Market Integration and Cost of Borders in Africa*

Preliminary and Incomplete

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Abstract

Africa's colonial border design has been understood to be associated with detrimental contemporary socio-economic outcomes. Little attention however has been paid to the implication of those borders to intra-regional trade and thus economic growth. In this paper we examine whether the removal of fragmented international borders in Africa improves the welfare of neighboring countries. Using a spatial general equilibrium model developed by Fajgelbaum and Schaal (2020), we show that existing links that are consequential for international trade are *under-invested* in both East and West Africa. Our framework will provide important policy-relevant insights given that a range of countries in Africa are trying to lessen trade friction across the borders by forming free-trade areas and currency unions.

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1 Introduction

Intra-Africa trade continues to remain low (UNCTAD 2019) and constrained by poor transportation links. This results in internal markets that are on average too small. These small markets limit economies of scale, which can in turn limit prosperity. The goal of this paper is to understand whether country border frictions of African countries are a limiting barrier to economic growth on the continent. This is a first-order issue, given that close to eighty percent of the continent's borders follow latitudinal and longitudinal lines (Alesina et al. 2011), and that many scholars in economics and political science believe that such artificial borders are at the root of Africa's economic tragedy (e.g. Easterly and Levine 1997; Herbst 2000; Michalopoulos and Papaioannou 2016).

While the nature of borders has been discussed at length in political science and more recently in economics (Allen et al. 2018), we are not aware of systematic work relating the nature of borders to the economic success of countries.[1] This paper makes progress on this to provide insights on the welfare consequences of the current demarcation of African country borders on the economy and how this would change if borders were laid out differently. More specifically, we will focus on the border effect on trade link infrastructure.

To do so, we will leverage a state-of-the-art model of infrastructure investment in spatial equilibrium developed by Fajgelbaum and Schaal (2020). This model gives the solution to a social planner's problem of building infrastructure network (i.e. optimal road network, optimal trade flow, and optimal allocation of consumption and production) and the paper provides conditions under which the problem can be numerically solved. This methodology will allows us to quantify the welfare gains of removing country borders and to run several different counterfactuals created by historical events. By using the removal of borders as a different counterfactual we can compare welfare with the baseline borders of a given country or set of countries. In essence we use Fajgelbaum and Schaal (2020) to assess how policies aimed at alleviating trade frictions between countries will affect economic growth in those states.

While all the data mentioned in Fajgelbaum and Schaal (2020) is not available for the African continent, we are able to make substantial progress to track the key variables to run the model. We assemble administrative datasets such as population and nighttime light and also digitize historical roads data. Our first countertfactual exercise simply unifies countries into two regional blocks. By treating the East African countries as one block and West African countries as another block. Our preliminary results indicate that the existing trade links are *under-invested* in both East and West Africa.

The remainder of the paper is organized as follows. Section 2 provides a brief literature review and links our paper to the nascent literature on the nature of borders in different contexts, on the political economy of infrastructure placement in Africa and elsewhere, and the growing literature on infrastructure network optimization. Section 3 describes the relevant details from Fajgelbaum and Schaal (2020) and modifies the framework to our context. Section 4 details the data we have assembled and digitized to track the theoretical framework. Section 5 links the theory with the empirical set up. Section 6 provides preliminary

[1] The consequence of African colonial border design and its implication on contemporary socio-economic outcomes (e.g. conflict, national identity, and trust amongst others) has been studied well; however its implication to trade and transportation links has not been analyzed.

results from the two simple counterfactual exercises of treating East African countries and West African countries as regional blocks. Section 7 offers some concluding remarks.

