flash intensity



4.2.3 Instrumental variable estimation strategy

To estimate the causal effects of infrastructure on employment, we use a two-stage least squares (2SLS) model. In the first stage, we regress the three main endogenous regressors (proximity to roads, proximity to electricity, and the interaction of both variables) on our instrumental variables, controlling for a wide range of individual and geographic characteristics and for country and year fixed effects. In the second stage, each of our outcome variables is regressed on the predicted values of the endogenous regressors obtained from the first stage, controlling for all the variables controlled in the first stage. Note that these two stages are executed simultaneously (and not separately). More precisely, we estimate the following equations:

$$Road_{ict} = \alpha_0 + \alpha_1 HypoRoad_{ict} + \alpha_2 FlashDensity_{ict} + \alpha_3 Elevation_{ict} + \alpha_4 Elevation_{ict} \times HypoRoad_{ict} + \mathrm{X}'_{ict}\delta + \mu_c + \theta_t + \epsilon_{ict} \tag{2}$$

$$Elect_{ict} = \beta_0 + \beta_1 HypoRoad_{ict} + \beta_2 FlashDensity_{ict} + \beta_3 Elevation_{ict} + \beta_4 Elevation_{ict} \times HypoRoad_{ict} + \mathrm{X}'_{ict}\pi + \mu_c + \theta_t + \epsilon_{ict} \tag{3}$$

$$Road \times Elect_{ict} = \lambda_0 + \lambda_1 HypoRoad_{ict} + \lambda_2 FlashDensity_{ict} + \lambda_3 Elevation_{ict} + \lambda_4 Elevation_{ict} \times HypoRoad_{ict} + X'_{ict}\kappa + \mu_c + \theta_t + \epsilon_{ict} \tag{4}$$

$$Emp_{ict} = \gamma_0 + \gamma_1 \widehat{Road_{ict}} + \gamma_2 \widehat{Elect_{ict}} + \gamma_3 Road_{ict} \widehat{\times} Elect_{ict} + X'_{ict}\tau + \mu_c + \theta_t + \epsilon_{ict} \tag{5}$$

In equations 2, 3 and 4, $HypoRoad_{ict}$, $FlashDensity_{ict}$, $Elevation_{ict}$, and $Elevation_{ict} \times HypoRoad_{ict}$ are respectively proximity to the hypothetical roads (also measured as the "negative" of the distance between the centroid of an individual's cluster to the closest hypothetical road); the density of lightning strikes in the closest location of individual i for which we have data; terrain elevation; and the interaction term between proximity to the hypothetical roads and terrain elevation for individual i, in country c, in survey year t; X'_{ict} is a vector of individual-level controls including age, gender, urban or rural residence, and education, and average temperature computed at the grid-cell level; μ_c captures country fixed effect; and θ_t captures survey year fixed effects. We do not control for grid-cell fixed effects because there is not a sufficient amount of variation in the instrumental variable for roads within the grid cells. We follow a similar approach used in Moneke (2020) in controlling for local characteristics. Table 3 presents the first-stage regressions. Equation 5 is the second-stage regression.

5 Average treatment effects of roads and electricity

5.1 Employment

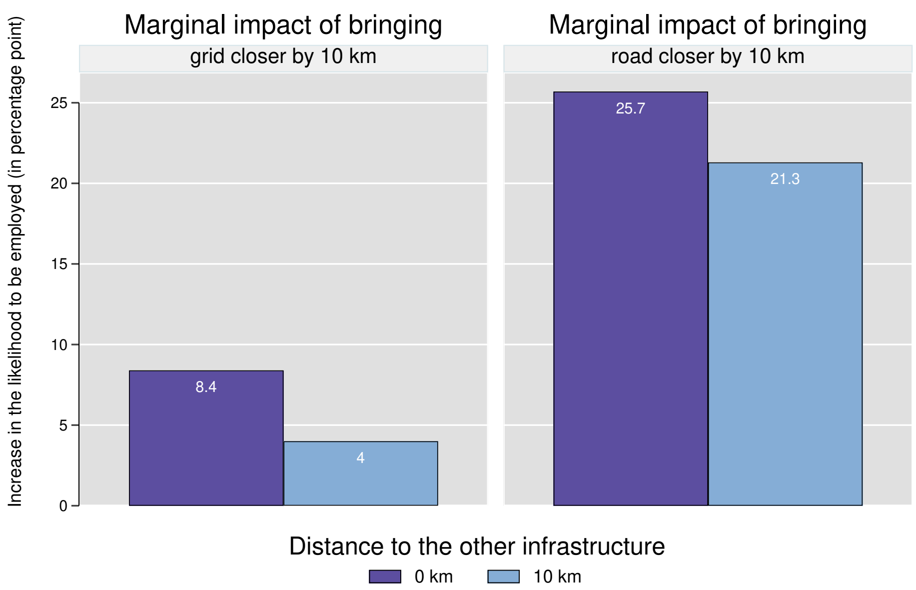
We present the estimates of the "average" treatment effects of proximity to roads and electricity grids and their interaction on employment outcomes in Table 4 in the Appendix. The first two columns display the estimated effects on work status at the survey for the LSMS and DHS samples, respectively. The third column shows estimated effects on the number of hours worked during the last seven days (derived from the LSMS sample only because information on the number of hours worked in not collected in the DHS).

These estimates show positive and highly complementary effects of roads and electricity on employment outcomes. Columns 1 and 2 show that for locations close enough to an electric grid bringing road networks 10 km closer marginally increases the probability of working by 25.7 percentage points in the

DHS sample, and by only 2.5 percentage points in the LSMS sample.[9] Similarly, for locations close enough to the road networks, bringing an electric grid 10 km closer marginally increases the probability of working by 8 percentage points in the DHS sample, and 6 percentage points in the LSMS sample. Differences in estimates obtained from the two samples differ as both surveys cover different sets of countries. Our preferred estimates come from the DHS sample, which covers more countries.

The joint marginal effect of these two types of infrastructure is positive, indicating that roads and electricity play complementary roles in job creation in sub-Saharan Africa. In other words, there are significant employment gains that arise from providing both types of infrastructure simultaneously. The estimates of Table 4 in the Appendix imply that being closer to a main road increases the positive effect of being closer to an electricity grid on the probability of being employed. These effects are statistically significant at the 0.1 percent level. To put these estimates in perspective, using the DHS sample, Figure 6 shows that the impact of increasing proximity to the electric grid grows for households that are closer to the road, and vice versa - the impact of increasing proximity to roads grows for households that have greater proximity to the electric grid. Being 10 km closer to the electric grid increases the probability that an individual is working by more than 8.4 percentage points when the individual's household is located next to a main road, but only by 4 percentage points when located 10 km away from the main road network. Similarly, being 10 km closer to a main road network increases the probability that an individual is working by more than 25 percentage points when that individual's household is located next to the electric grid, but by only 21 percentage points when the household is located 10 km away from the electric grid.

