HORN OF AFRICA REGIONAL ECONOMIC MEMORANDUM BACKGROUND PAPER 4

Infrastructure and Structural Change

- Matias Herrera Dappe and Mathilde Lebrand

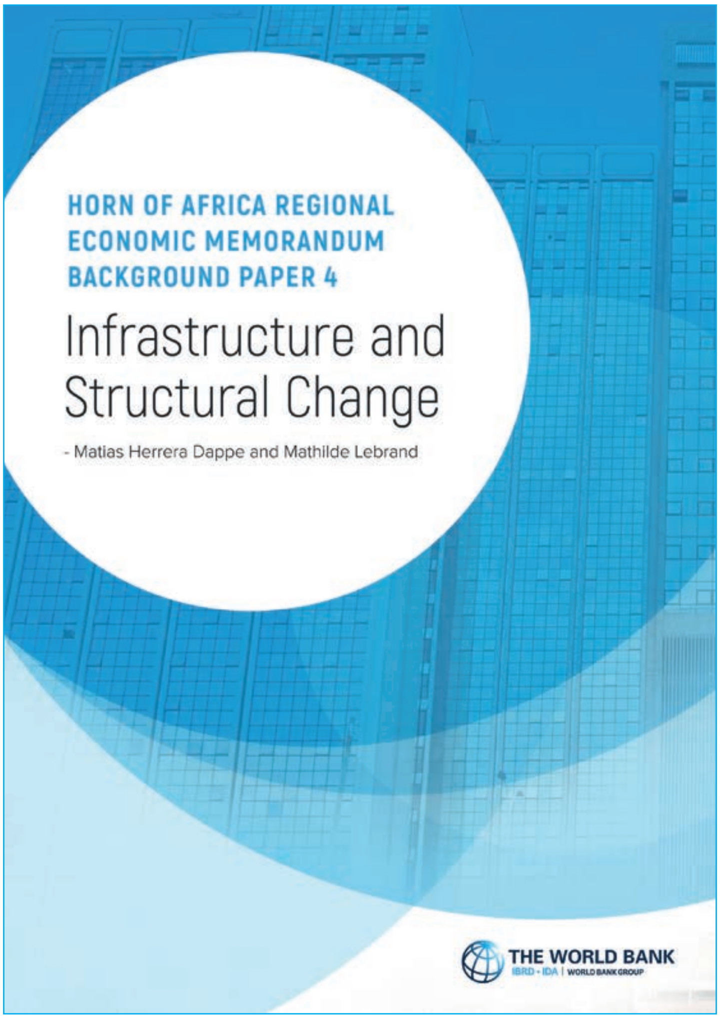
THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP

Photos: Shutterstock and Unsplash.

HORN OF AFRICA REGIONAL ECONOMIC MEMORANDUM BACKGROUND PAPER 4

Infrastructure and Structural Change

- Matias Herrera Dappe and Mathilde Lebrand*



* World Bank (mlebrand@worldbank.org). We thank Kezhou Miao and Han Byul Lee for excellent research assistance, Niclas Moneke and Immo Schott for their guidance, participants at workshops for helpful comments, and Alice Duhaut and Kevin Croke for their help with the data.

ABSTRACT

Access to infrastructure support economic development through both capital accumulation and structural transformation. This paper investigates the links between investments in electricity, Internet, and road infrastructure, in isolation and bundled, and economic development in the Horn of Africa, a region that includes countries with different levels of infrastructure and economic development. Using data on the expansion of the road, electricity, and Internet networks, it provides reduced-form estimates of the impacts of infrastructure investments on the sectoral composition of employment. It uses a spatial general equilibrium model, based on Moneke (2020), to quantify the impacts of future transport investments and trade facilitation measures on economic development in the Horn of Africa countries.

Keywords: Infrastructure, general equilibrium, transport corridors, structural change

JEL Classification: F15, J24, L16, O13, O14, O18, Q41, R1

CONTENTS

1 Introduction ... 1

2 Background ... 3

3 Data ... 5

4 Empirical Strategy and Results ... 9
4.1 Ordinary Least Squares ... 9
4.2 Instrumental Variables ... 15

5 Welfare Impacts of Infrastructure ... 19
5.1 The Model ... 19
5.2 Calibration of the Model ... 22
5.3 New transport infrastructure in the Horn of Africa ... 24
5.3.1 Calibration of counterfactuals ... 26
5.3.2 Welfare impacts ... 26
5.3.3 Spatial impacts ... 27

Conclusion ... 31

References ... 32

SECTION 1
Introduction

Infrastructure investments can support economic development through both capital accumulation and structural transformation.[1] Structural change—the movement of workers from lower- to higher-productivity employment—is essential to growth in low-income countries. Poor transport infrastructure may create large frictions that limit specialization and exchange within countries. Improved transport leads to faster journeys, making economic agents closer together, and may also trigger relocation of economic activity, which lead to productivity increases. Electricity and Internet allow for modern production technologies and complement transport infrastructure by boosting firm productivity.

The literature has studied specific infrastructure expansions as potential drivers of development, but little work has been done on the associated structural change or how the combinations of such investments matter. This paper investigates how investments in electricity, Internet, and transport infrastructure and their interactions affect economic development through productivity gains and structural change in the Horn of Africa.

This paper first uses reduced-form analysis to understand the relationship between past investments in electricity, Internet, and road infrastructure and sectoral structure of employment in Ethiopia and Kenya. Reduced-form results capture the localized effects in the areas that have been affected, but do not capture the general-equilibrium effects and spillovers due to the network nature of infrastructure such as roads. The paper then uses a spatial general-equilibrium model, based on Moneke (2020), to assess the aggregate and spatial impacts of planned infrastructure investments in the region. The general-equilibrium model captures the spillover effects that a localized investment has on the rest of the country and all the countries in the Horn of Africa and generates welfare estimates for the entire region and all its subregions. A companion paper undertakes similar work for countries around Lake Chad.

The paper finds different patterns of infrastructure push on sectoral employment compared to isolated investments from the reduced-form specifications. Investments in electrification have a large impact on sectoral change, moving workers from agriculture to services mostly. Roads alone cause a significant but small impact on structural change. In contrast, the interaction of roads and electrification causes a strong increase in manufacturing employment. Internet access is associated with moving workers from agriculture to services.

Simulations based on the structural model shows that better market access from new investments in regional corridors could bring large welfare gains, especially when complemented with lower border delays. Lower transport costs reduce spatial frictions, increase specialization within and across countries, and lead to sectoral change away from the agricultural sector. Better regional integration is predicted to reduce employment in agriculture the most in Kenya and the least in Somalia. However, Somalia benefits the most from lower border and transport frictions. Within country,

[1] There are two approaches for explaining economic growth (McMillan, Rodrik, and Sepulveda 2017). The first assumes that the accumulation of skills, capital, and broad institutional capabilities are needed to generate sustained productivity growth. The second assumes a dual economy in which long-run growth is driven by the flow of resources to modern economic activities, which operate at higher levels of productivity.

increased specialization will lead some regions to become relatively more agricultural, others less. Additional investments in electrification and internet connectivity would be necessary to bring larger sectoral changes.

Several papers have examined the impact of infrastructure investment on sectoral employment at the micro-level. Gertler et al. (2016) find that lower transport costs empower women by opening up labor market opportunities and increasing their employment in the nonagricultural sector. Asher and Novosad (2020) find that a new rural road in India causes a 9-percentage points decline in the share of agricultural workers and an equivalent rise in wage labor. This paper adds to this literature.

Most of the literature studying the impact of infrastructure at the micro- and macro-level considers the gains from energy, transport, and digital investments in isolation or bundled in a unique infrastructure index. The aggregate impact of infrastructure has been measured through the elasticity of output with respect to a synthetic infrastructure index, which includes transport along with electricity and telecommunications (Calderon, Moral-Benito, and Serven 2015). This approach does not allow to isolate the complementarities of different infrastructure. Moneke (2020) shows that transport and electricity investments are complementary and that they increased economic development in Ethiopia. He finds starkly different patterns of big-push infrastructure on sectoral employment compared with only road investments. Roads alone cause service sector employment to increase at the expense of agriculture and, especially, manufacturing employment. In contrast, the interaction of roads and electrification causes a strong reversal in manufacturing employment. We thereby complement this latest paper by looking at internet, electricity and transport, and their complementarities, for both Ethiopia and Kenya.

There is a growing body of literature using quantitative spatial general equilibrium models to assess the impacts of infrastructure. Allen and Arkolakis (2014) develop a general equilibrium framework to determine the spatial distribution of economic activity and uses to assess the impact of the US interstate highway system. Michaels, Rauch, and Redding (2011) look at changes in sectoral employment as an outcome that captures the underlying infrastructure-induced effects. Redding and Turner (2016) and Redding (2020) survey the literature on the impacts of transport infrastructure and the growing use of models to quantify these impacts. Bustos, Caprettini, and Ponticelli (2016) and Fried and Lagakos (2020) study the general equilibrium implications of electrification via its effect on productivity. Several papers provide policy counterfactuals for future road and border infrastructure improvements for the Belt and Road Initiative (Lall and Lebrand, 2020; Bird, Lebrand, and Venables 2020); in Bangladesh (Herrera Dappe and Lebrand, 2019); and between Bangladesh and India (Herrera Dappe, Lebrand, and Van Patten 2021).

This paper contributes to the literature on several areas. It assesses the interactions between different types of infrastructure and how it affects the sectoral structure of employment at the district level. The paper also assess the spatial general equilibrium impacts of several planned transport investments and trade facilitation measures in neighboring countries that are at different stages of development.

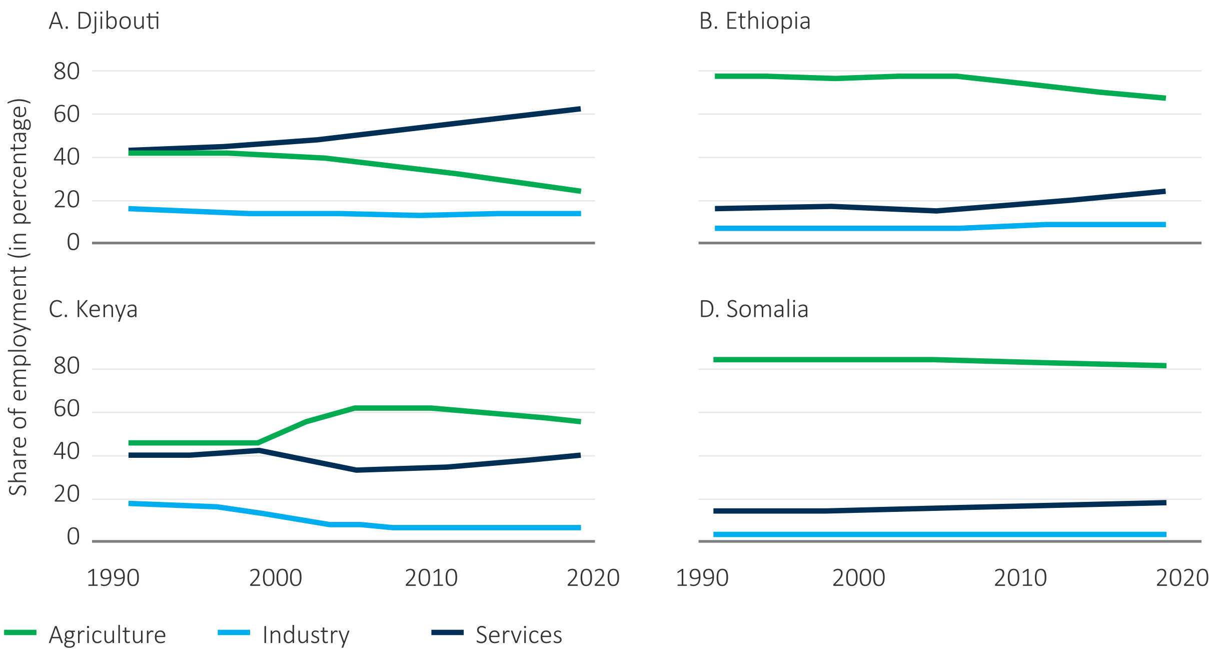
The paper is structured as follows. Section 2 provides an overview of the background in the Horn of Africa. Section 3 includes details of the data used in our analysis. Section 4 presents the empirical strategy and results. Section 5 develops a spatial general-equilibrium model to produce counterfactuals for more domestic and regional integration. Section 6 concludes.