2 Literature

While the effects of borders on infrastructure investment choices of neighboring countries have been understudied, there is an emerging literature that relates the nature of borders to economic success of neighboring countries. Seminal work by Michalopoulos and Papaioannou (2016) investigate how ethnic partitioning gave rise to negative socio-economic consequences in Africa. Their findings highlight that African colonial borders play an important role in shaping economic successes and failures. Allen et al. (2018) study the economic impacts of a border wall between the United States and Mexico. They find that the border wall expansion benefited low-skill US workers at the expense of high-skill US workers and both high- and low-skill Mexican workers. Santamaria (2020) develops a multi-region quantitative trade model with endogenous government infrastructure investment choice. Using an unexpected changes in border as an exogenous shock, she studies the importance of flexibility in the development of transport network. Relatedly, Ahlfeldt et al. (2015) build a quantitative model of internal city structure and apply the model to Berlin. Using Berlin's division and reunification as a natural experiment, they show that the systematic change in economic activities in West Berlin is explained by changes in commuting access and production and residential externalities. Our paper contributes to this emerging literature by providing the insight into the roles of country borders on infrastructure investment choices and the welfare implications.

The role of political economy in infrastructure placement has recently gained attention in economics. Burgess et al. (2015) investigate ethnic favoritism, in which Kenyan districts that share the ethnicity of the president receive disproportionate amount of road expenditure during autocratic periods however this bias is attenuated as the country transitions into democracy. Bonfatti et al. (2019) show that autocracies tend to connect natural resource deposits to ports while the networks expanded in a less interior-to-coast way in periods of democracy in West Africa. Our paper compliments these findings and makes progress by leveraging a spatial equilibrium model and expands the scope of current research to include most Sub-Saharan African countries. We contribute to the literature by demonstrating how international borders in Africa, which are artificial political artifacts, affect the distribution of infrastructure network.

There is a growing literature on infrastructure network optimization. While the previous literature has taken infrastructure investment and trade costs as primitives in the model, recent papers incorporate the endogenous nature of these variables into the model. Felbermayr and Tarasov (2015) construct an analytical framework of an open economy in which welfare-maximizing social planners non-cooperatively allocate infrastructure investment across space. Assuming that infrastructure investment increases in distance and transport costs are the function of transport network, they show that non-cooperative behavior of planners results in the underinvestment of infrastructure near the border. Allen and Arkolakis (2019) develop a theoretical framework that incorporates traffic congestion; they allow transport costs to respond endogenously to changes in the traffic flow and the distribution of economic activity.

Fajgelbaum and Schaal (2020), closely related to Allen and Arkolakis (2019), also develop a framework that consists of a neoclassical trade model and incorporates traffic congestion. In their model, the optimal transport network corresponds to the solution to the problem of a social planner who invests in transport network under the conditions that guarantee the convexity of the planner's problem. They apply the framework in order to study the optimal road network in Europe. However, the aforementioned papers, except for Felbermayr and Tarasov (2015), do not consider the border effect on trade link infrastructure.

3 Theory

Fajgelbaum and Schaal (2020) develop a spatial general equilibrium model. In this model, the social planner determines the optimal allocation of consumption and production factors, the optimal trade flow, and the optimal level infrastructure investment in order to maximize the aggregate welfare in the economy. We briefly describe the structure of the Fajgelbaum and Schaal (2020) model for reference.[2]

3.1 Preferences

The economy consists of a discrete set of N sectors and J locations. Utility of consumers who consume the per-capita traded goods bundle c_j and the per-capita non-traded good h_j is given by:

$$U_j = c_j^{\alpha} h_j^{1-\alpha}.$$

Thus, consumers spend a fraction α of their income on the traded goods bundle and a fraction $1-\alpha$ on the non-traded good.

The aggregate demand of the traded goods bundle in location j is defined as C_j. Goods from tradable sectors are combined into C_j through a homogeneous of degree 1 and concave aggregator:

$$C_j = \left(\sum_{n=1}^{N} (C_j^n)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

where σ is the elasticity of substitution and C_j^n is the output of sector n in location j.

3.2 Production

Labor is the only production factor:

$$Y_j^n = z_j^n L_j^n,$$

where z_j^n denotes the productivity of the tradable sector n in location j and L_j^n denotes the labor of the tradable sector n in location j. We assume that labors are mobile across the sectors but only within each location. Thus, the wage in the tradable sectors should be equalized in each location: $w_j^n = w_j$.

[2] Additional details are provided in the original paper.