Figure 6: Marginal impact of proximity to roads (left) and electricity (right) on employment

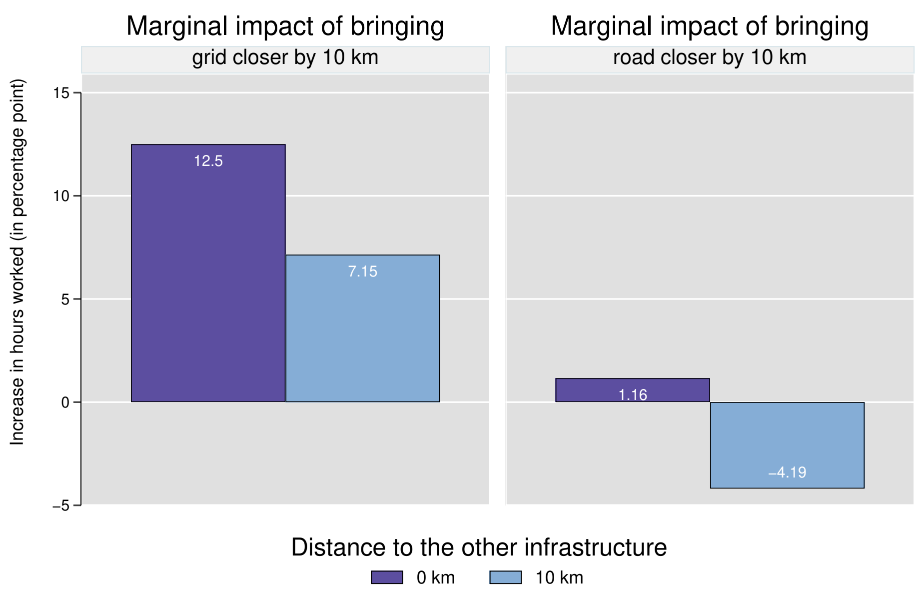


The effects of roads and electricity on the number of hours worked in the last seven days are consistent

[9]Note that the coefficient on the variable "Proximity to nearest road" measures its marginal effect for locations within zero km of the electric grid. Similarly, the coefficient on the variable "Proximity to electric grids" measures its marginal effect for locations within zero km of the road.

with their effects on employment. The estimates presented in Column 3 of Table 4 in the Appendix indicate that in areas close enough to an electric grid, bringing a main road 10 km closer marginally increases the number of hours worked by nearly 1.2 hours a week, but this effect is not statistically significant. Unlike proximity to roads, proximity to the electric grid has a much larger effect. In areas with high access to a main road, bringing the electric grid 10 km closer increases the number of hours worked by 12.5 hours a week. Importantly, it is more beneficial to provide both types of infrastructure simultaneously, as indicated by the positive coefficient on their interaction term. Indeed, bringing a main road 10 km closer increases the positive effect of bringing the electric grid 10 km closer, and by more than five hours of work every week. Using the DHS sample, Figure 7 shows that the impact of increasing proximity to the electric grid on the number of hours worked becomes higher for households that are closer to the road, and vice versa (the impact of increasing proximity to the roads also boosts the number of hours work for households that have greater proximity to the electric grid). Bringing an electric grid 10 km closer increases the number of hours worked by 12.5 hours for households located next to a main road, but only by just 7 hours when households are located 10 km away from the main road network. Similarly, bringing the main road network 10 km closer increases the number of hours worked by 1.2 hours when households are located next to the road, but such proximity actually reduces the number of hours when the household is located 10 km away from the electric grid. That is, increasing the proximity to the road only has a positive impact for workers located next to the electric grid.

Figure 7: Marginal impact of proximity to roads (left) and electricity (right) on employment



We note some consistency between the IV estimates and the OLS results reported in Table 10. In all cases but one, the IV coefficients have the same sign as the corresponding OLS coefficients; the only reversal of sign is the negative effect of electricity on the number of hours worked. Unsurprisingly, the OLS coefficients are smaller, indicating a downward bias.

Summarizing the findings, we note that supplying roads and electricity leads to significant employment and productivity gains in sub-Saharan African countries. The effect of electrification tends to be larger than that of roads. When supplied simultaneously, these two types of infrastructure reinforce each other, resulting in greater efficiency. Indeed, they are highly complementary in the sense that supplying one significantly raises the marginal effect of the other. This complementarity is robust across the two outcomes we have analyzed so far, and across the two data sources. We next examine heterogeneity in the effects of infrastructure on the type of employment and occupational sectors.

5.2 Skilled versus unskilled employment and occupational sectors

We analyze the separate and joint effects of roads and electricity on skilled and unskilled employment and on different occupational sectors. The results are presented in Table 5 in the Appendix. Access to road and electricity networks increases employment in skilled occupations and decreases employment in unskilled occupations, leading to a structural transformation that consists of a transition from to occupations that entail higher skills.

Expanding the connections to the two networks leads to a significant employment increase in skilled and high-skilled occupations, as evidenced by the findings obtained by both data sources, the DHS sample (columns 4 and 5) and the LSMS sample (Column 9). Being 10 km closer to an electricity grid in locations along a main road increases skilled employment by 10 percentage points (Column 4) in the DHS sample, and high-skilled employment by around 7 percentage points in both the LSMS and DHS samples (columns 5 and 9). Similarly, being 10 km closer to a main road in locations along the electricity grid increases skilled employment by 19 percentage points (Column 4) and high-skilled employment by 10 percentage point in the DHS sample (Column 5), and by 21 percentage points in the LSMS sample (Column 9).

The joint effect of the two types of infrastructure is positive and highly significant, showing that they play complementary roles in the creation of skilled jobs. The marginal impact of getting closer to a main road decreases as distance to the grid increases. Similarly, the marginal impact of getting closer to the grid decreases as distance to a main road increases. Indeed, being 10 km closer to a main road increases the employment gain that results from being 10 km closer to an electricity grid by 4 percentage points for skilled occupations (Column 4) and by 3 percentage points for high-skilled occupations in the DHS sample, and by 20 percentage points for high-skilled occupations in the LSMS sample.

In columns 1, 2, 3, 6, 7, and 8, we show estimates of the effects of roads and electricity on low-skilled employment, including separate effects for farming. Column 1 shows that the probability of self-employment in the farming sector decreases by 22 percentage points in response to being 10 km closer to a main road in locations along the electricity grid (Column 1). The probability of self-employment in the farming sector decreases to an even greater degree, by 43 percentage points in response to being 10 km closer to an electricity grid in areas along a main road (Column 1). Moreover, being both 10 km closer to a main road and 10 km closer to an electric grid decreases the probability of being self-employed in farming by an additional 13 percentage points.

Columns 2 for the DHS sample and column 6 for the LSMS sample consider employment in the farming sector as the dependent variable.[10] In locations along the grid, being 10 km closer to a main

[10] In column 2, we consider employment in the farming sector as the dependent variable from the DHS. In the LSMS, we

road decreases the probability to work as a farmer by 30 percentage points (DHS sample). In locations along a main road, being 10 km closer to the grid decreases the probability to work as a farmer by 30 percentage points (DHS sample). The impact is smaller when using the LSMS sample. Proximity to roads complements proximity to the electric grid. Farming employment decreases more from being closer to roads for locations closer to the grid, and vice versa. The joint effect of both infrastructures is larger in the DHS than in the LSMS sample. Overall, the findings indicate that these infrastructures reinforce each other in decreasing employment in the agricultural sector.

In columns 3, 7 and 8, we analyze how employment in low-skilled occupations responds to road and electricity expansion. In general, we find large negative effects. Columns 3 and 8 show that the probability of employment in a low-skilled occupation decreases by nearly 5 percentage points in both the DHS and LSMS samples in response to being 10 km closer to a main road in areas along the electric grid. Being 10 km closer to an electric gird in areas along a main road leads the probability of employment in a low-skilled employment to decrease to a far greater degree: falling by 21 percentage points in the DHS sample and by 15 percentage points in the LSMS sample. Again, the two types of infrastructure have greater effects in combination. Our analysis shows that being both 10 km closer to a main road and 10 km closer to an electric grid further decreases the probability of being employed in a low-skilled occupation by an additional 0.6 percentage points in the DHS sample and 0.5 percentage points in the LSMS sample.

These estimates have similar signs as the OLS estimates (Table 11) in most cases.

Overall, the findings indicate that improved access to roads and electricity increases the probability to be employed (Table 4) in the Appendix and induce labor reallocation, with workers moving from farming and other low-skilled employment to skilled sectors. Finally the two types of infrastructure have greater effects in combination.

5.3 Agricultural employment in rural areas

Given the essential role that agriculture plays in rural economies, we now focus on more detailed analysis of the effects of access to roads and electricity on agricultural employment. We analyze the separate and combined effects of greater proximity to these networks on agricultural jobs for populations of rural areas, using both the DHS and LSMS samples.

The regression results are presented in Table 6. They show that access to roads and electricity significantly decreases agricultural employment in rural areas. In the LSMS sample, being 10 km closer to a main road in a location along the grid decreases the likelihood of working in the farming sector by 5 percentage points (Column 1). Similarly, being 10 km closer to an electric grid in a location along a road decreases agricultural employment by nearly 9 percentage points. The marginal impact of being closer to a main road is smaller when closer to the grid, and vice versa. The estimated effects of these infrastructures are much larger in the DHS sample (Columns 2 and 3).