SECTION 2

Background

Economic growth in the Horn had been relatively strong before the COVID-19 pandemic struck, but the subregion still lags behind other African countries and the pace of structural change has been slower than expected. At approximately $1,000, the per capita income in the Horn of Africa remains well below the Sub-Saharan African average of about $1,500. Structural transformation out of agriculture is at different stages across countries. Employment in nonagricultural sectors accounts for about 45 percent of total employment in Kenya, 35 percent in Ethiopia, and less than 20 percent in Somalia (figure 1). The share of employment in agriculture in Djibouti, Ethiopia, and Kenya has been declining since the mid-2000s. In contrast, it has stagnated at high levels in Somalia. The main challenge for the subregion is generating enough adequate-quality jobs through economic transformation.

Figure 1: Employment per sector in Horn of Africa countries, 1990–2020



Source International Labour Organization, ILOSTAT database.

Economic activity has been converging across the Horn of Africa, but not in the borderlands, which are lagging. Evidence from nightlights points to faster growth in economic activity in less built-up and less well-lit areas (1992–2018), consistent with shared economic development and "catch-up" dynamics. However, a critical exception to this pattern is that border areas show slower growth relative to more developed, core areas. Little development is taking place in these areas, extending their historical marginalization and character as lagging, peripheral regions. Whether regional integration through improved connectivity and lower frictions at the borders will lead to stronger development in the lagging areas remains to be seen.

The extent and quality of infrastructure networks varies across the Horn; the subregion is a collection of national spaces rather than an integrated economic space. Ethiopia undertook significant investments in roads and electricity over the last decade, which lead to expansion in the road and electricity network. The all-weather road network expanded roughly fourfold between the late 1990s and the late 2010s, and the electricity network doubled, from 95 to 191 major electric substations (Moneke 2020). But the country still lags Kenya in access to electricity and all-weather roads in rural areas. Only 55 percent of the population had access to electricity in Ethiopia in 2018, a smaller share than in Djibouti (60 percent) or Kenya (75 percent). Access to all-weather roads and electricity is lagging in remote areas in Kenya, including the northern border areas. Somalia has limited infrastructure coverage. Only 32 percent of its rural population lived within 2 kilometers of an all-weather road in 2016, and only 35 percent of the total population had access to electricity in 2018. The Internet backbone fiber network and mobile coverage increased significantly in recent decades. Access in the region is still low, however, at 2 percent of the population in Somalia, 19 percent in Ethiopia, 22 percent in Kenya, and 56 percent in Djibouti in 2019.

SECTION 3
Data

This paper uses household survey data that have been georeferenced, new spatial infrastructure data, and district characteristics in order to study links between access to infrastructure and the structure of local economies as well as the complementarities between types of infrastructure.

Infrastructure

We collected new information on road network expansions, access to the electricity network, and access to Internet fiber backbone from various sources (table 1).

Table 1: Sources of infrastructure data

Type of infrastructure	Country	Years	Source
Roads	Ethiopia Kenya	1996, 2006, 2016 2003, 2009, 2016–18	Ethiopian Roads Authority (ERA) Kenya Road Board
Electricity	All	Varies across countries	Nighttime lights (VIIRS for 2016, DMSP for 1992-2013) / population raster (World Pop)
Electricity grid	All All	Around 2006 Most recent	Foster and Briceno-Garmendia (2010) gridfinder.org and Arderne et al. (2020)
Internet (fiber backbone)	All	2009–2019	Africa Bandwidth Maps 2009–19

Source: Authors.

We gathered geospatial maps of road expansion using government sources as well as previously harmonized collections of road networks (Foster and Briceno-Garmendia 2010; Jedwab and Storeygard 2020). The quality of the network and associated features and the frequency of updates vary across countries. For Ethiopia and Kenya, we used a rich panel of data on road network expansions complemented by details on road conditions (a panel of GIS data and maps for 1996, 2006, and 2016 for Ethiopia and 2003, 2009, and 2018 for Kenya that rely at least partially on actual road surveys). Panels of roads from the same source are rare. Figures A.2 and A.3 show the extensions of the paved road network for Kenya and Ethiopia. Related papers studying the expansion of the Ethiopian road network are Adamopoulos (2019), Gebresilasse (2019), and Kebede (2019), all of which focus on the feeder roads from the 2016 Ethiopian Roads Authority survey. The study by Moneke (2020), which focuses on all-weather (gravel, asphalt, or bitumen surface) roads, is closer to this study.

We used two methods to map access to the electricity network: nighttime lights and maps of power transmission grids. Nighttime light data are available for most years and locations but convey imperfect information on electrification. Historical maps of electricity grids are more difficult to find and use in a consistent way. We used satellite images of annualized nighttime lights (VIIRS for 2016, DMSP for 1992-2013) and population rasters from World Pop to calculate the percentage of the population that was electrified (lived in settlements that produce some light at night). We compared the results for two metrics: a dummy that is equal to one if at least 10 percent of the population has access to electricity and the share of the electrified population per district. Such methods have been used before to estimate electricity access in remote areas and guide grid extension programs.[2] This method assumes that locations that emit lights at night are in settlements that have electricity access and that their electricity is most likely supplied from an electrical grid. It assumes that small off-grid systems do not emit enough light to be captured by satellites but that larger isolated power networks do. We cross-checked the numbers obtained with country estimates of electrified population from the World Bank.[3] Figure A.1 in the appendix shows the share of the population in Ethiopia and Kenya with access to electricity.

We also collected information on transmission grids based on past efforts to harmonize data for infrastructure from primary sources and recent mapping strategies to infer the electricity grids based on satellite data. For past data, we used electricity grids from the Africa Infrastructure Country Diagnostic (AICD), which collected primary data covering network service infrastructure from 2001 to 2006 in 24 African countries (Foster and Briceno-Garmendia, 2010). To complement these data, we relied on a recent effort by the World Bank; Facebook; and other institutions (the KTH Royal Institute of Technology, the Energy Sector Management Assistance Program [ESMAP], World Resources Institute, and the University of Massachusetts Amherst) to use remote sensing, machine learning, and big data to map connected populations and the systems that support them. This group created an algorithm for estimating the location of medium-voltage infrastructure based on nighttime lights and the location of roads assuming that medium-voltage lines are more likely to follow (or be followed by) main roads.[4] Figure A.4 in the appendix shows the grid for the Horn of Africa using the AICD grid and using the most recent grid.

Internet infrastructure is proxied by access to the fiber broadband backbone network. We obtained data for all Africa for 2009–20 from Africa Bandwidth Maps, which provides the exact location of fiber nodes along the backbone network. We constructed a proxy for access to the fiber backbone that is equal to one if there is a node of the backbone in the location of interest. Each node has a year attribute, which allows us to build a panel for access to the backbone. We assume that access before 2008 was null everywhere, an assumption that is supported by World Bank data on access to Internet, which reports that less than 4 percent of individuals in Sub-Saharan countries (including high-income countries) had access to Internet in 2008. We confirmed our figures by cross-checking them against World Bank indicators reporting the percentage of the population using Internet.[5] Figure A.5 in the appendix shows the access to Internet in Ethiopia and Kenya.

Employment

We are interested in structural transformation, which we interpret as changes in sectoral employment, in line with the literature (Herrendorf et al. 2014). We derive sectoral employment shares from Demographic and Health Surveys (DHSs), which produce harmonized survey data with GPS coordinates for most surveys and are available for several rounds per country. The DHS is a repeated cross-section of enumeration areas (EA), with approximately 20–30 households enumerated per EA. Four rounds of survey data are covered in Ethiopia (2000, 2005, 2011, 2016) and four in Kenya (1991, 2003, 2009, 2018). For Ethiopia, the DHS rounds included 12,751 individuals in 2000, 14,052 in 2005, 21,080 in 2011, and 19,157 in 2016, from approximately 650

---

2 An example of mapping rural electrification based on night-time lights can be found at http://india.nightlights.io/.

3 The World Bank reports access to electricity (percent of population) for most countries for a long period at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS.

4 Details can be found in Arderne et al. (2019) and Arderne et al. (2020).

5 The World Bank reports access to Internet (percent of population) for most countries for a long time period. See https://data.worldbank.org/indicator/WeT.NET.USER.ZS.

EAs, which differ per round. Djibouti and Somalia did not conduct DHSs.

We use DHS data for which we have access to the occupation of the individuals as well as a proxy for their location. In order to construct the shares of employment per sector, we use respondents' answers to questions about their current occupation. We first compute the shares of nonworking individuals and then group all working individuals into three sectors: agriculture, manufacturing, and services. We aggregate individual responses within each EA and then generate an unbalanced panel of districts that had at least one EA during a survey round. The DHS–provided GPS coordinates for EA locations are not perfectly reliable because of the common random displacement applied to GPS coordinates for anonymity.[6] We aggregate EAs per geographic location.

District Characteristics

We use additional data to control for district heterogeneity. We use population data from the Global Human Settlement Layer (GHSL),[7] land categories from the European Space Agency land cover (see Defourny 2017), distance from the coast from the Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG),[8] distance to the border,[9] access to a city larger than 50,000 inhabitants from the Malaria Atlas Project,[10] temperature from Land Processes Distributed Active Archive Center,[11] and elevation from CGIAR-CSI.[12]

6 DHS coordinates of rural (urban) EAs are randomly displaced within a 0–10 kilometer (0–5 kilometer) radius.

7 Population count from the Global Human Settlement Layeris based on population data from Gridded Population of the World v4.10 polygons, distributed across cells using the GHSL global layer. Source data are provided in 9 arc-second (250 meters) grid cells.

8 Distance to the coast (on land only) is measured in meters. It is derived using World Vector Shorelines (Wessel and Smith 1996).

9 Distance to country borders is measured in meters. It is derived using the database of Global Administrative Areas (GADM) 2.8 ADM0 (Country) boundaries.

10 Data incorporate data from Open Street Map (OSM) and the Google roads database. See Weiss et al. (2018).

11 Yearly daytime land surface temperature are from Wan, Hook, and Hulley (2015).

12 Global elevation (in meters) are from Shuttle Radar Topography Mission (SRTM) dataset (v4.1) at 500-meter resolution. See Jarvis et al. (2008).