3.3 Transport Technology

The quality of goods shipped from j to $k \in \mathcal{N}(j)$ is given by Q^n_{jk}, where $\mathcal{N}(j)$ denotes the set of neighborhood nodes for location j. The total unit of goods shipped from j to k in order to transport one unit of good takes the form of iceberg cost: $1 + \tau^n_{jk}$. The transport cost is a function of the bundle of traded goods shipped along the link jk and of the level of infrastructure:

$$\tau_{jk} = \delta^{\tau}_{jk} \frac{(Q_{jk})^{\beta}}{(I_{jk})^{\gamma}},$$

where $Q_{jk}(= \sum_n Q^n_{jk})$ is the aggregate quantity of goods shipped from j to k and I_{jk} is the infrastructure investment along the link jk.

3.4 Flow Constraint

In every location, the sum of consumption and exports should be weakly less than the sum of production and imports:

$$D^n_j + \sum_{k \in \mathcal{N}(j)} Q^n_{jk} \leq Y^n_j + \sum_{i \in \mathcal{N}(j)} Q^n_{ij}.$$

3.5 Network Building Constraint

The social planner is constrained by the total supply of resources in the economy to build the road network:

$$\sum_j \sum_{k \in \mathcal{N}(j)} \delta^I_{jk} I_{jk} \leq K,$$

where K is the total supply of resources to build road network in the economy, Thus, this constraint implies that the total demand for resources should be weakly less than the total supply of resources.

3.6 Planner's Problem

The social planner maximizes the aggregate welfare in the economy subject to resource constraints for traded and non-traded commodities, flow constraint, labor-market clearing condition, network building constraint, and non-negativity constraints.

4 Data

In order to apply the model to the settings in Sub-Saharan Africa, we use administrative data from a number of sources and digitize road infrastructure data. For population data, we use the Gridded Population of the World (GPW) data published by the Socioeconomic Data and Applications Center. The GPW data is available at an output resolution of 2.5 arc-minutes (approximately 5 km at the equator) for 2000. We aggregate the GPW data to the principal administrative division of each country. To proxy for production data, we use GDP data provided by World Development Indicator (WDI) database published by the World Bank.

The WDI data is available at the country-level since 1960. In order to estimate the high-resolution per-capita GDP, we use the nighttime light data published by the National Oceanic and Atmospheric Administration and estimate the elasticity of per-capita GDP with respect to the nighttime light in Sub-Saharan Africa by following Henderson et al. (2012):

$$\log(y_{it}) = \alpha + \beta_1 \ln(NL_{it} + 1) + \kappa_t + \varepsilon_{it},$$

where y_{it} is the per-capita GDP of country i in year t, NL_{it} is the total luminosity value (0-63) of country i in year t and κ_t denote the year fixed effects. We then compute the total luminosity value for each principal administrative division and apply the estimated coefficients to the data in order to estimate per-capita GDP in each polygon.

We use the country boundary data which is downloadable from GADM maps in order to define the boundary for the East and West Africa regions. For topography data, we use ETOPO data which is available at a 1 resolution of arc-minute (approximately 2 km at the equator) and published by the National Oceanic and Atmospheric Administration.

We digitize Michelin Road maps (for details see Burgess et al. (2015)) into GIS shapefiles that contain the attributes of length and road type of each segment since 1961 for the whole of Sub-Saharan Africa. From the road GIS dataset, we construct edges that connect neighboring polygons. We next need to estimate the elasticity of intra-regional trade with respect to the distance; however, this is a challenge due to paucity of data for the continent. To circumvent this, we use a JICA report that presents the estimated intra-regional trade flows in Egypt.[3] We estimate the distance elasticity of trade in Sudan (which is the neighboring Sub-Saharan country of Egypt) by using Egyptian data as a benchmark and apply the population-weighted elasticity to the East and West Africa regions.