Improved access to electricity and to roads have a similar impact on the structure of occupations at the local level. Electricity and road access might create new job opportunities, mostly in services, providing a more reliable source of income than working in the agricultural sector. Individuals who have specific skills

---

also construct a variable that indicates being employed in the farming sector, but this variable does not indicate whether an individual is self-employed or an employee because this information is not provided (Column 6).

also have the opportunity to switch from less-skilled employment to more- skilled occupations. Indeed, tables 5 and 6 imply that people in low-skilled jobs, and those working in agricultural occupations (in either the employed or self-employed categories) move to more-skilled occupations in response to greater access to both types of infrastructure. These effects are more pronounced in rural areas.

The OLS estimates reported in Table 12 confirm all of these results with one exception.[11] The joint OLS effects of these infrastructures are also qualitatively in line with the IV estimates.

The findings suggest that self-employment in agriculture - which represents 25 percent of all jobs in the DHS sample - has declined as infrastructure has expanded. This indicates that Africa is undergoing the same transition - away from agriculture and to other occupations - that has occurred previously in other global regions.

6 Heterogeneous effects of roads and electricity on employment

In this section, we analyze the heterogeneity of the effects of greater access to roads and electricity. Our findings show that the impacts vary by level of economic development and by individual characteristics (gender, age, and place of residence). The analysis sheds some light on the possible mechanisms through which investment in infrastructure affects job creation.

We have seen that the effects of roads and electricity vary according to the nature of the occupation. If individual characteristics affect the likelihood of employment in particular sectors, then investments in infrastructure will likely have differential effects, depending on the characteristics of different individuals. Moreover, cultural and normative constraints on labor mobility that are prevalent in certain societies, such as those in sub-Saharan Africa, imply that investment in greater access to roads and electricity is likely to have lower impacts among members of certain groups (such as women, for example), depending on how binding such constraints are.

6.1 Economic development

We analyze how the effects of roads and electricity on employment differ by level of economic development. Theoretically, heterogeneous impacts could be driven by differences in occupational choice between countries that differ in level of economic development. Agricultural occupations, for instance, might be more prevalent in less developed economies, whereas the manufacturing and service sectors might be more present in more developed economies. We classify countries according to their 2019 GDP per capita (Table 1).

The results are reported in columns 7 and 8 of Table 7 in the Appendix. The effects of road expansion on employment differ by level of economic development. In areas with high access to electric grids, increasing proximity to the road network by 10 km marginally increases employment probability by 22.1 percentage points in more-developed countries in the LSMS sample and by 32.5 percentage points in the DHS sample. In less-developed countries, the corresponding effects are 2.5 percentage points (LSMS)

[11] In locations along a main road, greater electricity access increases farming employment for the LSMS sample. The OLS results obtained from the DHS sample are consistent with the IV estimates, but with smaller magnitudes. The effects of road access in locations that have high levels of access to electricity and of electricity in locations that have high access to roads are in the same direction as the IV effects.

Table 1: Sub-Saharan Africa: Nine Highest-Income Countries

Countries	GDP per capita (USD) -2019
Gabon	7,767.00
South Africa	6,001.40
Namibia	4,957.50
Angola	2,790.70
Nigeria	2,229.90
Ghana	2,202.10
Kenya	1,816.50
Zambia	1,305.10
Lesotho	1,118.10

and 25.9 percentage points (DHS), respectively. It follows that the effect of greater investments in road networks tends to be larger for more-developed economies. However, the differential effect is smaller in the DHS sample, which, likely offers a more accurate picture because of the greater number of countries included in it (27 countries) than in the LSMS sample (7 countries).

In areas with high access to road networks, being 10 km closer to an electric grid increases the probability of working by 25.0 percentage points in more-developed countries, compared to 5.5 percentage points for less-developed countries in the LSMS sample. In the DHS sample, the corresponding estimates are 11.0 versus 13.7 percentage points, respectively. Again, the effect tends to be larger in more-developed economies.

In locations that are far enough from road and electricity networks, increasing proximity to both has a positive effect, but this effect is stronger in more-developed countries. These findings imply that the complementary role of roads and electricity is stronger in more-developed African economies.

Results from the OLS regressions (reported in Appendix Table 13) confirm these findings. Corresponding coefficients have similar signs, although the OLS estimates are smaller. Overall, the findings show that investment in infrastructure promotes job creation, and that the impacts are larger in more economically advanced African countries. This differential effect tends to validate the idea that the nature of jobs varies across countries with different levels of development, and that the expansion of roads and electricity provides fewer benefits to the sectors that predominate in less-developed economies, and greater benefits to sectors that predominate in more-developed countries.

6.2 Place of residence

We examine how the employment impacts of expanding road and electricity access differ for urban and rural areas. Results are reported in columns 1 and 2 of Table 5 in the Appendix. There are net employment gains in response to road expansion in both urban and rural areas in the DHS sample. The marginal employment effect of roads is larger in rural areas. Estimates from the DHS sample shows that increasing proximity to the road network by 10 km marginally increases employment by 8.0 percentage points in urban areas, compared to 23.8 percentage points in rural areas along the grid. Similarly, in areas along a main road, expanding electricity access has a larger effect in rural areas; bringing an electric grid 10 km closer to areas with close road networks marginally increases the probability of working by 16.1 percentage points in rural areas, and by only 1.3 percentage points in urban areas. Additionally, the joint marginal effect of road and electricity access is positive and larger in rural areas. The rationale for such a result could simply be that rural areas have a larger percentage of unemployed laborers among their residents than is the case in urban areas; thus, the expansion of infrastructure creates employment opportunities to a greater degree for this unemployed and underemployed rural labor force.

Results based on the LSMS sample differ. While the estimated effects of roads and electricity are positive in rural areas (as in the DHS), both the marginal effect of roads and the joint effect of roads and electricity are negative. We should note that this discrepancy could be explained by the fact our LSMS sample is drawn mostly from rural areas. The representation of urban areas might not be sufficient. In Appendix Table 13, we present the OLS results, which reinforce the idea that roads and electricity play complementary roles in job creation in rural areas. In contrast to the IV estimates, the OLS estimates show complementarity for infrastructure investment impacts in urban areas.

We also analyze the differential effects of roads and electricity on low-skilled and high-skilled employment in urban and rural areas. The results are reported in Table 8 in the Appendix. The findings from both the LSMS and DHS samples show that low- and high-skilled employment respond differently to the expansion of infrastructure. Low-skilled employment decreases in rural areas but tends to increase in urban areas. By contrast, high-skilled employment tends to increase in both urban and rural areas. In areas along the grid, bringing road networks 10 km closer to a rural location marginally decreases the likelihood of working 56 percentage points in the DHS sample (column 4); in urban areas, bringing road networks 10 km closer increases the likelihood of working in a low-skilled occupation by 10 percentage points in the DHS sample (column 3). Similarly, in areas along a main road, bringing an electric grid 10 km closer in rural areas marginally decreases the likelihood of working in a low-skilled occupation by 27.3 percentage points in the DHS sample. The joint effect of roads and electricity is negative in rural areas, but positive in urban areas.

There are significant employment gains in high-skilled employment in response to the expansion of roads and electricity in both urban and rural areas, with few exceptions. In rural areas that are connected to electricity, bringing roads 10 km closer marginally increases this type of employment by 19.4percentage points in the LSMS sample, and by 13.0 percentage points in the DHS sample. In urban areas, the effect of increasing proximity of roads 10 km is positive in the LSMS sample (7 percentage points) but negative in the DHS (-2 percentage points), although the latter effect is not statistically significant. In rural areas with high access to roads, bringing electric grids 10 km closer marginally increases the probability of high-skilled employment by over 99 percentage points in the LSMS sample, and by 2.4 percentage points in the DHS sample. In urban areas, the corresponding effects are 14.7 (LSMS) and 1.5 (DHS) percentage points, respectively. In both urban and rural areas, the joint effect of expansion of the two types of infrastructure is positive and statistically significant, except in the DHS sample where it is negative and insignificant in urban areas. These findings are consistent with those of the OLS estimates (Table 14).

