Market Integration and Cost of Borders in Africa*

PRELIMINARY FIRST DRAFT

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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. We specifically consider different trade and colonial blocks and investigate to what extent frictions along the borders affect the patterns of infrastructure investment along links that play significant roles in international trade. Using a spatial general equilibrium model developed by Fajgelbaum and Schaal (2020), we show that existing links that are consequential for international trade and general trade are *under-invested* in the East African Community and West African Economic and Monetary Union. Moreover, we also find that border frictions on trade and infrastructure resources allocation limit the investment along international trade links in British East Africa and the Southern African Development Community. Our approach provides 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 leverage on a state-of-the-art model of infrastructure investment in a spatial equilibrium setting 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 provides conditions under which the problem can be numerically solved. This methodology 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 including population and nighttime light as well as digitize historical roads data. We implement three different counterfactual exercises: (i) each country in the block of countries separately optimizes the road network and trade flow; (ii) the global planner for the block of countries optimizes the road network and trade blow but cannot reallocate infrastructure resources across the country; (iii) the global planner for the block of countries optimizes the road network and trade flow without the aforementioned constraint.

We implement these counterfactual exercises in different trade and colonial blocks. Our preliminary results indicate that the removal of all border frictions significantly increases infrastructure investment along links consequential for foreign goods trade in the East African Community and West African Economic and Monetary Union. These results indicate that foreign trade links that *under-invested* in these economy blocks. While we do not observe

[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.

a significant increase in infrastructure investment along foreign trade links in British East Africa and the Southern African Development Community after removing all border frictions simultaneously, we still find that border frictions on trade and infrastructure resource allocation deviate infrastructure investment away from the optimal level, after controlling for domestic infrastructure investment misallocation. Lastly, in all colonial and trade blocks, we show that existing links that play significant roles in general trades receive more infrastructure investment under any counterfactual exercise. Thus, general trade links are heavily *under-investment* across Africa.

Related Literature. We next provide a brief literature review and links to 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.

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. Work by Michalopoulos and Papaioannou (2016) investigates 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 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 complements 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 welfaremaximizing 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.

The remainder of the paper is organized as follows. Section 2 describes the relevant details from Fajgelbaum and Schaal (2020) and modifies the framework to our context. Section 3 details the data we have assembled and digitized to track the theoretical framework. Section 4 links the theory with the empirical setup. Section 5 provides preliminary results from several counterfactual exercises of treating East African countries as regional blocks. Section 6 offers some concluding remarks.

2 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]

2.1 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.

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

2.2 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: $w_j^n = w_j$.

2.3 Transport Technology

The quality of goods shipped from j to $k \in \mathcal{N}(j)$ is given by Q_{jk}^n, 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: $1 + \tau_{jk}^n$. The transport cost is a function of the bundle of traded goods shipped along the link jk and of the level of infrastructure:

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

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

2.4 Flow Constraint

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

$$D_j^n + \sum_{k \in \mathcal{N}(j)} Q_{jk}^n \leq Y_j^n + \sum_{i \in \mathcal{N}(j)} Q_{ij}^n.$$

2.5 Network Building Constraint

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

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

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.

2.6 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.

3 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. One of the challenges for the cross-country analysis in Sub-Saharan Africa is that we don't have any statistical units that are consistent across African countries, unlike Europe. In order to overcome the challenge, we construct Voronoi polygons for cities based on the Africapolis data for each country in the analysis. Africapolis data is a polygon shapefile that compiles towns and cities with more than 10,000 inhabitants across Africa. For each country in Africa, we select cities with more than 50,000 inhabitants and create Voronoi polygons based on the centroids of the cities. For the country boundary, we use the GADM maps data in order to define the boundary for each African country.

We then aggregate a number of different data sources to the Voronoi polygons of African cities. 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 Voronoi polygons of cities in each country. To proxy for production data, we use GDP data provided by the World Development Indicator (WDI) database published by the World Bank. The WDI data is available at the country level from 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 Voronoi polygon and apply the estimated coefficients to the data in order to estimate per-capita GDP in each polygon.