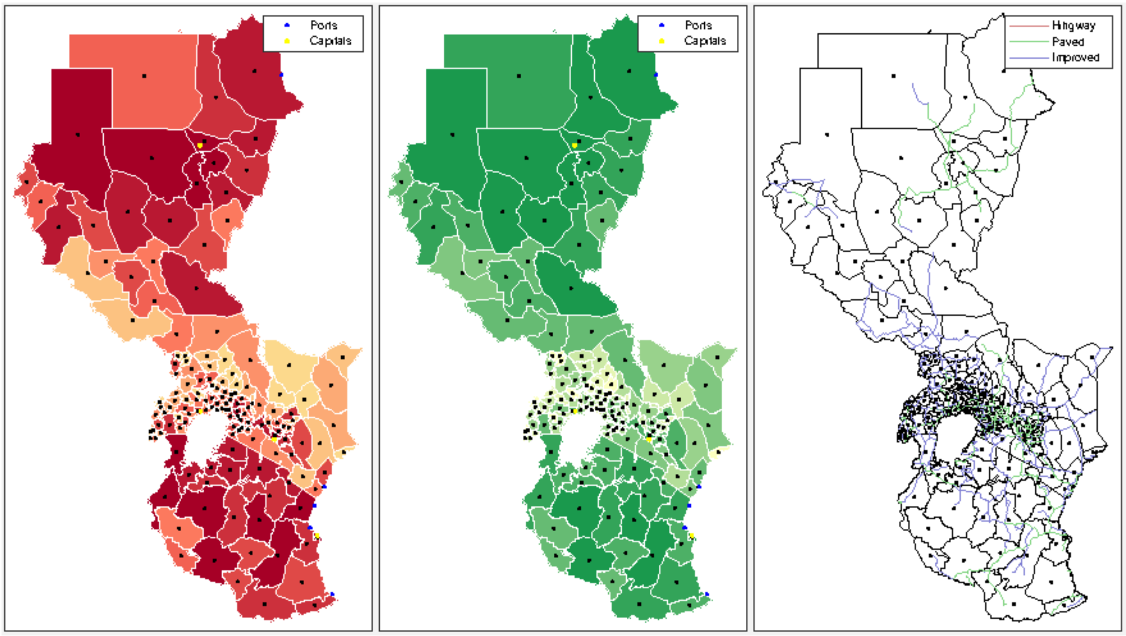
Figure 1 displays the population, GDP and actual road data in East and West Africa, respectively. Briefly, in East Africa, economic activity and road network are concentrated around the national capitals and the international ports. In West Africa, coastal countries are more well off and have higher road density than the inland countries.

[3]While Egypt might not be a representative of the whole Sub-Saharan Africa, we can check the robustness of the estimates by exploring different values of the elasticity based on the estimate.

Figure 1: Population, GDP, and Road Network in Africa

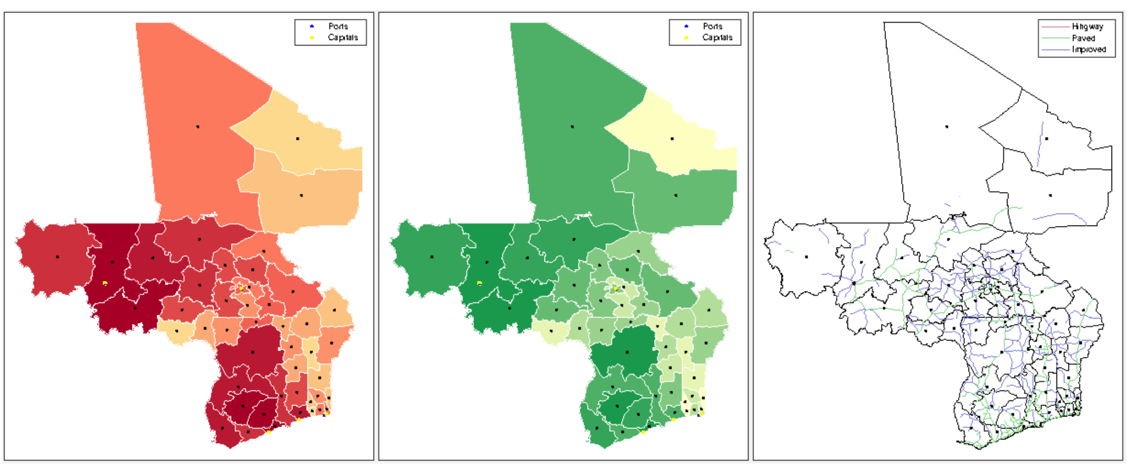
Panel A: East Africa

(a) Population (b) GDP (c) Actual Road



Panel B: West Africa

(d) Population (e) GDP (f) Actual Road



Figures (a) and (b) display the population and GDP data in East and West Africa, respectively. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Figure (c) depicts the actual road network in East and West Africa. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads. Yellow and blue dots are national capitals and international ports, respectively.