SECTION 4

Empirical Strategy and Results

4.1 Ordinary Least Squares

Our first empirical strategy uses panel ordinary least squares (OLS) regressions that include year and country fixed effects and a battery of initial district-level controls. The OLS specification is

$$
\begin{aligned}
Sector_{i,c,t} = {} & \alpha+\beta^{R} Paved\ road_{i,c,t} + \beta^{E} Electricity_{i,c,t} + \beta^{I} Internet_{i,c,t} \\
& +\gamma^{RE}\ Paved\ Road_{i,c,t} * Electricity_{i,c,t} + \gamma^{RI}\ Paved\ Road_{i,c,t} * Internet_{i,c,t} \\
& + Controls_{i,c,t} + FE + \epsilon_{i,c,t}
\end{aligned}
$$

where $\boldsymbol{Sector_{i,c,t}}$ is the share of employment in agriculture, manufacturing or services for district $\boldsymbol{i}$ in country $\boldsymbol{c}$, at year $\boldsymbol{t}$. *Paved Road*$_{i,c,t}$ is a dummy variable that takes a value of one if location $\boldsymbol{i}$ in country c contains a paved road at year $\boldsymbol{t}$. ***Electricity***$_{i,c,t}$ is a dummy variable that takes a value of one if location $\boldsymbol{i}$ in country $\boldsymbol{c}$ has more than 10 percent of its population with lights at night at year $\boldsymbol{t}$. ***Internet***$_{i,c,t}$ is a dummy variable that takes a value of one if location $\boldsymbol{i}$ in country c has more than 10 percent of its population with lights at night at year *t. Paved Road*$_{i,c,t}$***Electricity*$_{i,c,t}$ captures the interaction of the road and electricity infrastructure, and *Paved Road*$_{i,c,t}$***Internet*$_{i,c,t}$ the interaction of the road and internet infrastructures. We add interaction effects between the dummies to better understand the complementarities between infrastructures. We do not include an interaction effect for electricity and Internet, as access to Internet is assumed to rely on electricity access. ***Controls***$_{i,c,t}$ represents the additional location-specific controls, which include initial district population, access to a main city, land size, distance to the coast, distance to the border, access to a city of more than 50,000 inhabitants, temperature, and elevatio. ***FE*** is the year and country fixed-effects. The coefficients β capture the correlation between access to a type of infrastructure on the different sectoral employment shares, while the coefficients γ capture the infrastructure interaction terms.

We identify several identification challenges. Infrastructure investments are likely endogenously allocated with respect to the outcomes of interest. Given the high cost of infrastructure investments, conscious allocation decisions are to be expected (by, for example, targeting high growth potential locations or politically demanded locations). Measurement error in the right-hand side variables may lead to attenuation bias (from, for example, inaccurate information on the timing of infrastructure expansion or imprecise historic road and grid maps). Measurement errors, which are expected to be large in this case, lead to an OLS estimate that is biased toward zero.

We report results for the unbalanced panel of districts that include at least one EA. We first estimate local average associations of the three infrastructure investments—roads, electricity, and Internet—and the interaction between these investments on sectoral employment at the district-year level. Then we analyze within-country heterogeneity in structural transformation across districts. All regressions exclude the Somali region of Ethiopia, because coverage of this region in the DHS data is poor.

Average effects

We start with a regression that includes all countries in the Horn of Africa. We then compare the results by country. Throughout, standard errors are clustered at the district level, the level of treatment.

Horn of Africa

Access to electricity is associated with a transformation away from agriculture in the Horn of Africa. Table 2 reports the results of pooling data from Ethiopia and Kenya. Having access to electricity at the district level is associated with a 6 percentage-point reduction in the employment share of agriculture and a 4 percentage-point increase in the employment share of services. Big-push investments that combine paved roads and Internet are also associated with structural changes in employment. The combined investments are associated with a 12 percentage-point additional increase in the share of employment in services. Table A.1, in the appendix, presents the results using the dummy variable, which capture electricity access based on grid expansion.

Table 2: OLS results for Horn of Africa

	Agriculture	Manufacturing	Services
Paved road	-0.0152	0.0113	0.00451
	(-0.70)	(0.92)	(0.25)
Internet	0.0344	0.0126	-0.0641
	(0.52)	(0.26)	(-1.34)
Electricity	-0.0573**	0.0122	0.0407**
	(-3.04)	(1.45)	(2.78)
Road + Internet	-0.0979	0.000701	0.121*
	(-1.41)	(0.01)	(2.41)
Road + Electricity	-0.0290	0.0157	0.0159
	(-1.16)	(1.14)	(0.80)
Year + Country fixed effect	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.426	0.308	0.369
Number of observations	1,887	1,887	1,887

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

By Country

In Ethiopia, access to electricity and big-push investments are associated with a reduction in agriculture employment and an increase in employment in manufacturing and services (table 3). At the district level, having access to electricity is associated with a 6.2 percentage-point reduction in the agriculture employment share, an almost 2 percentage-point increase in the manufacturing employment share, and a 4.5 percentage-point increase in the employment share of services. By itself, having access to a paved road is not associated with any change in employment.

Table 3: OLS results for Ethiopia

	Agriculture	Manufacturing	Services
Paved road	0.0154	-0.00257	-0.0128
	(0.47)	(-0.17)	(-0.52)
Internet	0.0804	-0.0287^{+}	-0.0516
	(1.28)	(-1.89)	(-0.88)
Electricity	-0.0624**	0.0173*	0.0452**
	(-3.14)	(2.05)	(2.98)
Road + Internet	-0.206**	0.0592**	0.147*
	(2.73)	(-2.84)	(2.27)
Road + Electricity	-0.0664^{+}	0.0325^{+}	0.0338
	(-1.65)	(1.78)	(1.14)
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.291	0.099	0.311
Number of observations	1162	1162	1162

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

Big-push investments that combine investments in roads and electricity or Internet are associated with changes in employment away from agriculture toward the manufacturing and services sectors. These findings are similar to those of Moneke (2020). Combined investment in roads and electricity is associated with a reduction in the employment share of agriculture of almost 13 percentage points and an increase in the employment share of manufacturing of almost 5 percentage points. Combined investment in roads and Internet is associated with a reduction in the employment share of agriculture of almost 21 percentage points, an increase in the employment share in manufacturing of 3 percentage points, and an increase in the employment share of services of almost 15 percentage points. The findings on manufacturing indicate that the reductions in transport costs might not be enough to lead to expansion of the manufacturing sector but that once combined with investments in Internet and electricity, which increase productivity, the manufacturing sector benefits from lower transport costs.

Table 4 reports the results of the regression for Kenya only. Access to Internet alone is associated with an increase in the share of manufacturing employment; but combined access to Internet and paved roads is associated with a reduction in the share of manufacturing employment. Combined investment in paved roads and Internet has a positive impact on the share of services employment, however.

Table 4: OLS results for Kenya

	Agriculture	Manufacturing	Services
Paved road	-0.0255	0.0213	0.00418
	(-0.70)	(0.88)	(0.12)
Internet	-0.0591	0.185^{+}	-0.126
	(-0.32)	(1.74)	(-1.35)
Electricity	-0.0992	0.0353	0.0638
	(-1.49)	(1.06)	(1.02)
Road + Internet	0.0358	-0.198^{+}	0.162^{+}
	(0.19)	(-1.84)	(1.69)
Road + Electricity	0.0218	-0.00950	-0.0123
	(0.32)	(-0.26)	(-0.19)
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.298	0.200	0.298
Number of observations	725	725	725

Note: t statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

Heterogenous effects

This section analyzes the within-country heterogeneity in structural transformation across districts, focusing on the share of agricultural employment and the population-weighted distance to the largest town, as in Moneke (2020).

By share of agricultural employment

Table 5 confirms the spatial heterogeneity of outcomes across districts in Ethiopia. Results are reported for quantile 0.25 (49 percent of employment in agriculture), quantile 0.5 (75 percent of employment in agriculture), and quantile 0.75 (90 percent of employment in agriculture). Access to electricity only is associated with a reduction in the shares of agriculture employment in all districts, with the association strongest in districts with low shares of agriculture employment. Access to roads and electricity is also associated with the largest reduction in the share of agricultural employment in less agricultural districts. These results are in line with Moneke (2020).

Table 5: Heterogenous effects on employment in agriculture in Ethiopia, by initial share of agricultural employment

Share of employment in agriculture	Quantile 0.25 (49%)	Quantile 0.5 (75%)	Quantile 0.75 (90%)
Paved road	0.0385	0.0485	0.0119
	(1.11)	(0.95)	(0.62)
Internet	0.129	0.0978	–0.0448
	(1.02)	(0.87)	(–1.07)
Electricity	–0.112**	–0.0395+	–0.0268*
	(-3.40)	(-1.69)	(–2.41)
Road + Internet	–0.203	-0.303*	–0.0954
	(–1.31)	(–2.02)	(–1.28)
Road + Electricitity	-0.153**	-0.106 +	–0.0236
	(–3.25)	(–1.90)	(–1.17)
Year fixed effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Number of observations	1162	1162	1162

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

By distance to a main city

Do changes in the shares of manufacturing and services employment associated with access to infrastructure vary with distance to large towns? Table 6 reports the estimation results for the share of manufacturing employment across quartiles of distance to a town of at least 50,000 inhabitants for Ethiopia. Expansions in Internet access are associated with reductions in the share of manufacturing employment in districts close to towns (second quartile of distance) and increases in manufacturing employment in districts far from towns (fourth quartile of distance). These results may indicate that in isolated districts, access to Internet provides firms with information that helps them increase productivity and access to new customers but that firms in such districts are protected from outside competition because of high transport costs. In contrast, in districts close to large towns, Internet access may increase competition from products from other parts of the country (Moneke 2020; Behrens et al. 2006).

Table 6: Heterogenous effects on employment in manufacturing in Ethiopia, by distance to a main city

Share of employment in manufacturing	Quartile 2	Quartile 3	Quartile 4
Paved road	–0.0322	0.0460	–0.0280
	(–1.65)	(1.25)	(–1.31)
Internet	-0.0820**	–0.00571	0.0646+
	(–3.70)	(–0.13)	(1.89)
Electricity	0.0179	0.0214	0.00411
	(0.96)	(1.17)	(0.30)
Road + Internet	0.110*	0.0325	0
	(2.32)	(0.52)	(.)
Road + Electricity	0.0419+	–0.0362	0.0854**
	(1.89)	(–0.84)	(2.95)
Year fixed effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Number of observations	0.261	0.158	

Note: *t* statistics in parentheses.
+$p < 0.10$, * $p < 0.05$, ** $p < 0.01$

In Ethiopia, investments that combine types of infrastructure are associated with increases in the share of manufacturing employment in districts that are closest to a main town (quartile 2) and farthest away (quartile 4). Isolated investments in roads or Internet are either not associated or negatively associated with changes in the share of employment in manufacturing. In contrast, bundled investments in roads and Internet are associated with increases in the share of manufacturing employment, particularly in districts close to large towns. These results suggest that even though improvements in road access can increase competition from manufactures from other parts of the country, the reduction in transport costs benefits the manufacturing sector. The positive coefficient of combined road and electricity investments supports such argument.