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 lastly 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]

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

4 Linking Theory to Data

4.1 Counterfactual Exercises and Regression Specifications

In order to analyze the effects of international borders on the distribution of infrastructure networks in Africa, we do a first application of Fajgelbaum and Schaal (2020) model to the following blocks of countries:

1. **Anglophone Africa:** Botswana, Eswatini, Kenya, Lesotho, Malawi, South Africa, South Sudan, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe
2. **Francophone Africa:** Benin, Central African Republic, Chad, Côte d'Ivoire, Guinea, The Gambia, Mali, Mauritania, Niger, and Senegal
3. **East African Community (EAC):**[4] Democratic Republic of the Congo, Kenya, Rwanda, South Sudan, Tanzania, Uganda
4. **West African Economic and Monetary Union (UEMOA):**[5] Benin, Burkina-Faso, Côte d'Ivoire, Mali, Niger, Senegal, Togo
5. **Southern African Development Community (SADC):**[6] Angola, Botswana, The Democratic Republic of the Congo, Eswatini, Lesotho, Malawi, Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe

For the aforementioned sets of countries, we first calibrate the model fundamentals such as the labor productivity and the cost of infrastructure, and then implement counterfactual exercises. We consider three different counterfactual exercises in which the social planner optimizes the aggregate welfare in the economy:

1. Each country's social planner optimizes while the distributions in the other countries are fixed (separate counterfactual)
2. Global social planner optimizes the entire block of countries but does not reallocate infrastructure resources (e.g., asphalt) across the borders (semi-global counterfactual);
3. Global social planner optimizes the entire block of countries and reallocates infrastructure resources across the borders (global counterfactual)

Under the separate counterfactual exercise, we implement the counterfactual exercise across the economy by assigning positive weights to all locations in the country of interest and zero weights to all the other locations. We also add (i) constraint on differentiated goods consumption in the country of interest and (ii) constraints on differentiated good exports and imports in the country of interest in order to ensure that consumers across the entire economy consume all differentiated goods. More specifically, we set upper bounds on consumption, exports, and imports of all differentiated goods for the country of interest.

[4] We exclude Burundi.

[5] We exclude Guinea-Bissau.

[6] We exclude several islands Comoros, Madagascar, Mauritius, Seychelles as well as Namibia.

The idea behind the separate counterfactual exercise is that each country's social planner addresses the resource misallocation within the country but the coordination failure among countries still takes place. In contrast, in the semi-global counterfactual exercise, the global social planner overcomes the coordination failure but still faces the same constraint on infrastructure resources as country-specific social planners do in the separate counterfactual exercise. Lastly, in the global counterfactual exercise, the global social planner can freely reallocate infrastructure resources across the border along the block of countries in the economy, addressing the misallocation of infrastructure across the countries.

In applying the model to each block, 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 landlocked), we assume that all the cities with ports produce a differentiated good. We also assume that the three most populous city in the economic block produces city-specific differentiated goods — all the remaining cities/towns produce a homogeneous agricultural good.[7]

In order to analyze how the presence of international borders distorts the infrastructure investment away from the optimal road network that maximizes aggregate welfare in the economy, we first run the following regression specification:

$$\begin{aligned}\ln\left(\frac{I^*_{jk}}{I_{jk}}\right) =& \gamma_1 Foreign\ Trade_{jk} + \gamma_2 Total\ Trade_{jk} \\ &+ \gamma_3 \ln(L_{jk}) + \gamma_4 \ln(y_{jk}) + \gamma_5 \ln(I_{jk}) + \epsilon_{jk},\end{aligned} \tag{1}$$

where I_{jk} and I^*_{jk} are the status quo 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.

Once we compare the status quo and optimal infrastructure investment under each counterfactual exercise, we also compare the counterfactual exercise results: (i) separate vs semi-global; and (ii) semi-global and global. The first comparison shows to what extent the reduction of the trade coordination failure affects the optimal infrastructure investment. The second comparison suggests how much the optimal infrastructure investment changes once the misallocation of infrastructure resources across borders is eliminated.

Once we estimate how the foreign trade links are under- or over-invested, we then analyze the heterogeneity by country. We thus interact the indicators for all the countries and the border links with the standardized optimal foreign and total trade measures. More specifically, we run the following regression specification:

$$\begin{aligned}\ln\left(\frac{I^*_{jk}}{I_{jk}}\right) =& \sum_{c\in C} \delta_c \mathbf{1}\{Country_{jk} = c\} \times Foreign\ Trade_{jk} + \sum_{c\in C} \eta_c \mathbf{1}\{Country_{jk} = c\} \\ &\times Total\ Trade_{jk} + \zeta_3 \ln(L_{jk}) + \zeta_4 \ln(y_{jk}) + \zeta_5 \ln(I_{jk}) + u_{jk},\end{aligned} \tag{2}$$

[7] 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.

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."