5 Linking Theory to Data

In order to analyze the effects of international borders on the distribution of infrastructure network in Africa, we do a first application of Fajgelbaum and Schaal (2020) model to the East African block of countries (defined as Kenya, South Sudan, Sudan, Tanzania, and Uganda) and West African block of countries (defined as Benin, Burkina Faso, Ghana, Mali, and Togo). More specifically, we first calibrate the model fundamentals such as the labor productivity and the cost of infrastructure and then implement a counterfactual exercise. In the counterfactual exercise, the social planner optimizes the aggregate welfare across the block of countries in the economy. This counterfactual exercise shows the distribution of optimal infrastructure network across all the countries in the block in the absence of country borders. Thus, it helps us understand how the presence of international borders affects the infrastructure investment in the regional blocks.

In applying the model to East and West Africa, we modify the application on one dimension to match our setting. Since international ports play an important role in the African economy (33% of African countries are land locked), we assume that all the cities with ports produce differentiated goods. We also assume that the most populous city in each country produces country-specific differentiated goods — all the remaining cities/towns produce a homogeneous agricultural good.[4]

6 Results

6.1 Main Results

Our first objective is to apply the Fajgelbaum and Schaal (2020) model to the block of countries defined earlier as East and West Africa and analyze how the presence of the international borders distorts the infrastructure investment away from the optimal road network that maximizes aggregate welfare in the economy. We specifically run the following specification:

$$\ln\left(\frac{I^*_{jk}}{I_{jk}}\right) = \gamma_1 Foreign\ Trade_{jk} + \gamma_2 Total\ Trade_{jk} + \gamma_3 \ln(L_{jk}) + \gamma_4 \ln(y_{jk}) + \gamma_5 \ln(I_{jk}) + \epsilon_{jk},$$

where I_{jk} and I^*_{jk} are the baseline and optimal infrastructure investment in road jk, respectively, $Foreign\ Trade_{jk}$ and $Total\ Trade_{jk}$ denote the standardized optimal foreign and total trade flows along road jk, respectively, L_{jk} is the average population between locations j and k, and y_{jk} is the weighted average of per-capita GDP between locations j and k. The coefficient of interest is γ_1, which measures the level of under- or over-investment in links consequential for foreign imports.

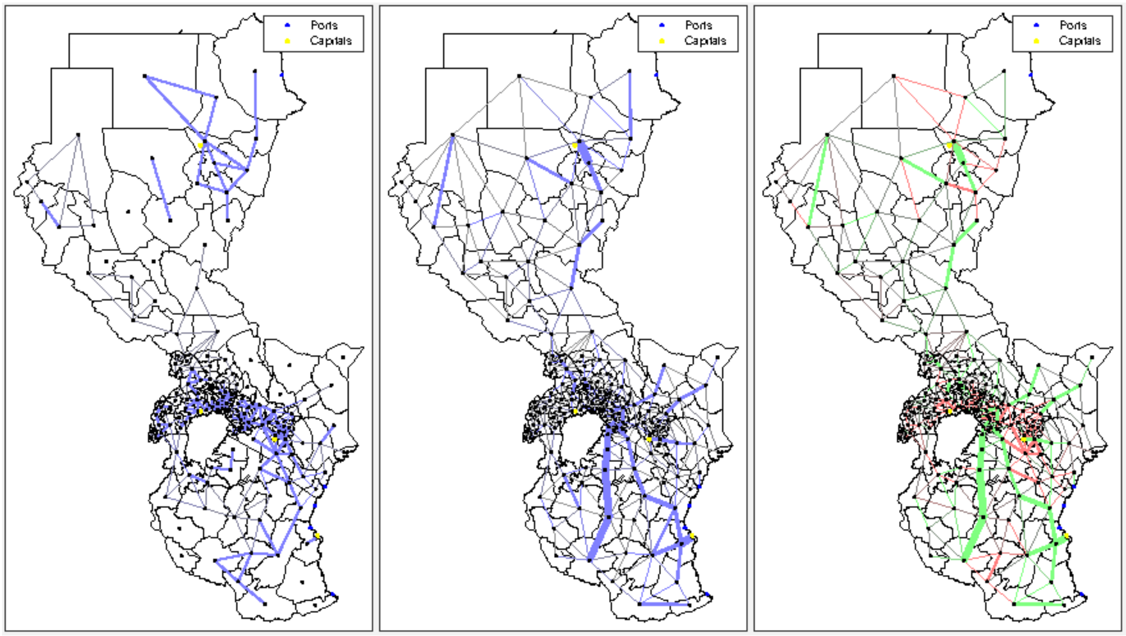
We compare the optimal road network against the baseline road network. We thus examine whether links essential for foreign trade are under-invested or over-invested at the baseline. Figure 2 presents the baseline and optimal road network as well as the percentage change in infrastructure investment in East and West Africa, respectively.