Table 7 reports similar results for employment in the services sector. Isolated investments in roads and Internet are associated with a negative impact on services employment in locations close to a main town (quartile 2), but bundling road and Internet investments is associated with large increases in the share of services employment. In districts that are farther away, isolated investments in electricity (districts in quartile 3) or roads (districts in quartile 4) are associated with larger shares of employment in services; bundling investments is less of a priority in isolated regions.

Table 7: Heterogenous effects on service employment in Ethiopia, by distance to a main city

Share of employment in services	Quartile 2	Quartile 3	Quartile 4
Paved road	−0.0381	−0.00549	0.0672*
	(−1.73)	(−0.29)	(2.15)
Internet	−0.132**	−0.00343	0.0448
	(−4.21)	(−0.14)	(1.19)
Electricity (>10p)	0.0269	0.0601**	0.0137
	(0.96)	(2.73)	(0.43)
Road + Internet	0.167**	0.0252	0
	(3.52)	(0.51)	(.)
Road + Electricity	0.0236	−0.0404	0.0442
	(0.67)	(−1.17)	(1.01)
Year fixed effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Number of observations	0.261	0.158	0.269

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

4.2 Instrument Variables

In this section, we use an instrumental variables identification strategy to deal with the potential endogeneity in the placement of the infrastructure. We instrument both roads and electricity, and the interaction terms.

We instrument electrification and access to a paved road. Regarding electrification, the instrumental variable relies on four assumptions. First, electricity generation must be connected to demand, which comes mostly from the main cities. Second, the sources of energy generation that are identified are the main sources of electricity generation. Third, the locations of the supply sources are exogenous to economic geographic development. Finally, the locations between the generation sources and the main demand centers are more likely to be electrified.

We identified two sources of energy generation that can be used for the IV strategy: dams for hydroelectricity and wind farms. The main sources of energy supply are hydropower in Ethiopia and hydropower and wind in Kenya (table 8). Similar to Moneke (2020), we developed an IV that yields a hypothetical electrification status based on a location's proximity to a straight-line corridor from electricity generators to the main cities. We identified the locations of the electricity generators using two databases, one on the opening year of dams and another on the locations of power plants (Platts database). For Ethiopia, we used a database including all dams in Africa, their location, and their year of opening. For Kenya, we used the global power plant database, which includes the capacity and year of commissioning of all power plants by type of energy (hydro, wind, gas, and geothermal). From the year of the dam opening or power plant commissioning onward, all districts lying along the straight lines connecting the dams or power plants to the main demand centers are considered as having access to electricity. We then identified the main sources of demand in each country (Addis Ababa in Ethiopia and Nairobi and Mombasa in Kenya).

Table 8: Sources of energy for electricity production in Ethiopia and Kenya, 1990 and 2015 (percent of total)

	1990		2015	
Source of energy	Ethiopia	Kenya	Ethiopia	Kenya
Hydro	89	81	93	39
Renewable, excluding hydro	0	14	7	48
Oil, gas, and coal, and others	11	5	0	13

Our IV satisfies the main assumptions of an IV strategy. The choice of location of hydro and wind generators can be assumed to be driven by geographic and climatic characteristics of the locations and not by economic activity in the area. The timing of opening can be considered exogenous, as years of delay are common for such projects. The random assignment assumption of the IV would imply that a district's inclusion along a straight-line corridor is spatially and temporally as good as random assignment.

To instrument for the timing of a district's paved road connection, we find the optimal network to connect all cities with more than 50,000 inhabitants in a least-cost fashion by using common minimum spanning tree algorithms, such as Kruskal's and Boruvka's algorithms. The list of cities with more than 50,000 inhabitants varies over time because of changes in population, which creates a panel of roads for each country.

We run a two-stage least squares (2SLS) regression on the following specifications, with province and year fixed effects and district-level initial values as controls:[13]

$$
\begin{aligned}
Road_{i,t}\#Electricity_{i,t} &= \alpha + \beta^{R} RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 0) \\
&\quad + \beta^{E}\,(RoadIV_{i,t} = 0 \;\&\; ElectricityIV_{i,t} = 1) \\
&\quad + \gamma^{RE}(RoadIV_{i,t} = 1 \;\&\; ElectricityIV_{i,t} = 1) + \beta^{I}\, Internet_{i,t} + Controls_{i} \\
&\quad + FE + \epsilon_{i,t}
\end{aligned}
$$

where $Road_{i,t}\#\,Electricity_{i,t}$ is one of the interactions terms between the dummies $Road_{i,t}$ and $Electricity_{i,t}$.

The second stage equation is given by:

$$
\begin{aligned}
&Sector_{i,t} = \\
&\alpha + \beta^{R,SLS}(RoadIV_{i,t} = 1 \;\&\; \widehat{ElectricityIV}_{i,t} = 0) \\
&+ \beta^{E,SLS}\,(RoadIV_{i,t} = 0 \;\&\; \widehat{ElectricityIV}_{i,t} = 1) \\
&+ \gamma^{RE,SLS}(RoadIV_{i,t} = 1 \;\&\; \widehat{ElectricityIV}_{i,t} = 1) + \beta^{I,SLS}\, Internet_{i,t} \\
&+ Controls_{i} + FE + \epsilon_{i,t}
\end{aligned}
$$

where $Sector_{i,t}$ is the share of employment in agriculture, manufacturing, or services in district i in year t.

13 District-level control variables are interacted with the country dummy such that the effects of distances can be compared only within countries.

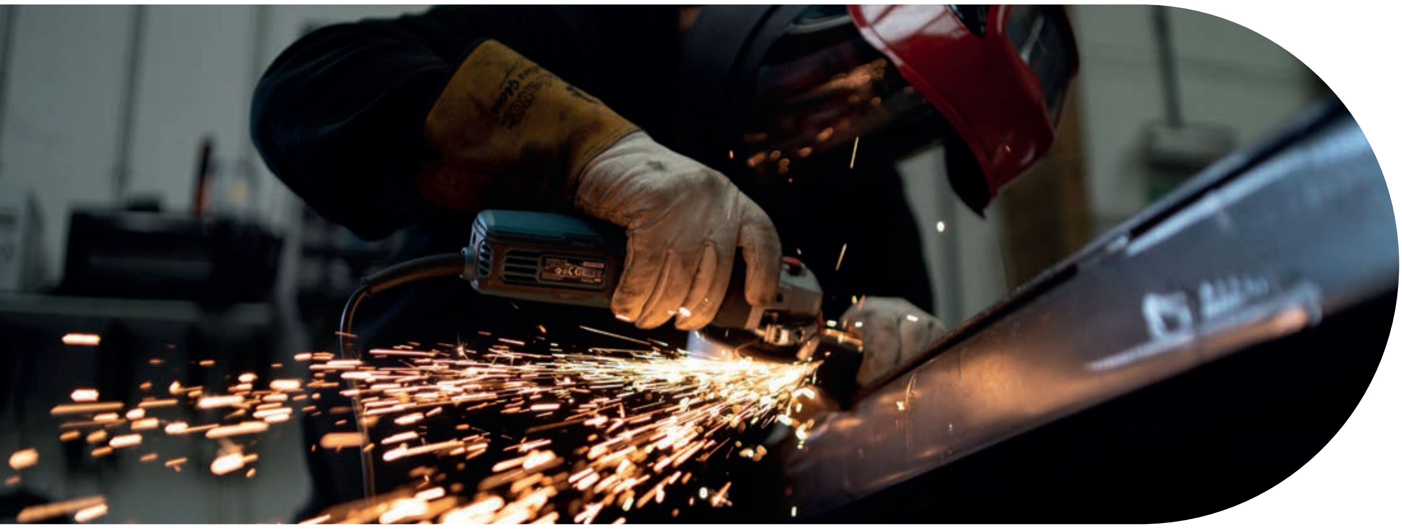
Table 9 reports the results for the 2SLS method for Ethiopia and Kenya. First-stage results and weak instrument tests are available on demand. Access to electricity led to only a 7.7 percentage-point decrease in the share of agriculture employment and a 6.2 percentage-point increase in the share of services employment; access to paved roads led to only a 3.2 percentage-point increase in manufacturing employment. Districts with access to paved roads and electricity saw a 5.2 percentage-point shift of workers from agriculture to manufacturing. Access to Internet was associated with a 2 percentage-point increase in service employment.

Table 9: Two-stage least squares regression results for Ethiopia and Kenya

Share of employment	Agriculture	Manufacturing	Services
Paved road=0 x Electricity=1	-0.295*	0.102	0.193*
	(-2.42)	(1.60)	(2.11)
Paved road=1 x Electricity=0	-0.0506+	0.0491**	0.00150
	(-1.21)	(2.74)	(-0.25)
Paved road=1 x Electricity=1	-0.150*	0.0955**	0.0548
	(-2.37)	(3.16)	(1.05)
Internet	-0.0335+	-0.00192	0.0354*
	(-1.80)	(-0.18)	(2.26)
Year + province FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.563	0.425	0.492
Number of observations	1887	1887	1887

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

Table 10 reports the results of the IV specification for Ethiopia only. Access to paved roads and electricity led to a 7.6 percentage-point increase in manufacturing employment and a 7 percentage-point decrease in Ethiopian districts. These findings are similar to the findings in Moneke (2020).[14]



[14] The results go in the same direction, but the coefficients vary, because the specification differs and the instruments are not the same.

Table 10: Two-stage least squares regression results for Ethiopia

Share of employment	Agriculture	Manufacturing	Services
Paved road=0 x Electricity=1	-0.404**	0.192**	0.211*
	(-2.94)	(2.96)	(2.16)
Paved road=1 x Electricity=0	-0.0659*	0.0577**	0.00824
	(-2.26)	(4.09)	(0.38)
Paved road=1 x Electricity=1	-0.191*	0.153**	0.0378
	(-2.25)	(4.27)	(0.55)
Internet	-0.0615+	0.00496	0.0565+
	(-1.65)	(0.30)	(1.88)
Year + province FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.425	0.174	0.427
Number of observations	1162	1162	1162

Note: *t* statistics in parentheses.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Access to electricity reduces the share of employment in agricultural activities, moving workers to the services sector when there is no paved road and to the manufacturing sector when there is one. On its own, access to paved roads increases the share of manufacturing employment, as it did for Ethiopia and Kenya combined.

SECTION 5

Welfare Impacts of Infrastructure

This section presents the general equilibrium model we use to assess the welfare impacts of infrastructure investments, including the calibration of the model, and shows the results under several counterfactual scenarios.

5.1 The Model

The spatial general equilibrium model is based on Moneke (2020). It is characterized by the following features. Locations differ in their productivity, geography, and trade links. Road investments are assumed to have general equilibrium effects via changes in trade costs and the resulting reallocation of labor across space, as in Allen and Arkolakis (2014) and Redding (2016). Electrification investments are assumed to have general equilibrium effects via productivity, similar to models of differential productivity shocks across space such as Bustos, Caprettini, and Ponticelli (2016). The economy is assumed to consist of multiple sectors of production, such that changes in sectoral employment across locations (i.e., spatial structural transformation) capture an outcome of interest, as in Michaels, Rauch, and Redding (2011) and Eckert and Peters (2018).

Compared to Moneke (2020), we consider a geography that includes several countries that can trade with each other, with additional trade barriers applying for cross-border trade. Workers can move across locations within but not across countries.