The findings imply that in urban areas, investment in road and electricity infrastructure promotes job creation in both low- and high-skilled occupations. However, in rural areas, there is clear occupational mobility in response to the expansion of roads and electricity, with residents moving from low-skilled jobs to high-skilled jobs. This latter finding is consistent with the negative effect of these two types of infrastructure expansion on agricultural employment (shown in Table 6) in rural areas.

6.3 Gender

In this section, we examine the different effects on the employment of men and women that stem from investments in roads and electricity. We run separate regressions for each gender group, and present the results in columns 3 and 4 of Table 7 in the Appendix. We find that the direction in which these infrastructure investments affects employment does not differ by gender. However, the magnitude of the effects does differ.

The DHS sample results show that roads and electricity have greater marginal effects for women than for men. Columns 3 and 4 show that in locations along the grid, bringing roads 10 km closer marginally increases employment by 7.6 percentage points among men and by 39 percentage points among women, with these effects being statistically significant. The additional employment gain due to the joint investment in bringing both roads and electricity 10 km closer is larger for women (6.5 percentage points) than for men (2.2 percentage points).

Unlike in the DHS sample, the impacts from using the LSMS sample of countries are relatively similar between men and women.

The OLS results are reported in the Appendix Table 13. The main conclusions from these results qualitatively mirror those from the IV estimates, with a few differences. The OLS results show that electricity expansion increases employment both for men and women, and continues to increase employment in areas with high access to roads; this is consistent with the findings from the IV regressions. The OLS results show that, while the joint effect of roads and electricity is positive for both groups, its magnitude is larger for women.

The findings imply that employment gains from investment in road and electricity infrastructure in Africa accrue to a greater degree among women than among men. However, in certain countries, the effects might be larger for men, as shown in the LSMS. Africa is undergoing a spectacular transition away from low-paid jobs towards skilled and better-paid occupations; our results show that this transition differs by gender.

6.4 Age group

To analyze the differential employment effects of roads and electricity by age, we categorize individuals in age groups: 20-45 and 46-66 years old. Because of differences in occupational choices made by individuals in different age groups, the employment effect of infrastructure expansion might differ by age.

The IV results are reported in columns 7 and 8 of Table 7. For both samples, the results show greater net employment gains for the 20-45 age group than for the 45-66 age group. In locations with high access to electricity, brining road networks 10 km closer increases the likelihood of working to a greater degree among those in the younger group than those in the older group (+25.6 vs. +20 in the DHS sample, and +5.0 vs. -2.3 in the LSMS). In locations that have high access to roads, increasing proximity to an electric grid by 10 km marginally increases employment by 4 percentage points in the younger age group and 15 percentage points in the older age group in the LSMS sample; the corresponding estimates for the DHS sample are 9 percentage points for the younger age group and -2 percentage points for the older age group. The joint effect of roads and electricity is positive and statistically significant for both age groups in the LSMS sample, with a greater magnitude for the older group. By contrast, in the DHS sample, the effect is significant only among those in the younger group.

The OLS results are reported in Table 13 and largely mirror the findings from the IV results, with a few differences. However, overall, both the OLS and the IV estimates show that expanded access to roads and electricity affect employment mostly among young and middle-aged individuals. These findings therefore suggest that younger individuals have a greater ability to benefit from the expansion of these types of infrastructure, most likely because people in these groups can more easily change occupations.

7 Conclusions

Using two sources of geo-referenced household surveys and spatial data on road and electricity expansion in sub-Saharan Africa, we analyze the average and heterogeneous impacts on job creation that stem from investments in roads and electrification. We examine the impacts that stem from expanding access to road networks and electric grids, both in isolation and in combination. We find that significant, positive complementarity effects emerge between both types of investments. The positive impacts are heterogeneous across countries, locations, gender, and age groups. The gains from investing in roads and electricity grids tend to be greater in more-advanced economies, where the complementarities are greater. Within countries, the benefits of expanding the reach of such infrastructure differ between urban and rural areas. Employment gains from roads accrue to a greater degree in rural areas. Moreover, the complementarity between the two types of infrastructure is much stronger in rural areas. At the same time, the expansion of such infrastructure leads to a decline in low-skilled employment, including in agricultural jobs, as people move into other types of work requiring higher skills. In general, though both women and men benefit from better access to roads and electricity, women benefit more. The employment gains from better infrastructure access tend to be greater for younger individuals. Our findings imply that roads and electricity play important roles in the structural transformation of sub-Saharan Africa. The continent is undergoing the same transition away from low-productivity agriculture and toward other occupations as other parts of the world.

References

Aggarwal, S., B. Giera, D. Jeong, J. Robinson, and A. Spearot (2018): "Market access, trade costs, and technology adoption: Evidence from northern Tanzania," Working Paper 25253, National Bureau of Economic Research.

Agrawal, D. R. (2021): "The internet as a tax haven?" *American Economic Journal: Economic Policy*, 13, 1–35.

Aklin, M., P. Bayer, S. Harish, and J. Urpelainen (2017): "Does basic energy access generate socioeconomic benefits? A field experiment with off-grid solar power in India," *Science Advances*, 3.

Alvehag, K. and L. Soder (2010): "A reliability model for distribution systems incorporating seasonal variations in severe weather," *IEEE Transactions on Power Delivery*, 26, 910–919.

Amorim, G., R. C. Lima, and B. Sampaio (2018): "Broadband internet and protests: Evidence from the occupy movement," *Political Anthropology eJournal*.

Andersen, Thomas Barnebeck, B. J., C.-J. Dalgaard, and P. Selaya (2011): "Does the internet reduce corruption? Evidence from US states and across countries," *The World Bank Economic Review*, 25, 387–417.

Andersen, Thomas Barnebeck, B. J. D. C.-J. S. and Pablo (2012): "Lightning, IT diffusion, and economic growth across US states," *Review of Economics and Statistics*, 94, 903–924.

Andersen, T. B. and C.-J. Dalgaard (2013): "Power outages and economic growth in Africa," *Energy Economics*, 38, 19–23.

Arderne, C., C. Zorn, C. Nicolas, and E. Koks (2020): "Predictive mapping of the global power system using open data," *Scientific data*, 7, 1–12.

Asher, S. and P. Novosad (2018): "Rural roads and local economic development," Policy Research Working Paper Series 8466, The World Bank.

Baum-Snow, N., L. Brandt, J. V. Henderson, M. A. Turner, and Q. Zhang (2016): "Highways, market access and urban growth in China," SERC Discussion Papers 0200, Spatial Economics Research Centre, LSE.

Behrens, K., C. Gaigne, G. I. Ottaviano, and J.-F. Thisse (2006): "Is remoteness a locational disadvantage?" *Journal of Economic Geography*, 6, 347–368.

Berg, C., B. Blankespoor, and H. Selod (2018): "Roads and rural development in Sub-Saharan Africa," *Journal of Development Studies*, 54, 856–874.

Berg, C., U. Deichmann, Y. Liu, and H. Selod (2017): "Transport policies and development," *Journal of Development Studies*, 53, 465–480.

Blankespoor, B., T. Bougna, R. Garduno-Rivera, and H. Selod (2017): "Roads and the geography of economic activities in Mexico," Policy research working paper series, The World Bank.

Blimpo, M. P., R. Harding, and L. Wantchekon (2013): "Public investment in rural Infrastructure: Some political economy considerations," *Journal of African Economies*, 22, 83.

Bonfatti, R., Y. Gu, and S. Poelhekke (2019): "Priority roads: the political economy of Africa's interior-to-coast roads," Tinbergen Institute Discussion Paper TI 2019-006/VIII, Amsterdam and Rotterdam.

Buhaug, H. and J. K. Rod (2006): "Local determinants of african civil wars, 1970â2001," *Political geography*, 315–335.