[4] Fajgelbaum and Schaal (2020) explore different assumptions on the number of differentiated goods (i.e. 10 and 15) in order to check the robustness of the results; we can also explore different numbers of differentiated goods in order to examine if the results are sensitive to the assumption.

Figure 2: Optimal Road Network in Africa

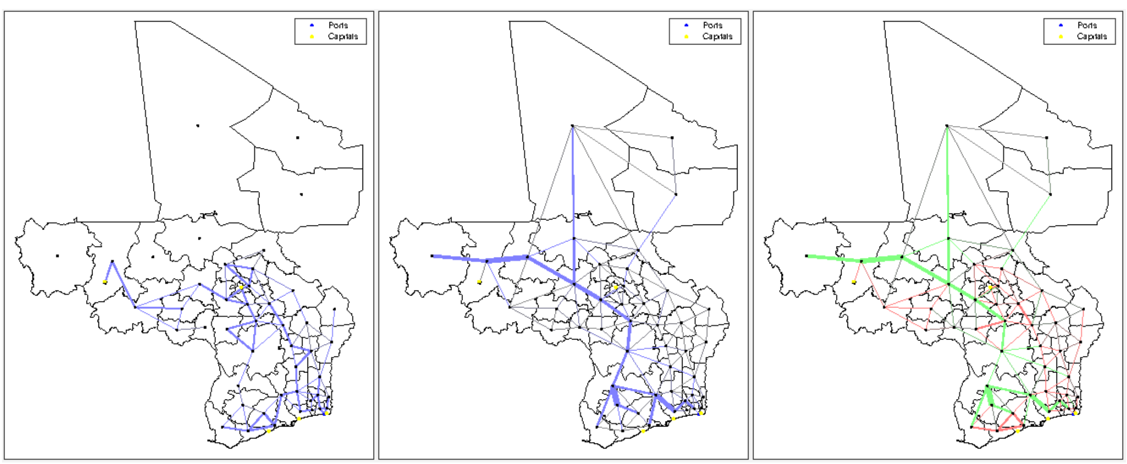
Panel A: East Africa

(a) Baseline Road Network (b) Optimal Road Network (c) Gains from Optimization



Panel B: West Africa

(d) Baseline Road Network (e) Optimal Road Network (f) Gains from Optimization



Graphs (a), (b), (d), and (e) present the baseline and optimal road network in East and West Africa, respectively. The width of each edge denotes the intensity of infrastructure investment: The wider edge corresponds to the more intense infrastructure investment. Graphs (c) and (f) present the percentage change from the baseline to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The width of each edge denotes the absolute change in infrastructure investment: The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Table 1 shows the regression results of analysis under road network optimization in East Africa. The unit of analysis is an edge. The coefficient on the foreign trade measure is significantly positive. Thus, links that receive more foreign trade flow are likely to receive more infrastructure investment under road network optimization without political borders, which implies that the existing links essential for foreign trade are *under-invested*. Similarly, the coefficient on the total trade measure is significantly positive. This suggests that links that receive more total trade flow are likely to receive more infrastructure investment, which is consistent with the social planner's objective. In contrast, the coefficient on the initial levels of infrastructure investment is negative. Thus, edges that initially have low level of infrastructure investment are likely to receive more infrastructure investment. This is also in line with the goal of the planner who would like to reduce the spatial inequality in infrastructure investment.