The whole geography consists of many locations $n \in N$ of varying land size H_n and endogenous population L_n. Consumers value consumption of agriculture goods, C^T , manufacturing goods, C^M , services, C^S, and land, h. The utility of a representative household in location n is assumed to follow an upper-tier Cobb-Douglas functional form over goods and land consumption, scaled by a location-specific amenity shock V_n:

$$U_n = V_n C_n^a h_n^{1-a}$$

with 0<α<1. The goods consumption index is defined over consumption of each tradable sector's composite good and services:

$$C_n = [\psi^T (C_n^T)^{\rho} + \psi^M (C_n^M)^{\rho} + \psi^S (C_n^S)^{\rho}]$$

assuming consumption of sectoral composite goods to be complementary

$$(0 < \kappa = \frac{1}{1-\rho} < 1)$$

Consumers exhibit love of variety for both tradeable sectors' goods, C^T and C^M, which we model in the standard CES fashion, where n denotes the consumer's location and i the producer's location, whereas j is a measure of varieties. Consumption of each tradeable sector's good is defined over a fixed continuum of varieties $\mathrm{j} \in [0, 1]$:

$$C_n^T = \left[\sum_{i \in N} \int_0^1 \left(C_{ni}^T(j) \right)^v dj \right]^{1/v}$$

where v is the elasticity of substitution across varieties, such that varieties within each sector are substitutes for each other $\sigma = \frac{1}{1-v} > 1$. An equivalent formulation is used for C^M. The following equation provides the classic Dixit-Stiglitz price index over traditional sector goods:

$$P_n^T = \left[\sum_{i \in N} \int_0^1 \left(p_{ni}^T(j) \right)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}}$$

On the production side, there are two tradable sectors from which firms produce varieties that can be traded across many other locations. Production uses labor and land as inputs under constant returns to scale subject to stochastic location:

$$Y_n^i = Z^i \left(\frac{L_n^i}{\mu^i} \right)^{\mu^i} \left(\frac{h_n^i}{1 - \mu^i} \right)^{1 - \mu^i} \qquad i = T, M$$

where $0 < \mu^i < 1$ and, z^i denotes the sector-location-specific realization of productivity z for a variety in sector i and location n. Following Eaton and Kortum (2002), locations draw sector- specific idiosyncratic productivities for each variety j from a Fréchet distribution:

$$F_n^i \left(Z^i \right) = e^{\left(-A_n^i z^i \right)^{-\theta}} \qquad i = T, M$$

where A_n^i is the average sectoral productivity in location n. The shape parameter, θ , determines the variability of productivity draws across varieties in a given location n.

Trade in both sectors' final goods is costly, and trade costs are assumed to follow an iceberg structure. Trade costs between locations n and m are denoted as d_{nm}, such that quantity d_{nm} has to be produced in m for one unit to arrive in n. We assume that trade costs are the same across sectors and are symmetric.

Given perfect competition in both production sectors, the price of a given i-sector variety equals marginal cost inclusive of trade costs:

$$p^i_{nm} = \frac{\omega_m^{\mu^i} r_m^{1-\mu^i} d_{nm}}{z^i_m}$$

where $\omega_m^{\mu^i}$ is the wage of a worker and r_m the price of land.
Each location n will buy a given variety from its minimum-cost supplier location m:

$$p^i_{nm} = \mathit{min}\ \{p^i_{m,} m \in N\}$$

The share of expenditure that the destination location n spends on agricultural sector (and equivalently manufacturing sector) goods produced in origin m is given by

$$\pi^i_{nm} = \frac{A^i_m \left(\omega_m^{\mu^i} r_m^{1-\mu^i} d_{nm}\right)^{-\theta}}{\sum_{k \in N} A^i_k \left(\omega_m^{\mu^i} r_m^{1-\mu^i} d_{nk}\right)^{-\theta}}$$

Production of non-tradable services also uses labor and land as inputs, but output is a single homogeneous service. We assume agriculture to be the most and services the least land-intensive sector $\mu^T < \mu^M < \mu^S$.

Within each location, the expenditure share on each tradable sector's varieties and services depends on the relative (local) price of each sector's (composite) good:

$$\xi^K_n = \frac{(\psi^K)^\kappa (P^K_n)^{1-\kappa}}{(\psi^M)^\kappa (P^M_n)^{1-\kappa} + (\psi^T)^\kappa (P^T_n)^{1-\kappa} + (\psi^S)^\kappa (P^S_n)^{1-\kappa,}} \qquad K \in \{T, M, S\}$$

Given the properties of the Fréchet distribution of productivities, tradable sectoral price indices can be further simplified:

$$P^i_n = \gamma \left[\sum_{k \in N} A^i_k \left(\omega_k^{\mu^i} r_k^{1-\mu^i} d_{nk}\right)^{-\theta}\right]^{-1/\theta} = \gamma\, (\Phi^T_n)^{-1/\theta}$$

To arrive at a spatial equilibrium, we provide conditions for land market clearing, labor market clearing, and a labor mobility condition. For an equilibrium in the land market, total income from land must equal total expenditure on land, where the latter summarizes land expenditure by consumers, M-sector firms, T-sector firms and S-sector firms. Similarly, labor market clearing requires that total labor income earned in one location must equal total labor payments across sectors on goods purchased from that location everywhere. We assume that workers can freely move across locations within but not across countries. Free mobility of workers across locations within a country therefore implies that the wage earned by workers in each location after correcting for land and goods prices, as well as a location's amenity value, must be equalized across locations within a country. The welfare in each location of a same country c is given by:

$$V_{n,c} = \overline{V}_c = \frac{\alpha^{\alpha}\,(1-\alpha)^{1-\alpha} V_{n,c}\,\omega_{n,c}}{[P_{n,c}]^{\alpha/(1-k)}\, r_{n,c}^{1-\alpha}},\ \forall n \in \text{country}$$

where $P_{n,c}=(\phi^{M})^{\kappa}(P^{M}_{n,c})^{1-\kappa} + (\phi^{T})^{\kappa}(P^{T}_{n,c})^{1-\kappa} + (\phi^{S})^{\kappa}(P^{S}_{n,c})^{1-\kappa}$. We follow the specification in Moneke (2020) and Michaels, Rauch, and Redding (2011) to include the district-specific parameter $V_{n,c}$ in the wage, so that the welfare can be interpreted as the real income in each location.

5.2 Calibration of the Model

We calibrate the model by using some parameters from the literature and recovering the key productivity parameters and wages to obtain an equilibrium for the current situation. Table A.2 in the appendix reports the parameters from the literature used to calibrate the model, which are similar to the ones in Moneke (2020). We use the sectoral labor shares from Ethiopia in both Ethiopia and Kenya. To recover the productivity parameters, we use the labor market–clearing conditions, the land market conditions, and the labor mobility conditions. For each location, the model admits three equations for the three endogenous variables in each location—land market clearing, labor market clearing, and labor mobility condition—that allow us to solve for a general equilibrium of the model in terms of its core endogenous variables: wages, land rental rates, and population. Moneke (2020) shows the uniqueness of the equilibrium based on similar work by Michaels, Rauch, and Redding (2011). We obtain a series of $\{A^{T}_{n}, A^{M}_{n}, A^{S}_{n}\}_{n \in N}$ for which the distribution of population, employment, and land is an equilibrium given the current trade costs.

We calibrate the model to assess the welfare and spatial impacts of new transport investments. First, we calibrate the model to obtain the underlying parameters of the model for the baseline situation, without the new investments. Second, we update the trade costs based on the new assumptions. Third, we use the model to obtain the new employment shares given the new transport costs, the wage per location, and therefore the real wage given the new equilibrium goods and housing prices.

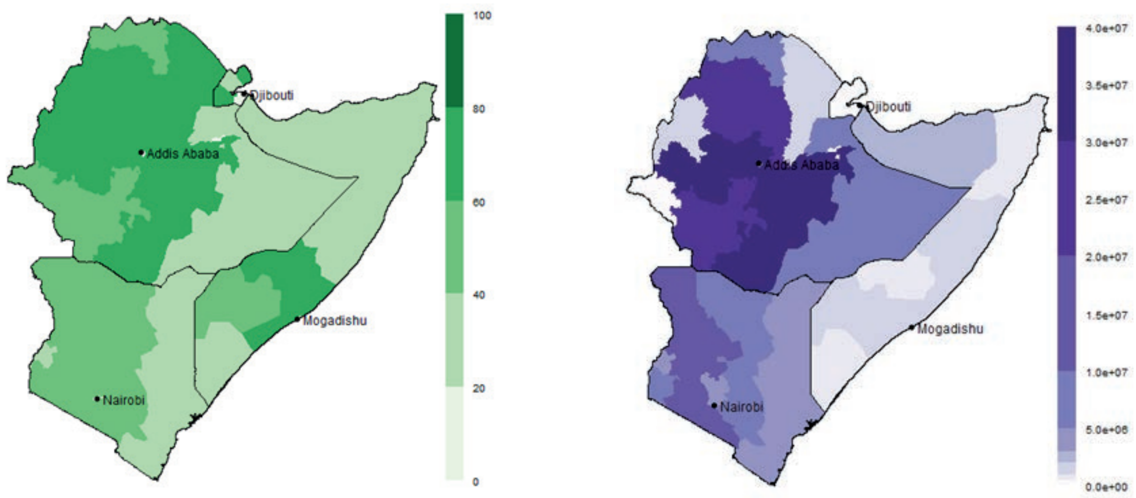
We use the available road networks for each country, making assumptions about speed along the networks based on the type and condition of roads that are registered. For Kenya, we used reported speed from our sources for the latest year. For other countries, we relied on additional features, such as the type of surface and the condition of the roads. Investments are assumed to increase the speed at which vehicles can travel along segments that are improved or build new links between locations. We assume trade costs to be iceberg costs, such that the costs between the origin location (o) and the destination (d) are given by $d_{od} = max\ (1,time^{\tau})$ Border costs are also added to trace costs, as detailed below.

We calibrate the model using spatial data for land, population, and sectoral shares from the sources used earlier. Because of the complexity of a three-sector model to converge in order to recover the initial sectoral productivities, we reduce the spatial disaggregation to fewer locations. Such aggregation also smoothed measurement issues of sectoral employment based on the DHS data. We divide the Horn of Africa into 32 regions, including 11 first-order administrative divisions in Ethiopia, 5 in Djibouti, 8 groupings of first-order administrative divisions in Somalia, and 8 groupings in Kenya. Figure 2 shows the share of agricultural employment and the population for each subnational region.

Figure 2: Descriptive statistics for the 32 regions in the Horn of Africa

A. Share of employment in agricultural sector (in percentage of total employed population)

B. Population



Source: Authors' calculations using DHS data from latest year available per country and population from GHS 2015.