Burgess, R. and D. Donaldson (2017): "Railroads and the demise of famine in colonial India," Tech. rep.

Burgess, R., R. Jedwab, E. Miguel, A. Morjaria, and G. P. i Miquel (2015): "The value of democracy: Evidence from road building in Kenya," *The American Economic Review*, 105, 1817–1851.

Burlig, F. and L. Preonas (2016): "Out of the darkness and into the light? Development effects of rural electrification," Working Paper 268. 268, Energy Institute at Haas.

Calderon, C., E. Moral-Benito, and L. Serven (2015): "Is infrastructure capital productive? A dynamic heterogeneous approach," *Journal of Applied Econometrics*, 30, 177–198.

Canning, D., M. Mabeu, and R. Pongou (2020): "Colonial origins and fertility: Can the market overcome history?" *Unpublished Manuscript.*

Cecil, D. J., D. E. Buechler, and R. J. Blakeslee (2014): "Gridded lightning climatology from TRMM-LIS and OTD: Dataset description," *Atmospheric Research*, 135, 404–414.

Chandra, A. and E. Thompson (2000): "Does public infrastructure affect economic activity?: Evidence from the rural interstate highway system," *Regional Science and Urban Economics*, 30, 457–490.

Cosar, A. K. and P. D. Fajgelbaum (2016): "Internal geography, international trade, and regional specialization," *American Economic Journal: Microeconomics*, 8, 24–56.

Dave Donaldson, R. H. (2016): "Railroads and American economic growth: A & quot; Market Access & quot; approach," *The Quarterly Journal of Economics*, 131, 799–858.

Deng, F. M. (1997): "Ethnicity: an African predicament," *The Brookings Review*, 15, 28–31.

Dinkelman, T. (2011): "The effects of rural electrification on employment: New evidence from south Africa," *American Economic Review*, 101, 3078–3108.

Donaldson, D. (2018): "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*, 108, 899–934.

Durante, R. (2009): "Risk, cooperation and the economic origins of social trust: An empirical investigation," MPRA Paper 25887, University Library of Munich, Germany.

Edward Miguel, S. S. and E. Sergenti (2004): "Economic shocks and civil conflict: An instrumental variables approach," *Journal of Political Economy*, 112, 725–753.

Faber, B. (2014): "Trade integration, market size, and industrialization: Evidence from China's national trunk highway system," *Review of Economic Studies*, 81, 1046–1070.

Fajgelbaum, P. and S. J. Redding (2014): "External integration, structural transformation and economic development: evidence from argentina," CEP Discussion Papers dp1273, Centre for Economic Performance, LSE.

Fajgelbaum, P. D. and E. Schaal (2020): "Optimal transport networks in spatial equilibrium," *Econometrica*, 88, 1411–1452.

Fearon, J. D. and D. D. Laitin (2003): "Ethnicity, insurgency, and civil war," *The American Political Science Review*, 97, 75–90.

Fried, S. and D. Lagakos (2020): "Electricity and firm productivity: A general-equilibrium approach," NBER Working Papers 27081, National Bureau of Economic Research, Inc.

Ghani, E., A. G. Goswami, and W. R. Kerr (2016): "Highway to success: The Impact of the golden quadrilateral project for the location and Performance of Indian manufacturing," *Economic Journal*, 126, 317–357.

Grainger, C. A. and F. Zhang (2019): "Electricity shortages and manufacturing productivity in Pakistan," *Energy Policy*, 132, 1000–1008.

Han, E. and C. Paik (2017): "Ethnic integration and development in China," *World Development*, 93, 31–42.

Herbst, J. (2000): "Economic incentives, natural resources and conflict in Africa," *Journal of African Economies*, 9, 270–294.

——— (2014): *States and power in Africa*, Princeton University Press.

Herrera Dappe, M. and M. Lebrand (2021): "Infrastructure and structural change in the horn of Africa," Policy Research Working Paper Series WPS 9870, The World Bank.

Hjort, J. and J. Poulsen (2019): "The arrival of fast internet and employment in Africa," *American Economic Review*, 109, 1032–79.

Jedwab, R. and A. Storeygard (2021): "The average and heterogeneous effects of transportation investments: Evidence from Sub-Saharan Africa 1960-2010," *Journal of the European Economic Association.*

Karagiannis, G. M., S. Chondrogiannis, E. Krausmann, and Z. I. Turksezer (2017): "Power grid recovery after natural hazard impact," *Joint Research Center: European Union.*

KEBEDE, H. A. (2020): "The gains from market integration: The welfare effects of new rural roads in Ethiopia ," Mimeo, University of Virginia.

LALL, S. V. AND M. LEBRAND (2020): "Who wins, who loses? Understanding the spatially differentiated effects of the belt and road initiative," *Journal of Development Economics*, 146.

LEBRAND, M. (2022): "Infrastructure and structural change in the lake Chad region," Policy Research Working Paper Series WPS 9899, The World Bank.

MANACORDA, M. AND A. TESEI (2020): "Liberation technology: Mobile phones and political mobilization in Africa," *Econometrica*, 88, 533–567.

MARTINCUS, C. V., J. CARBALLO, AND A. CUSOLITO (2017): "Roads, exports and employment: Evidence from a developing country," *Journal of Development Economics*, 125, 21–39.

MIGUEL, E. (2005): "Poverty and witch killing," *Review of Economic Studies*, 72, 1153–1172.

MINNAAR, U., C. GAUNT, AND F. NICOLLS (2012): "Characterisation of power system events on South African transmission power lines," *Electric power systems research*, 88, 25–32.

MONEKE, N. (2020): "Can big push infrastructure unlock development? Evidence from Ethiopia," Tech. rep., Mimeo.

MORTEN, M. AND J. OLIVEIRA (2018): "The Eeffects of roads on trade and migration : Evidence from a planned capital city," Nber working paper 22158.

MU, R. AND D. VAN DE WALLE (2011): "Rural roads and local market development in Vietnam," *Journal of Development Studies*, 47, 709–734.

MULLER-CREPON, C., P. HUNZIKER, AND L.-E. CEDERMAN (2020): "Roads to rule, roads to rebel: Relational state capacity and conflict in Africa," *Journal of Conflict Resolution*, 65, 002200272096367.

MURDOCK, G. P. (1959): "Africa its peoples and their culture history," .

NELSON, A. AND U. DEICHMANN (2004): "African population database documentation," *Retrived from http://na. unep. net/siouxfalls/globalpop/africa/Africa_index. html.*

OKOYE, D., R. PONGOU, AND T. YOKOSSI (2019): "New technology, better economy? The heterogeneous impact of colonial railroads in Nigeria," *Journal of Development Economics*, 140, 320–354.

OSTROM, E. (1990): *Governing the Commons: The evolution of institutions for collective action*, Political Economy of Institutions and Decisions, Cambridge University Press.

PAXSON, C. H. (1992): "Using weather variability to estimate the response of savings to transitory income in Thailand," *American Economic Review*, 82, 15–33.

RALEIGH, C. AND H. HEGRE (2009): "Population size, concentration, and civil war. A geographically disaggregated analysis," *Political Geography*, 28, 224–238.

ROMER, C. D. AND J. BERNSTEIN (2009): "The job impact of the American recovery and reinvestment plan," Tech. rep.

SAMAD, H. AND F. ZHANG (2018): "Electrification and household welfare: evidence from Pakistan," .

SAMAD, H. A. AND F. ZHANG (2016): "Benefits of electrification and the role of reliability: evidence from India," *World Bank Policy Research Working Paper*.

——— (2017): "Heterogeneous effects of rural electrification: evidence from Bangladesh," *World Bank Policy Research Working Paper*.

SANDERSON, E. AND F. WINDMEIJER (2016): "A weak instrument F-test in linear IV models with multiple endogenous variables," *Journal of Econometrics*, 190, 212–221.

SELOD, H. AND S. SOUMAHORO (2019): "Highway politics in a divided government : Evidence from Mexico," Policy Research Working Paper Series 8710, The World Bank.