Table 1: Optimal Infrastructure Investment in East Africa

Dependent Variable:	Infrastructure Growth		
	(1)	(2)	(3)
Optimal foreign trade	1.299***	1.420***	0.686***
	(0.417)	(0.422)	(0.182)
Optimal total trade	1.906***	1.865***	1.463***
	(0.424)	(0.409)	(0.249)
Population		-2.336***	0.514*
		(0.724)	(0.307)
Income		2.892***	-0.576*
		(0.665)	(0.296)
Infrastructure			-1.063***
			(0.022)
Observations	385	385	385
Adjusted R-squred	0.11	0.15	0.86

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the baseline to optimal infrastructure investment. Optimal foreign (total) trade and is the standardized measure of optimal foreign (total) trade flow through each edge. Population denotes the weighted sum of the baseline population of cells which are connected by the edge. Infrastructure denotes the baseline infrastructure investment on the edge. Income denotes the population-weighted sum of the baseline income in cells connected by the edge. *** = 1% significance, ** = 5%, * = 10%.

Table 2 shows the regression results of analysis under road network optimization in West Africa. While signs of coefficients are the same as in Table 1, the coefficient on the foreign trade measure is not significant. Thus, trade links in West Africa are not severely *under-invested* relative to trade links in East Africa.

Table 2: Optimal Infrastructure Investment in West Africa

Dependent Variable:	Infrastructure Growth		
	(1)	(2)	(3)
Optimal foreign trade	0.573	0.885	0.279
	(0.857)	(0.847)	(0.217)
Optimal total trade	2.872***	2.667**	1.638***
	(1.018)	(1.022)	(0.336)
Population		-3.852***	1.327
		(1.372)	(0.800)
Income		6.673***	-2.203**
		(1.560)	(0.966)
Infrastructure			-1.094***
			(0.041)
Observations	115	115	115
Adjusted R-squred	0.15	0.24	0.89

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the baseline to optimal infrastructure investment. Optimal foreign (total) trade and is the standardized measure of optimal foreign (total) trade flow through each edge. Population denotes the weighted sum of the baseline population of cells which are connected by the edge. Infrastructure denotes the baseline infrastructure investment on the edge. Income denotes the population-weighted sum of the baseline income in cells connected by the edge. *** = 1% significance, ** = 5%, * = 10%.

6.2 Heterogeneity by Country

In order to understand the heterogeneity by country, we then interact the indicators for all the countries and the border links with the standardized optimal foreign and total trade measures. Thus, we run the following specification:

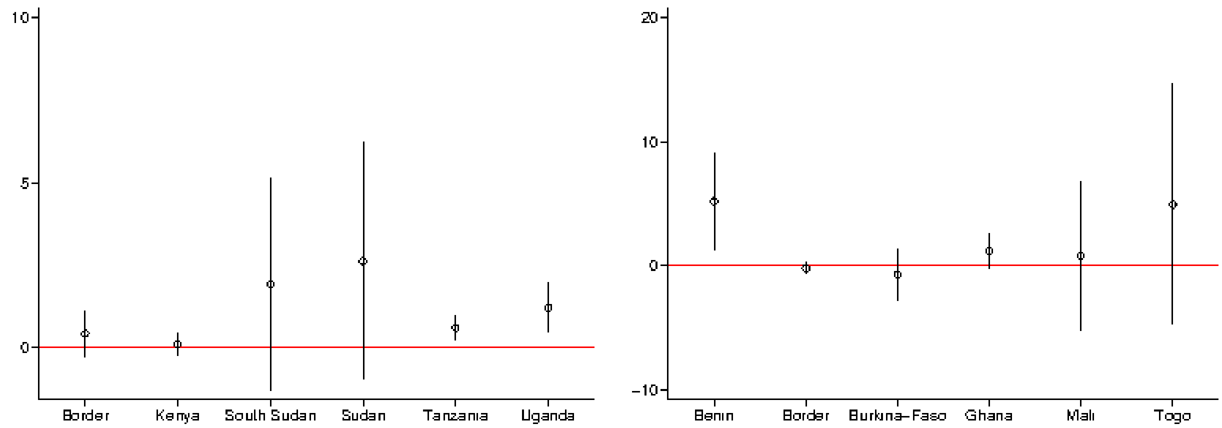
$$\begin{aligned}\ln\left(\frac{I^*_{jk}}{I_{jk}}\right) =& \sum_{c\in C}\delta_c\mathbf{1}\{Country_{jk}=c\}\times Foreign\ Trade_{jk}+\sum_{c\in C}\eta_c\mathbf{1}\{Country_{jk}=c\}\times Total\ Trade_{jk}\\ &+\zeta_3\ln(L_{jk})+\zeta_4\ln(y_{jk})+\zeta_5\ln(I_{jk})+u_{jk},\end{aligned}$$