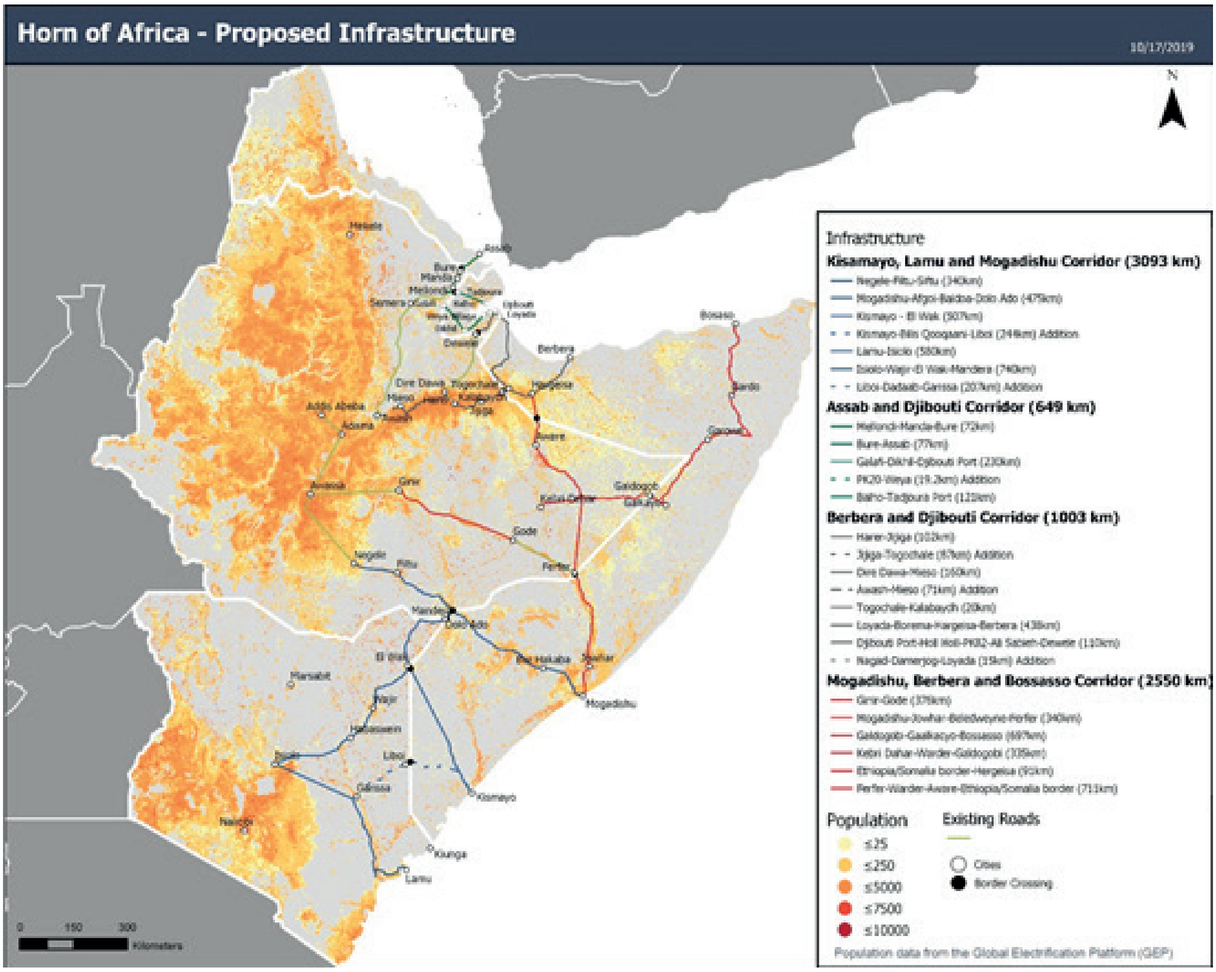
5.3 New transport infrastructure in the Horn of Africa

We investigate the impact of several regional transport corridors listed in table 11 and mapped in figure 3.

Table 11: **Summary of counterfactual scenarios**

Scenario	Country	Road Infrastructure	Policies
		Baseline	
1	Djibouti, Ethiopia, Kenya, Somalia	Speed and road conditions from latest surveys	High Trade border costs
		With transport infrastructure investments	
2.1	Kenya, Somalia, Ethiopia	Corridor 1: Kismayo, Lamu and Mogadishu Corridor with 3093km of rehabilitation or new roads	High Trade border costs
2.2	Djibouti, Ethiopia	Corridor 2: Assab and Djibouti Corridor with 649km of rehabilitation or new roads	High Trade border costs
2.3	Somalia, Djibouti	Corridor 3: Berbera and Djibouti Corridor with 1003km of rehabilitation or new roads	High Trade border costs
2.4	Djibouti, Ethiopia, Somalia	Corridor 4: Mogadishu, Berbera and Bossasso Corridor with 2550km of rehabilitation or new roads	High Trade border costs
		With border infrastructure investments	
3	Djibouti, Ethiopia, Kenya, Somalia	Corridors 1–4	50% reduction in border times at border posts along corridors 1–4

Figure 3: Proposed road corridors in the Horn of Africa



Source: World Bank.

Corridor 1: Kismayo, Lamu, and Mogadishu Corridor

Corridor 1 links population centers in Ethiopia, Kenya, and Somalia with the Somali ports of Mogadishu and Kismayo and the Kenyan port of Lamu. The corridor serves several purposes. It provides an important bilateral artery between the Kenyan and Ethiopian economies, pillars of the regional market that are currently largely disconnected. It also connects three ports that are underutilized for national and regional trade (Lamu, Kismayo, and Mogadishu) with economic centers and hinterland demand. It also establishes connectivity within some of the most remote corners of the three countries.

Corridor 2: Assab and Djibouti Corridor

Corridor 2 complements the trade corridor connecting population centers in Ethiopia with global markets through links with the port of Djibouti. It provides an alternate route between Ethiopia and the coast in Djibouti and complements existing linkages, reestablishing the historically important route to the port of Assab in Eritrea.

Corridor 3: Berbera and Djibouti Corridor

Corridor 3 is a vital import route as well the primary path for export of goods out of Ethiopia. Its Djibouti–Ethiopia segments are already fundamental links between the population centers of landlocked Ethiopia and global markets.

Corridor 4: Mogadishu, Berbera, and Bossasso Corridor

Corridor 4 provides access to the Port of Mogadishu in the southeast, through population centers on the Somali agricultural heartland along the Shabeelle River, the trading center of Beledweyne, following the river through Ferfer and toward the more populated western regions, including Addis Ababa. In the north, it connects to the Port of Bossasso, through Garowe and into Ethiopia, connecting the scattered population of Ethiopia's Somali region and linking up to Hargessa and Corridor 3 in the northwest. The corridor is intended to improve the connectivity of residents of the arid regions at the tip of the Horn of Africa.

5.3.1 Calibration of counterfactuals

We create counterfactuals using the transport networks from each country described in section 2. Figure A.6 in the appendix shows the new corridors and investments in border posts. We assume a speed of 70 kilometers an hour for the new corridors and reduce the time at the border in some of the scenarios.

5.3.2 Welfare impacts

Welfare is defined as the real income available for workers in a specific location, with nominal wages deflated by the prices for goods and housing across locations as well as an amenity from living in different places. We compute the welfare impact in each counterfactual and compare it to the baseline welfare:

$$\Delta Welfare_{n,c} = \Delta[Population_{n,c} \times V_{n,c}] \tag{4.13}$$

Table 12 shows the changes in the shares of employment in nonagricultural sectors. The proposed investments in transport corridors would lead to a 3 percentage-point increase in the share of employment in nonagricultural sectors in the four countries in the Horn of Africa. Kenya would experience the largest increase, followed by Ethiopia, Djibouti, and Somalia. Trade facilitation measures that reduce border times by half would add only a half percentage-point to the change in the share of employment in nonagricultural sectors in the Horn of Africa, but it would lead to significant increases in the share of employment in nonagricultural sectors in Kenya and Djibouti.

Table 12: Counterfactual increases in share of nonagricultural employment in Horn of Africa, by country (percentage points)

Country	Transport only	With trade facilitation
Djibouti	1.3	4.3
Ethiopia	2.6	1.0
Kenya	4.2	10.7
Somalia	0.4	0.8
Total	3.0	3.5

Table 13 shows the change in real income when considering only new road corridors and trade facilitation measures that reduce border frictions. The overall increase in welfare is just 1 percent when only investments in transport corridors are made; it is four times larger when times are also reduced at border posts along the corridors. Somalia enjoys the largest gains, followed by Djibouti, Kenya, and Ethiopia.

Table 13: Counterfactual increases in real income in Horn of Africa, by country (percentage points)

Country	Investments in transport corridors	Investments in transport corridors and trade facilitation
Djibouti	0	5.3
Ethiopia	1.3	3.9
Kenya	0.7	4.9
Somalia	1.4	6.3
Total	1.0	4.3

5.3.3 Spatial impacts

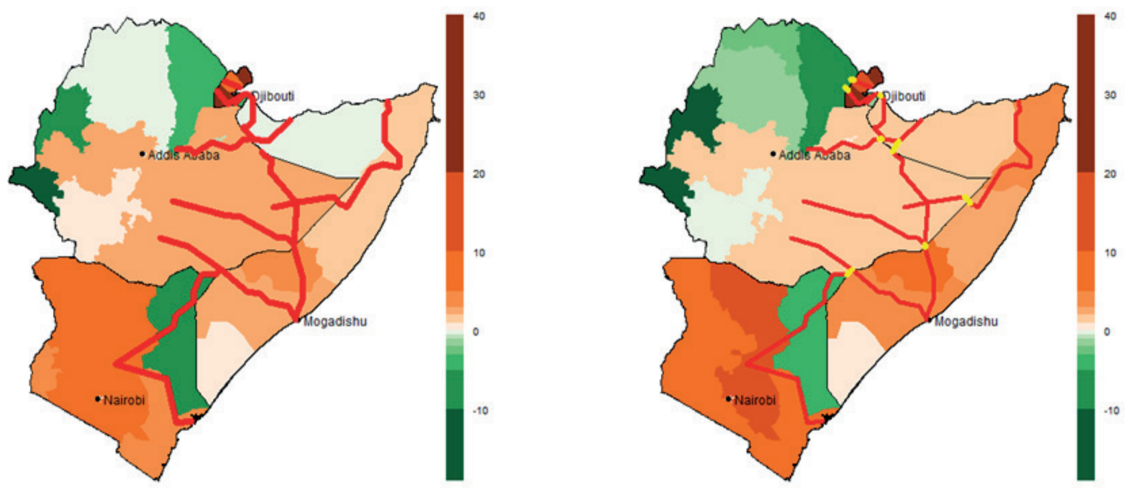
The total share of employment in nonagricultural sectors increases in all countries, but not in every subnational region. Lower transport and trade costs increase market access, providing more opportunities for producers in districts that benefit from transport investments. Better connectivity leads to higher specialization and increases competition from imports from other regions in the country for the traded good sectors (manufacturing and agricultural activities). Workers move across locations and sectors in response to changes in wages and prices.

For some regions, better regional connectivity translates into higher specialization in agricultural production. In figure 4, the green areas are regions here the share of nonagricultural employment will decrease because of the transport corridor investments and better trade facilitation; the orange and red areas are regions where it will increase. The regions that experience an increase in the share of agricultural employment are either isolated regions or border regions, mostly in the northwest of Ethiopia and the northeast of Kenya. The spatial patterns remain the same when the time to cross the borders is reduced by half, but the largest changes become larger.