TAAFFE, J., R. L. MORRILL, AND P. R. GOULD (1963): "Transport expansion in underdeveloped Countries: A comparative analysis," *Geographical Review*, 53, 503–52910.

TOLLEFSEN, A. AND H. BUHAUG (2015): "Insurgency and inaccessibility," *International Studies Review*, 17, 6–25.

TOMBE, T. AND X. ZHU (2019): "Trade, migration, and productivity: A quantitative analysis of China," *American Economic Review*, 109, 1843–1872.

VAN DE WALLE, D., M. RAVALLION, V. MENDIRATTA, AND G. KOOLWAL (2017): "Long-term gains from electrification in rural India," *The World Bank Economic Review*, 31, 385–411.

WORLD ECONOMIC FORUM, WORLD BANK, AND AFRICAN DEVELOPMENT BANK (2017): "The Africa competitiveness report 2017 : Addressing Africaâs demographic dividend." .

ZHANG, F. (2018): *In the dark: how much do power sector distortions cost south Asia?*, The World Bank.

Tables of results

Table 2: Descriptive statistics

LSMS

Variables	Observations	Mean	Std. Dev.	Min	Max
Proximity to road	1,650,576	-14.61424	22.1436	-192.6164	-0.0035672
Proximity to electric grid	1,650,576	-7.908698	19.25365	-226.9208	-0.0000467
Interaction term	1,650,576	280.1463	1315.935	0.0000519	17144.38
Proximity to ethnic road	1,377,444	-80.46674	252.7191	-14129.83	-0.0205457
Elevation	1,645,066	978.6015	735.5545	0	3451
Lightning	1,650,642	0.4280752	0.2808742	0.0003547	2.120674
Ethnic road * elevation	1,374,477	-50603.81	93940.01	-4889321	0
Survey year	1,650,657			2005	2019
Currently working	1,650,657	0.5531446	0.4971678	0	1
Hours worked	661,717	10.86494	25.46781	0	120
Farmer	1,172,226	0.4380239	0.4961443	0	1
Low skilled worker	1,650,657	0.2382845	0.4260342	0	1
High skilled worker	1,578,631	0.3080365	0.4616819	0	1
Age	1,650,657	36.18561	12.01152	20	65
Female individual	1,650,657	0.5394991	0.4984375	0	1
Rural residence	1,189,655	0.8615641	0.3453571	0	1
No education	1,650,655	0.188318	0.390966	0	1
Primary education	1,590,234	0.1751396	0.3800866	0	1
Higher education	1,595,663	0.5038351	0.4999854	0	1
More developed countries	1,650,657	0.0262798	0.1599663	0	1

DHS

Variables	Observations	Mean	Std. Dev.	Min	Max
Proximity to road	1,230,299	-10.45875	18.97043	-221.4656	-0.0000708
Proximity to electric grid	1,192,404	-25.79411	43.87656	-332.8077	-0.000216
Interaction term	1,192,185	542.5078	2172.048	1.40E-07	46875.13
Proximity to ethnic road	1,231,968	-32.92357	32.98761	-273.9815	-0.0010025
Elevation	1,204,028	711.2029	638.3857	-92	3979
Lightning	1,228,343	0.5413241	0.3829411	0	5.023981
Ethnic road * elevation	1,204,028	-22881.91	34405.31	-384234.9	6539.948
Survey year	955,110			1998	2018
Currently working	846,328	0.6903281	0.4623586	0	1
self employed farmer	929,833	0.2474971	0.4315582	0	1
Farmer employee	929,833	0.0666743	0.2494573	0	1
Farmer	929,833	0.3141715	0.4641853	0	1
Low skilled worker	1,106,243	0.2171286	0.4122911	0	1
Skilled worker	1,215,382	0.157915	0.3646614	0	1
High skilled worker	946,750	0.1193969	0.3242551	0	1
Age	960,059	32.49127	9.08965	20	64
Female individual	960,059	0.6913638	0.4619309	0	1
Rural residence	960,059	0.6347693	0.481495	0	1
No education	960,045	0.3458838	0.4756558	0	1
Primary education	960,045	0.306921	0.4612166	0	1
Higher education	960,045	0.3471952	0.4760787	0	1
More developed countries	960,059	0.3589956	0.4797062	0	1

Table 3: First stage regressions

	(1) Proximity to nearest main road	(2) Proximity to electric grids	(3) Interaction term	(1) Proximity to nearest main road	(2) Proximity to electric grid	(3) Interaction term
Variables		LSMS			DHS	
Proximity to hyp. roads	0.000339***	0.0000392**	-0.0150***	0.0178***	0.225***	-3.821***
	(0.0000327)	(0.0000150)	(0.00139)	(0.00208)	(0.00581)	(0.166)
Elevation	0.0287***	-0.0273***	0.806***	-1.024***	-2.551***	65.02***
	(0.00720)	(0.00425)	(0.185)	(0.0536)	(0.172)	(3.910)
Lightning	-0.118***	-0.0642***	-0.492	0.305***	-0.176**	-13.56***
	(0.0144)	(0.0135)	(0.332)	(0.0234)	(0.0607)	(2.235)
Hyp. road*Elevation	-0.000360***	7.25e-05	0.00874***	-0.000648	-0.0490***	1.112***
	(7.17e-06)	(4.00e-06)	(0.000235)	(0.000148)	(0.000413)	(0.00980)
N	1014105	1014105	1014105	929699	900209	900019
R-sq	0.012	0.014	0.003	0.075	0.224	0.104
Cragg-Donald Wald F	103.488	103.488	103.488	44.65	44.65	44.65
Windmeijer F	270.38	249.57	740.22	398.98	94.17	142.38
F-test statistic	389.41	2140.65	4100.64	34284.47	1.10E+05	72840.8
Age	✓	✓	✓	✓	✓	✓
Gender	✓	✓	✓	✓	✓	✓
Type of place of residence	✓	✓	✓	✓	✓	✓
Education	✓	✓	✓	✓	✓	✓
Temperature	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 4: IV effects of roads and electricity on employment

	(1)	(2)	(3)
	Currently working		Hours worked in the last 7 days
Variables	**LSMS**	**DHS**	**LSMS**
Proximity to nearest main road	0.00249***	0.0257***	0.116
	(0.000459)	(0.00200)	(0.0752)
Proximity to electric grids	0.00561***	0.00840***	1.250***
	(0.00117)	(0.00115)	(0.260)
Interaction term	0.000286***	0.000446***	0.0535***
	(0.0000332)	(0.0000346)	(0.00569)
N	1014139	795983	475640
R-sq	0.037	-1.308	-1.021
Cragg-Donald Wald F	103.49	44.646	25.48
Windmeijer F	270.38	142.38	102.54
P value	0	0	0
Hansen J statistic F	11.143	18.877	121.77
P value	0.0008	0.0029	0
Age	✓	✓	✓
Gender	✓	✓	✓
Type of place of residence	✓	✓	✓
Education	✓	✓	✓
Temperature	✓	✓	✓
Country FE	✓	✓	✓
Year FE	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 5: IV effects of roads and electricity on employment by sector of occupation