where $Country_{jk}$ denotes the country to which edge jk belongs. If nodes j and k span across different countries, we classify edge jk as "Border."

Figure 3 presents the estimate of δ, which are the coefficients on the interaction term between the country indicator and the optimal foreign trade measure. The point estimates indicate that Sudan and South Sudan in East Africa as well as Benin and Togo in West Africa observe notable *under-investment* in trade links relative to other countries. Interestingly, edges that span across different countries are not necessarily *under-invested.*

Figure 3: Optimal Road Network in Africa

(a) Foreign Trade Coefficients in East Africa (b) Foreign Trade Coefficients in West Africa



Graphs (a) and (b) present the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in East and West Africa, respectively. "Border" indicates the edges that cross international boundaries.

7 Concluding Remarks

While colonial border designs and its relation to contemporary conflict, discrimination and national identity has been thoroughly investigated (e.g. Michalopoulos and Papaioannou 2016), this paper adds an important and understudied dimension, the role of borders in limiting infrastructure to promote trade amongst African countries. The share of intra-African exports as a percentage of total African exports has increased from about 10 percent in 1995 to around 17 percent in 2017, but it still remains very low compared to levels seen in Europe (69%), Asia (59%), and North America (31%). We apply the conceptual framework built by Fajgelbaum and Schaal (2020) to East and West Africa in order to understand how eliminating trade frictions within these regional blocks such as the institution of borders affects infrastructure investment and welfare. We specifically run counterfactuals by treating the East African countries as one economic block and the Western African countries as another economic block and compare the baseline and optimal infrastructure investment along the border links.

We find that the existing trade links are *under-invested* in both East and West Africa relative to the optimal road network in the absence of international borders. However, the degree of *under-investment* along trade links varies across countries: Sudan and South Sudan in East Africa and Benin and Togo in West Africa observe notable distortion of infrastructure investment. Our preliminary results provide significant policy tools for Africa. For instance, these results could help us understand the potential economic consequences of free trade agreement such as the recently signed African Continental Free Trade Agreement (AfCFTA) which was ratified in 2018 by 22 states and the largest free-trade area in the world in terms of participating countries since the formation of the WTO; the ECO currency union fostered by the Economic Community of West African States, the proposal of 5 countries in East Africa (Kenya, Uganda, Tanzania, Burundi, and Rwanda) to reach a single currency area by 2024 as well as prior agreements such as the Southern Africa Development Community (SADAC). Our study will provide direct insight on both the hypothetical gains of removing borders and, perhaps more importantly, from partially reducing barriers to trade across national borders in Africa through such policies.

Beyond Africa, our analysis can help provide a guiding framework to understand the issue of artificial borders, as they are not unique to the African continent. Around the globe, including Syria, Iraq, Afghanistan and other parts of the Middle East, failed states, conflict, and economic trauma are often very stark at borders left over by colonizers, borders which bore little resemblance to the natural division of peoples. We believe that the choices that colonizers made regarding borders and their subsequent long-run implications can be overcome and deserve deeper study.

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