Figure 4: Changes in share of nonagricultural employment in counterfactual scenarios relative to baseline (in percentage)

A. Transport corridor investments

B. Transport corridor investments and trade facilitation



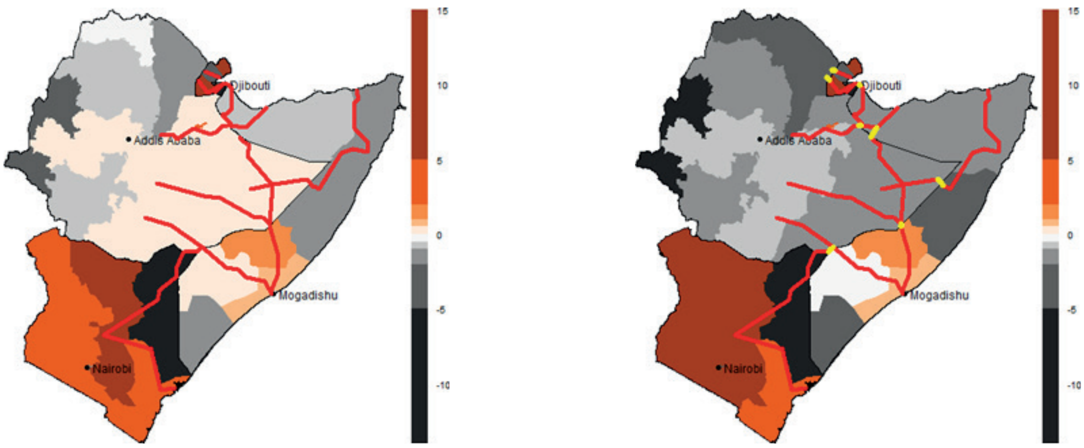
Source: Authors' calculations.

Specialization in manufacturing—the traded nonagricultural good—changes most in regions that benefit from corridor improvement. However, not all regions that benefit from better connectivity experience an increase in specialization in manufacturing. The shares of manufacturing employment will increase the most in Djibouti and Kenya; they increase only slightly in the central and eastern parts of Ethiopia and in the regions around Mogadishu in Somalia (figure 5). When transport investments are complemented with trade facilitation measures that reduce border times by half, the share of employment in manufacturing decreases across Ethiopia. In Somalia, and particularly in Kenya, the changes in employment shares become even larger, with most regions in Kenya further specializing in manufacturing. Complementary investments in electricity and Internet could increase productivity and support the manufacturing sector in some of those locations where improved connectivity will have a negative effect.

Figure 5: Change in share of manufacturing employment in counterfactual scenarios relative to baseline (in percentage)

A. Transport corridor investments

B. Transport corridor investments and trade facilitation



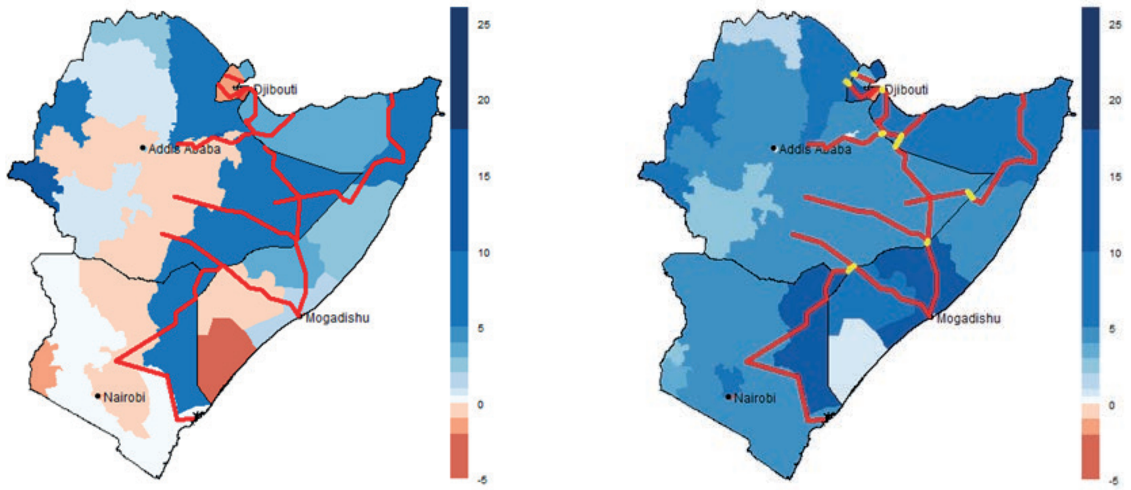
Source: Authors' calculations.

Overall, welfare, measured as real income, increases at the aggregate level for all countries but not for all subnational regions when only transport corridor improvements are undertaken (figure 6). Real income tends to increase in the regions the new corridors will traverse. If border times also decrease, almost all regions in the Horn of Africa enjoy higher welfare, with some regions in Kenya and Somalia benefiting the most in percentage terms.

Figure 6: Welfare impacts in counterfactual scenarios relative to baseline (in percentage points)

A. Transport corridor investments

B. Transport corridor investments and trade facilitation



Source: Authors' calculations.

SECTION 6

Conclusion

This paper investigates how infrastructure—transport, electricity and Internet—affects economic development through the channels of sectoral employment and structural change. It first estimates the impacts of past transport, electricity, and Internet investments in Ethiopia and Kenya on sectoral employment. The empirical analysis shows that access to electricity triggered a shift in employment from agriculture to services, that access to paved roads led to an increase in the share of manufacturing employment, and that access to Internet led to an increase in the share of service employment and, in Ethiopia only, a shift away from agriculture.

One of the main contributions of the paper is the finding that, on average, combining investments in electricity and paved roads led to a shift from agriculture to manufacturing, with no significant change in the share of employment in services. Combining investments induces a movement out of agricultural employment in locations near main towns but not in isolated locations.

The paper's spatial general equilibrium model estimates the potential impacts of proposed regional transport corridor projects in the Horn of Africa. The analysis also looks at the impact of complementary trade facilitation measures. It shows the importance of such complementary interventions in facilitating regional trade and enhancing the benefits of transport corridors.

The spatial general equilibrium model does not consider investments in electricity or Internet. The plan for future research is to include those sectors in the model and to link them with the empirical analysis.

References

Adamopoulos, Tasso, "Spatial Integration, Agricultural Productivity, and Development: A Quantitative Analysis of Ethiopia's Road Expansion Program," 2019 Meeting Papers 86, Society for Economic Dynamics 2019.

Adukia, Anjali, Sam Asher, and Paul Novosad, "Educational Investment Responses to Economic Opportunity: Evidence from Indian Road Construction," *American Economic Journal: Applied Economics,* January 2020, 12 (1), 348–376.

Allen, Treb and Costas Arkolakis, "Trade and the Topography of the Spatial Economy," *The Quarterly Journal of Economics,* 2014, 129 (3), 1085–1140.

Arderne, C., C. Zorn, C. Nicolas, and E. Koks, "Predictive mapping of the global power system using open data.," *Sci Data* 7, 19, 2020.

Asher, Sam and Paul Novosad, "Rural roads and local economic development," Policy Research Working Paper Series 8466, The World Bank June 2018.

Behrens, Kristian, Carl Gaigne, Gianmarco I.P. Ottaviano, and Jacques-Francois Thisse, "Is remoteness a locational disadvantage?," *Journal of Economic Geography,* June 2006, 6 (3), 347–368.

Bird, Julia, Mathilde Lebrand, and Anthony J. Venables, "The Belt and Road Initiative: Reshaping economic geography in Central Asia?," *Journal of Development Economics,* 2020, 144 (C).

Bustos, Paula, Bruno Caprettini, and Jacopo Ponticelli, "Agricultural Productivity and Structural Transformation: Evidence from Brazil," *American Economic Review,* June 2016, 106 (6), 1320–1365.

Calderon, Cesar, Enrique Moral-Benito, and Luis Serven, "Is infrastructure capital productive? A dynamic heterogeneous approach," *Journal of Applied Econometrics,* March 2015, 30 (2), 177–198.

Croke, Kevin and Alice Duhaut, "The Impact of Roads on Land-Use Change in Ethiopia: Evidence from Satellite Imagery," 2020.

Donaldson, Dave, "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review,* April 2018, 108 (4-5), 899–934.

Eckert, Fabian and Michael Peters, "Spatial Structural Change," 2018 Meeting Papers 98, Society for Economic Dynamics 2018.

Foster, Vivien and Cecilia Briceno-Garmendia, *Africa's Infrastructure: A Time for Transformation [Infrastructures africaines]* number 2692. In 'World Bank Publications.', The World Bank, June 2010.

Fried, Stephie and David Lagakos, "Electricity and Firm Productivity: A General- Equilibrium Approach," Working Paper 27081, National Bureau of Economic Research May 2020.

Gebresilasse, Mesay, "Rural roads, agricultural extension, and productivity," 2019.

Gertler, Paul J., Marco Gonzalez-Navarro, Tadeja Gravcner, and Alexander D. Rothen- berg, "Road Quality, Local Economic Activity, and Welfare: Evidence from Indonesia's Highways," 2016.

Herrendorf, Berthold, Rogerson, Richard and Valentinyi, Akos, (2014), Growth and Structural Transformation, ch. 06, p. 855-941 in , Handbook of Economic Growth, vol. 2, Elsevier.

Herrera Dappe, Matías and Mathilde Lebrand, "The Spatial Effects of Logistics Interventions on the Economic Geography of Bangladesh," 2019.

Herrera Dappe, Matías, Mathilde Lebrand, and Diana Van Patten, "Bridging India and Bangladesh: Cross-border Trade and the BBIN Motor Vehicles Agreement," 2021.

Jedwab, Remi and Adam Storeygard, "The Average and Heterogeneous Effects of Transportation Investments: Evidence from Sub-Saharan Africa 1960-2010," NBER Working Pa- pers 27670, National Bureau of Economic Research, Inc August 2020.

Kebede, Hundanol, "The gains from market integration: The welfare effects of rural roads in Ethiopia," 2019.

Lall, Somik V. and Mathilde Lebrand, "Who wins, who loses? Understanding the spatially differentiated effects of the belt and road initiative," *Journal of Development Economics,* 2020, 146 (C).

McMillan, Margaret, Dani Rodrik, and Claudia Sepulveda, "Structural Change, Fundamentals and Growth: A Framework and Case Studies," Working Paper 23378, National Bureau of Economic Research May 2017.

Michaels, Guy, Ferdinand Rauch, and Steve Redding, "Technical note: an Eaton and Kortum (2002) model of urbanization and structural transformation.," 2011.

Moneke, Niclas, "Can Big Push Infrastructure Unlock Development? Evidence from Ethiopia," Technical Report 2020.

Ngai, L. Rachel and Christopher A. Pissarides, "Structural Change in a Multisector Model of Growth," *American Economic Review,* March 2007, 97 (1), 429–443.

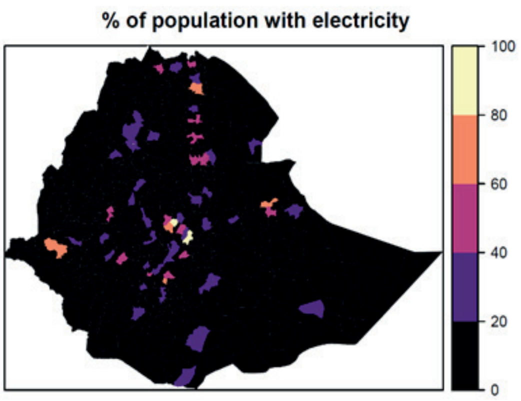
Redding, Stephen J., "Goods trade, factor mobility and welfare," *Journal of International Economics,* 2016, 101 (C), 148–167.