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Farming self-employed	**Farming employee and self-employed**	**Low skilled worker**	**Skilled worker**	**High Skilled worker**	**Farming**	**Low skilled worker**	**Farming and low skilled worker**	**High Skilled worker**
Variables	**DHS**					**LSMS**			
Proximity to road	-0.0221	-0.031	-0.0049	0.0187**	0.0099*	-0.00676***	0.0115***	-0.00465***	0.0212***
	(0.0277204)	(0.0215)	(0.0126957)	(0.0082485)	(0.0058973)	(0.000247)	(0.000714)	(0.000440)	(0.000917)
Proximity to electric grids	-0.0431***	-0.0312**	-0.0207***	0.0103**	0.0071**	0.00303	-0.0213***	-0.0152***	0.0666***
	(0.0165801)	(0.0128)	(0.0076113)	(0.0049327)	(0.0035232)	(0.00342)	(0.00191)	(0.00122)	(0.00589)
Interaction term	-0.0013*	-0.0011**	-0.0006*	0.0004**	0.0003**	-0.0000111	-0.000460***	-0.000490***	0.00177***
	(0.0007097)	(0.0005502)	(0.000325)	(0.0002108)	(0.0000852)	(0.0000924)	(0.0000453)	(0.0000344)	(0.000147)
N	552573	552573	553410	553410	553410	868322	1014139	1014139	953244
R-sq	-20.804	-10.742	-3.887	-3.714	-2.436	0.731	-0.921	0.132	-5.331
Cragg-Donald Wald F	60.928	60.928	52.655	60.928	56.932	5.19	73.3	103.49	27.67
Windmeijer F	192.24	192.24	167.88	192.24	176.33	26.7	333.98	270.38	87.7
P value	0	0	0	0	0	0	0	0	0
Hansen J statistic F	44.992	17.437	33.807	43.625	33.950	26.277	218.013	391.074	254.89
P value	0	0	0	0	0	0	0	0	0
Baseline controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 6: IV effects of roads and electricity on farming in rural areas

Variables	(1) Farming LSMS	(2) Farming self-employed DHS	(3) Farming employee and self-emploed DHS
Proximity to road	-0.00499***	-0.0824***	-0.0666***
	(0.000234)	(0.0177)	(0.0133)
Proximity to electric grids	-0.00886***	-0.0330***	-0.0210**
	(0.00240)	(0.00949)	(0.00719)
Interaction term	-0.000296***	-0.00150***	-0.00112***
	(0.0000637)	(0.000350)	(0.000264)
N	796434	350275	350275
R-sq	0.764	-15.604	-8.316
Cragg-Donald Wald F	7.091	37.13	36.3
Windmeijer F	43.77	91.79	9.87
P value	0	0	0.0001
Baseline controls	✓	✓	✓
Country FE	✓	✓	✓
Year FE	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 7: Heterogeneity: IV effects of roads and electricity on employment

LSMS	Currently working							
	(1)	(2)	(3)	(4)	(7)	(8)	(9)	(10)
Variables	**Urban area**	**Rural area**	**Male sample**	**Female sample**	**20-45 age group**	**46-66 age group**	**Less developped countries**	**More developped countries**
Proximity to road	-0.00299**	0.00308***	0.00215***	0.00290***	0.00499***	-0.00229	0.00246***	0.0221**
	(0.00113)	(0.000481)	(0.000611)	(0.000684)	(0.000535)	(0.00122)	(0.000459)	(0.00680)
Proximity to electric grids	0.00141*	0.0155***	0.00679***	0.00507**	0.00402***	0.0152***	0.00551***	0.0250*
	(0.000606)	(0.00266)	(0.00157)	(0.00179)	(0.00113)	(0.00425)	(0.00117)	(0.0105)
Interaction term	-0.0000583	0.000537***	0.000317***	0.000261***	0.000266***	0.000538***	0.000282***	0.00186*
	(0.0000299)	(0.0000709)	(0.0000428)	(0.0000526)	(0.0000322)	(0.000129)	(0.0000330)	(0.000802)
N	120097	894042	487673	526466	781371	232768	997779	16360
R-sq	0.210	-0.299	-0.024	0.086	0.068	-0.515	0.038	-0.143
Cragg-Donald Wald F	58.793	30.125	64.975	40.427	105.122	9.585	103.554	21.597
Windmeijer F	90.29	90.77	148.1	121.25	256.15	34.53	270.75	48.09
P value	0	0	0	0	0	0	0	0
DHS	**Currently working**							
	(1)	(2)	(3)	(4)	(7)	(8)	(9)	(10)
Variables	**Urban area**	**Rural area**	**Male sample**	**Female sample**	**20-45 age group**	**46-66 age group**	**Less developed countries**	**More developed countries**
Proximity to road	0.00802	0.0238***	0.00758*	0.0393***	0.0256***	0.0200***	0.0259***	0.0325**
	(0.00535)	(0.00634)	(0.00299)	(0.00379)	(0.00218)	(0.00405)	(0.00289)	(0.0113)
Proximity to electric grids	0.00126*	0.0161***	0.00576***	0.0117***	0.00914***	-0.00247	0.0137***	0.0110***
	(0.000641)	(0.00339)	(0.00130)	(0.00237)	(0.00116)	(0.00229)	(0.00304)	(0.00223)
Interaction term	0.000116**	0.000509***	0.000217***	0.000652***	0.000460***	0.000106	0.000553***	0.000614***
	(0.0000385)	(0.000123)	(0.0000263)	(0.0000811)	(0.0000345)	(0.0000716)	(0.0000900)	(0.000161)
N	295346	500637	197318	598665	719152	76831	508369	287614
R-sq	0.074	-2.458	-0.788	-2.610	-1.408	-0.126	-3.226	-0.994
Cragg-Donald Wald F	40.962	5.927	15.707	16.984	44.923	3.633	14.132	12.007
Windmeijer F	95.21	15.26	89.42	46.09	152.92	2.43	33.81	12.31
P value	0	0	0	0	0	0.0881	0	0
Baseline controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 8: IV effects of roads and electricity on employment by type of occupation and by place of residence

	(1)	(2)	(3)	(4)
		Low skilled worker		
	Urban area	Rural area	Urban area	Rural area
Variables	LSMS		DHS	
Proximity to road	0.00506***	-0.000408	0.00958	-0.0562***
	(0.000926)	(0.000382)	(0.00597)	(0.0135)
Proximity to electric grids	0.00495***	-0.0120**	-0.00163**	-0.0273***
	(0.000620)	(0.00420)	(0.000723)	(0.00727)
Interaction term	0.000195***	-0.000311**	0.0000772	-0.00111***
	(0.0000307)	(0.000110)	(0.0000428)	(0.000268)
N	120097	894042	202714	350696
R-sq	0.184	-0.013	0.130	-10.234
Cragg-Donald Wald F	43.912	4.441	37.49	37.4
Windmeijer F	76.67	23.76	91.72	101.4
P value	0	0	0	0

	(1)	(2)	(3)	(4)
		High skilled worker		
	Urban area	Rural area	Urban area	Rural area
Variables	LSMS		DHS	
Proximity to road	0.00690***	0.0194***	-0.00184	0.0130***
	(0.00113)	(0.00129)	(0.00546)	(0.00330)
Proximity to electric grids	0.0147***	0.0996***	0.00155*	0.00248
	(0.000943)	(0.0133)	(0.000666)	(0.00181)
Interaction term	0.000167***	0.00248***	-0.00000703	0.000199**
	(0.0000308)	(0.000315)	(0.0000391)	(0.0000669)
N	119186	834058	202714	350696
R-sq	0.203	-9.932	0.132	-0.703
Cragg-Donald Wald F	64.585	7.609	37.49	37.4
Windmeijer F	111	33.61	91.72	101.4
P value	0	0	0	0
Baseline controls	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Appendix Tables

Table 9: Surveys

Countries		DHS				LSMS					
1-	**Angola**				2015						
2-	**Benin**		2001	2012	2017						
3-	**Burkina Faso**			2003	2010						
4-	**Burundi**			2010	2016						
5-	**Congo**			2007	2013						
6-	**Ethiopia**		2005	2011	2016				2011	2014	2015
7-	**Gabon**				2012						
8-	**Ghana**		2003	2008	2014						
9-	**Guinea**		2005	2012	2018						
10-	**Kenya**		2003	2008	2014						
11-	**Liberia**			2007	2013						
12-	**Lesotho**		2004	2009	2014						
13-	**Mali**	2001	2006	2012	2018					2014	2017
14-	**Malawi**	2000	2004	2010	2015		2005	2010	2013	2017	2019
15-	**Mozambique**			2011	2015						
16-	**Niger**									2011	2014
17-	**Nigeria**	2003	2008	2013	2018				2010	2015	2018
18-	**Namibia**		2000	2006	2013						
19-	**Sierra Leone**			2008	2013						
20-	**Senegal**	2005	2010	2015	2016						
21-	**Chad**				2014						
22-	**Togo**			1998	2013						
23-	**Tanzania**		1999	2012	2015	2008	2010	2011	2012	2014	2016
24-	**Uganda**	2000	2010	2011	2016		2005	2009	2010	2011	2013
25-	**South Africa**				2017						
26-	**Zambia**		2007	2013	2018						
27-	**Zimbabwe**		2005	2010	2015						

Table 10: OLS effects of roads and electricity on employment

	(1)	(2)	(3)
	Currently working		**Hours worked in the last 7 days**
Variables	**LSMS**	**DHS**	**LSMS**
Proximity to nearest main road	0.0000362	0.000354***	0.0172***
	(0.0000255)	(0.0000530)	(0.00103)
Proximity to electric grids	0.000165***	0.0000158	-0.0223***
	(0.0000317)	(0.0000150)	(0.00421)
Interaction term	0.00000692***	0.00000152***	0.0000622
	(0.000000616)	(0.000000428)	(0.000107)
N	1135766	814394	484673
R-sq	0.194	0.136	0.039
Age	✓	✓	✓
Gender	✓	✓	✓
Type of place of residence	✓	✓	✓
Education	✓	✓	✓
Temperature	✓	✓	✓
Country FE	✓	✓	✓
Year FE	✓	✓	✓

Standard errors in parentheses. * $p<0.1$ ** $p<0.01$ *** $p<0.001$.

Table 11: OLS effects of roads and electricity on employment by sector of employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Farming self-employed	**Farming employee and self-employed**	**Low skilled worker**	**Skilled worker**	**High skilled worker**	**Farming**	**Low skilled worker**	**Farming and low skilled worker**	**High Skilled worker**
Variables			**DHS**				**LSMS**		
Road	-0.00233***	-0.00332***	-0.000288***	0.00128***	0.000322***	-0.000393***	-0.000068***	-0.000103***	0.000118***
	(0.0000628)	(0.0000673)	(0.0000613)	(0.0000548)	(0.0000450)	(0.0000139)	(0.0000186)	(0.0000190)	(0.0000195)
Electricity	-0.000426***	-0.000607***	0.0000177	0.000286***	0.000120***	0.000320***	0.000464***	0.000145***	0.000196***
	(0.0000163)	(0.0000173)	(0.0000176)	(0.0000158)	(0.0000135)	(0.0000268)	(0.0000222)	(0.0000244)	(0.0000165)
Interaction	-0.0000114***	-0.0000179***	-0.000000142	0.00000801***	0.00000216***	-0.00000569***	-0.0000028***	-0.00000246***	0.00000293***
	(0.000000522)	(0.000000538)	(0.000000490)	(0.000000432)	(0.000000357)	(0.000000674)	(0.000000349)	(0.000000353)	(0.000000277)
N	563061	563061	563934	563934	563934	886766	1130303	1135766	1074871
R-sq	0.370	0.341	0.221	0.196	0.186	0.766	0.2336	0.571	0.404
Baseline controls	✓	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 12: OLS effects of roads and electricity on farming in rural areas

Variables	(1) Farming **LSMS**	(2) Farming self-employed **DHS**	(3) Farming employee and self-emploed **DHS**
Proximity to road	-0.0004***	-0.00214***	-0.00238***
	(0.0000139)	(0.0000691)	(0.0000742)
Proximity to electric grids	0.0003***	-0.000460***	-0.000639***
	(0.0000268)	(0.0000225)	(0.0000242)
Interaction term	-0.0006***	-0.0000147***	-0.0000161***
	(0.000674)	(0.000000589)	(0.000000608)
N	891219	356865	356865
R-sq	0.762	0.353	0.232
Baseline controls	✓	✓	✓
Country FE	✓	✓	✓
Year FE	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 13: Heterogeneity: OLS effects of roads and electricity on employment

LSMS	Currently working							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Urban area**	**Rural area**	**Male sample**	**Female sample**	**20-45 age group**	**46-66 age group**	**Less developped countries**	**More developped countries**
Proximity to road	0.00112***	0.000509***	0.000522***	0.000803***	0.000676***	-0.0000443	0.000665***	0.000666***
	(0.0000710)	(0.0000291)	(0.0000382)	(0.0000376)	(0.0000269)	(0.000342)	(0.0000299)	(0.0000605)
Proximity to electric grids	0.00195***	0.00143***	0.00153***	0.00165***	0.00159***	-0.0000130	0.00162***	0.00124***
	(0.0000742)	(0.0000372)	(0.0000506)	(0.0000438)	(0.0000333)	(0.000607)	(0.0000388)	(0.0000628)
Interaction term	0.0000271***	0.0000163***	0.0000168***	0.0000222***	0.0000195***	0.0000668	0.0000183***	0.0000209***
	(0.00000137)	(0.000000727)	(0.000000907)	(0.000000898)	(0.000000637)	(0.0000421)	(0.000000727)	(0.00000131)
N	156058	974245	543391	586912	1097862	32441	872180	258123
R-sq	0.135	0.126	0.131	0.129	0.126	0.007	0.129	0.147
DHS	Currently working							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variables	**Urban area**	**Rural area**	**Male sample**	**Female sample**	**20-45 age group**	**46-66 age group**	**Less developped countries**	**More developped countries**
Proximity to road	-0.000325*	0.000199***	0.000423***	0.000312***	0.000554***	0.000196	0.000345***	0.000473**
	(0.000143)	(0.0000579)	(0.0000844)	(0.0000641)	(0.0000606)	(0.000109)	(0.0000563)	(0.000152)
Proximity to electric grids	0.0000651**	0.0000109	0.000000880	0.00000747	-0.000101***	0.000299***	0.00000886	0.0000875*
	(0.0000247)	(0.0000190)	(0.0000230)	(0.0000186)	(0.0000181)	(0.0000274)	(0.0000160)	(0.0000415)
Interaction term	-0.000000584	-0.00000187***	0.00000182**	0.00000147**	0.000000648	0.00000899***	0.00000151***	0.00000165
	(0.00000109)	(0.000000476)	(0.000000688)	(0.000000519)	(0.000000472)	(0.00000112)	(0.000000454)	(0.00000126)
N	301687	512707	200445	613949	521446	292948	735841	78553
R-sq	0.120	0.168	0.076	0.116	0.145	0.132	0.137	0.141
Baseline controls	✓	✓	✓	✓	✓	✓	✓	✓
Country FE	✓	✓	✓	✓	✓	✓	✓	✓
Year FE	✓	✓	✓	✓	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.

Table 14: OLS effects of roads and electricity on employment by type of occupation and by place of residence

	(1)	(2)	(3)	(4)
	Low skilled worker			
	Urban area	Rural area	Urban area	Rural area
Variables	LSMS		DHS	
Proximity to road	0.0001***	-0.00007**	-0.000452*	-0.000621***
	(0.0000296)	(0.0000211)	(0.000180)	(0.0000649)
Proximity to electric grids	-0.0006**	-0.00038**	-0.0000160	0.00000762
	(0.0000454)	(0.0000255)	(0.0000309)	(0.0000207)
Interaction term	-0.000006**	-0.000001**	0.000000601	-0.00000436***
	(0.0000511)	(0.0000430)	(0.00000136)	(0.000000530)
N	156058	974245	206631	357303
R-sq	0.354	0.2176	0.157	0.277

	(1)	(2)	(3)	(4)
	High skilled worker			
	Urban area	Rural area	Urban area	Rural area
Variables	LSMS		DHS	
	(0.0000147)	(0.0000226)	(0.000155)	(0.0000452)
Proximity to electric grids	0.00041***	0.00022***	0.0000400	0.000164***
	(0.0000434)	(0.0000178)	(0.0000275)	(0.0000135)
Interaction term	0.000358***	0.000255***	0.00000286*	0.00000273***
	(0.0000440)	(0.0000317)	(0.00000115)	(0.000000361)
N	155147	914261	206631	357303
R-sq	0.5	0.383	0.144	0.128
Baseline controls	✓	✓	✓	✓
Country FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

Standard errors in parentheses. * p<0.1 ** p<0.01 *** p<0.001.