A Appendix

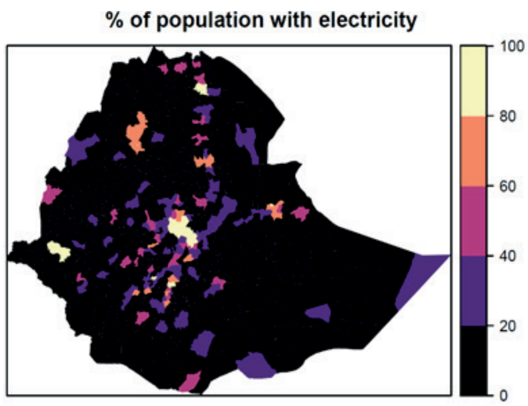
Figure A1: Share of subnational population with access to electricity in Ethiopia and Kenya based on nightlights in 2016 (in percentage)

Ethiopia

A. 1998

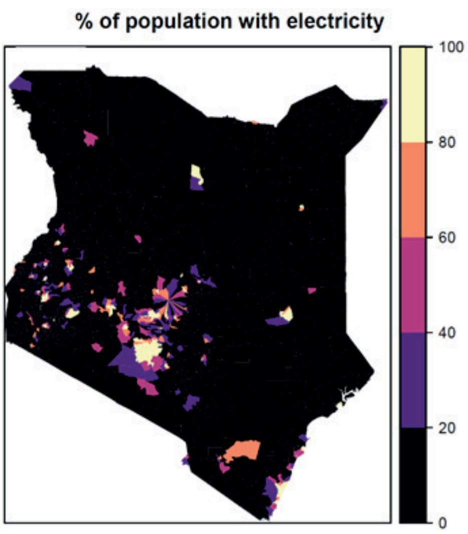


B. 2016

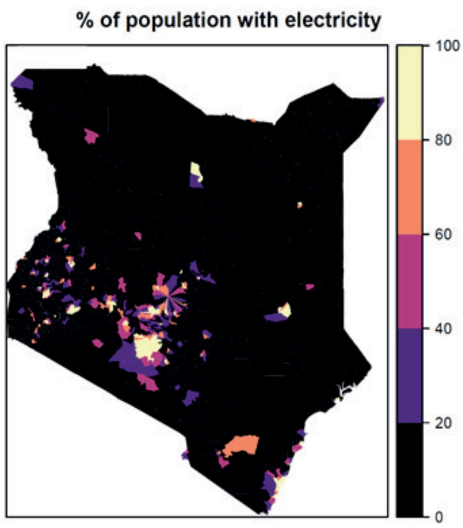


Kenya

A. 1998



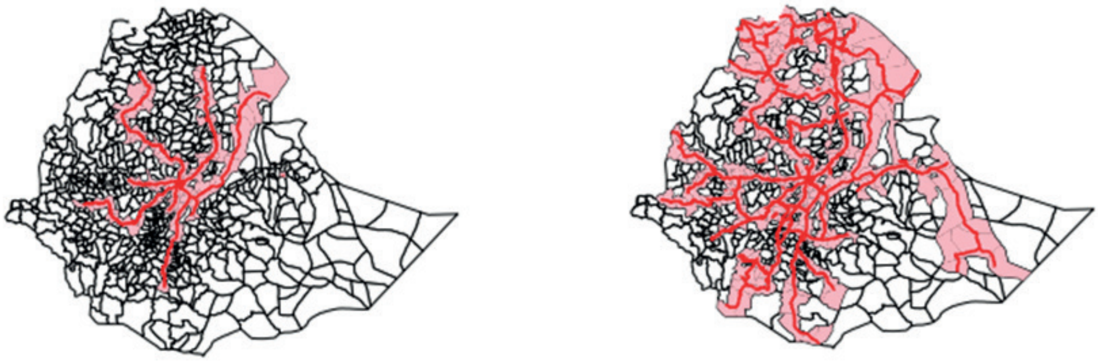
B. 2016



Source: Authors’ calculations.

Figure A2: Paved road network in Ethiopia, 1996 and 2016

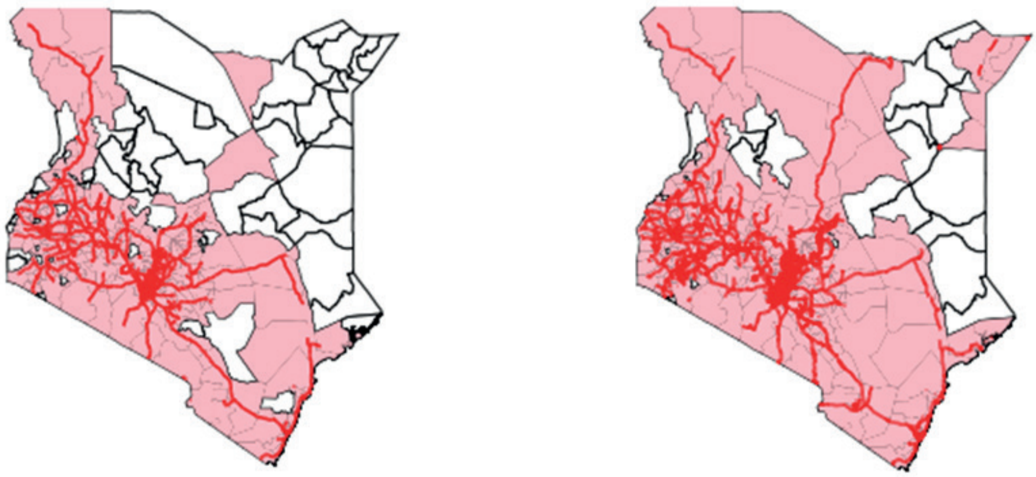
A. 1996 B. 2016



Source: Data from the Ethiopian Roads Authority used in Croke and Duhaut (2020).

Figure A3: Paved road network in Kenya, 2003 and 2018

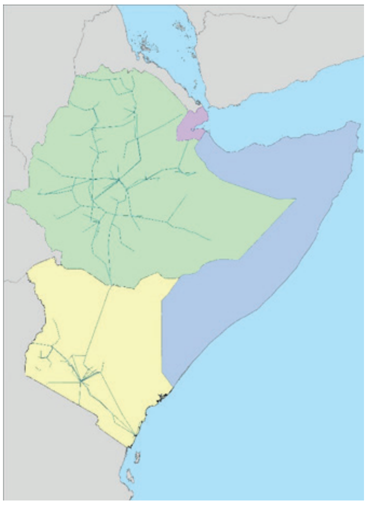
A. 2003 B. 2018



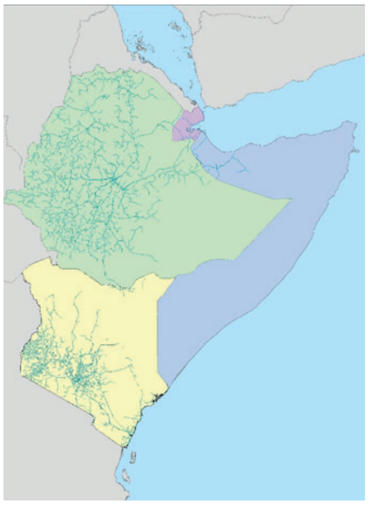
Source: Kenya Road Board.

Figure A4: Electricity grid in Ethiopia and Kenya, 2007 and 2018

A. 2007



B. 2018



Source: Foster and Briceno-Garmendia (2010), gridfinder.org, and Arderne et al. (2020).

Figure A5: Access to Internet backbone in Ethiopia and Kenya, 2009 and 2019

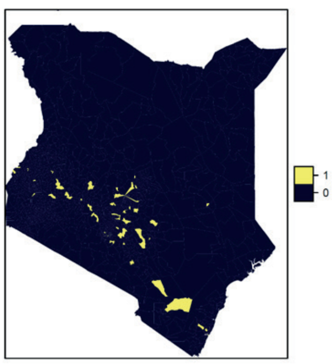
Ethiopia

A. 2009

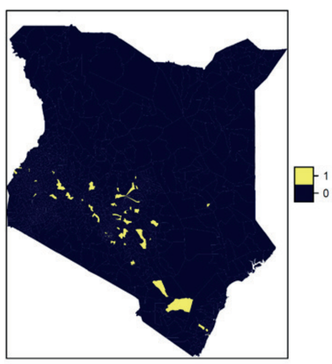
B. 2019

Kenya

C. 2009

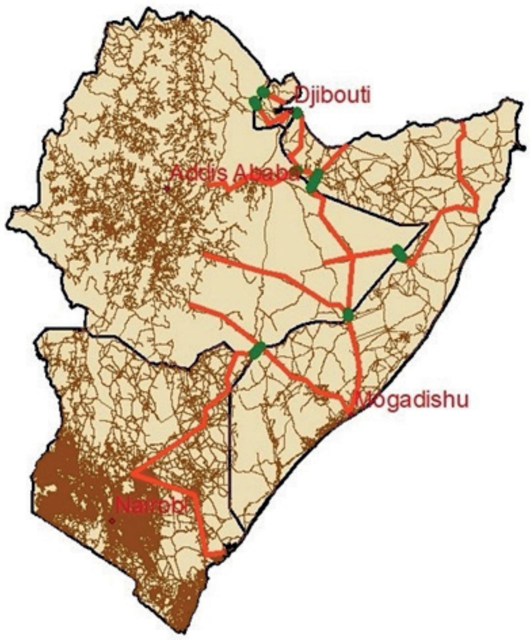


D. 2019



Source: Africa Bandwidth Maps.

Figure A6: Transport network, new corridors, and border points benefiting from lower border delays in the Horn of Africa as coded to quantify the counterfactuals



Source: Authors' based on country road networks as listed in Section 3.

Table A1: OLS results for the Horn of Africa using the electricity grid

Share of employment per sector	Agriculture	Manufacturing	Services
Paved roads	-0.0587*	0.0171	0.0191
	(-2.36)	(1.34)	(0.99)
Internet	0.00760	0.0189	-0.0461
	(0.11)	(0.37)	(-0.97)
Electricity grid	-0.0143	0.00675	0.0174
	(-0.77)	(0.78)	(1.28)
Road + Internet	-0.0797	-0.00368	0.108*
	(-1.12)	(-0.07)	(2.17)
Road + Electricity grid	0.00914	0.0106	0.00795
	(0.35)	(0.80)	(0.40)
Year + Country FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
R-squared	0.418	0.307	0.363
Number of observations	1887	1887	1887

Note: *t* statistics in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$

Table A2: Parameters for structural estimation

Parameter	Value	Source	Description
σ	4	Bernard et al. (2003)	Elasticity of substitution between varieties
		Data for Ethiopia (HCES)	Expenditure share on land/housing
	0.5	Ngai and Pissarides (2007)	Elasticity of substitution across sectors
μ^M	0.82	Moneke (2020) for Ethiopia	Labor share in M-production
μ^T	0.78	Moneke (2020) for Ethiopia	Labor share in T-production
μ^S	0.84	Moneke (2020) for Ethiopia	Labor share in S-production
τ	0.3	Moneke (2020) for Ethiopia	Elasticity of trade cost with respect to distance
θ	4	Donaldson (2018)	Shape parameter of productivity distribution across varieties & locations

THE WORLD BANK
IBRD • IDA | WORLD BANK GROUP