4.2 Descriptive Statistics

Figures A.1, A.3, A.5, A.7, and A.9 display the population, GDP and road network data in Anglophone Africa, Francophone Africa, EAC, UEMOA, and SADC, respectively. Briefly, in Anglophone Africa and EAC, economic activity and road networks are concentrated around the economic hubs in East Africa (e.g. Nairobi, Mombasa, Dar es Salaam, and Kampala) and in South Africa. In Francophone Africa and UEMOA, coastal countries are more well-off and have higher road density than the inland countries.

5 Results

5.1 Anglophone Africa

We first compare the optimal road network against the status quo road network in Anglophone Africa. We thus examine whether links essential for foreign trade are under-invested or over-invested at the status quo. Figures A.2, 1, 2 present the status quo and optimal road network as well as the percentage change in infrastructure investment in Anglophone Africa. Subfigures (a) in figures 1 and 2 suggest the misallocation of infrastructure resources along the links that connect with major economic hubs in each country of the economy block. Subfigures (b) in figures 1 and 2 show that the reduction in trade coordination failure barely affects the reallocation of domestic infrastructure investment in this economy block. However, subfigures (c) in figures 1 and 2 indicate that the social planner of this economy block would reallocate infrastructure resources from Southern Africa to Tanzania, South Sudan, Sudan, and Zambia.

Table 1 shows the estimates of equation 1 under road network optimization in Anglophone Africa. For the outcome variable, we compare the infrastructure investment growth from the status quo to each counterfactual exercise result. The unit of analysis is an edge. The coefficient on the foreign trade measure is not statistically significant across all the counterfactual exercises. Thus, links that receive more foreign trade flow do not necessarily receive more infrastructure investment under road network optimization without political borders both domestically and internationally. This implies that the existing links essential for foreign trade are not necessarily *under-invested*. In contrast, the coefficient on the total trade measure is significantly positive across all the counterfactual exercises. 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. The coefficient on the initial levels of infrastructure investment is negative across all the counterfactual exercises. 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

Table 2 shows the estimates of equation 1 in Anglophone Africa. However, the outcome variable is the infrastructure investment growth from one counterfactual to another. In columns (1), (2), and (3), we compare the status quo and separate counterfactual exercise; in columns (4), (5), and (6), we compare the separate and semi-global counterfactual exercises; in columns (7), (8), and (9), we compare the semi-global and global counterfactual exercises. The unit of analysis is an edge. Now, the coefficients on the foreign trade measure are significant and positive for columns (4) to (9). This suggests that the reduction in trade coordinate failure and border frictions on infrastructure resources increases the resource reallocation toward the links that are consequential for foreign trade.

We now analyze the heterogeneity by country. Figures 3 and 4 show the coefficients estimates of equation 2 for each country and border links in Anglophone Africa. The former figure shows that foreign trade links in Eswatini, South Sudan, Sudan, and Tanzania are under-invested across all the counterfactual exercises. In contrast, the latter figure suggests that the reduction of border frictions on infrastructure reallocation has significantly positive effects on foreign trade links in Kenya, Malawi, and Zimbabwe.

5.2 Francophone Africa

Figures A.4, 5, 6 present the status quo and optimal road network as well as the percentage change in infrastructure investment in Francophone Africa. Subfigures (a) in figures 5 and 6 suggest the misallocation of infrastructure resources along the links that connect with major coastal economic hubs in each country of the economy block. Subfigures (b) in figures 5 and 6 show that the reduction in trade coordination failure barely affects the reallocation of domestic infrastructure investment in this economy block. However, subfigures (c) in figures 5 and 6 indicate that the social planner of this economy block would reallocate infrastructure resources from Guinea and Mali to Benin and Chad.

Table 3 shows the estimates of equation 1 under road network optimization in Francophone Africa. For the outcome variable, we compare the infrastructure investment growth from the status quo to each counterfactual exercise result. The unit of analysis is an edge. The coefficient on the foreign trade measure is not statistically significant across all the counterfactual exercises. Thus, links that receive more foreign trade flow do not necessarily receive more infrastructure investment under road network optimization without political borders both domestically and internationally. This implies that the existing links essential for foreign trade are not necessarily *under-invested*. In contrast, the coefficient on the total trade measure is significantly positive across all the counterfactual exercises. 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. The coefficient on the initial levels of infrastructure investment is negative across all the counterfactual exercises. 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

Table 4 shows the estimates of equation 1 in Francophone Africa. However, the outcome variable is the infrastructure investment growth from one counterfactual to another. In columns (1), (2), and (3), we compare the status quo and separate counterfactual exercise; in columns (4), (5), and (6), we compare the separate and semi-global counterfactual exercises; in columns (7), (8), and (9), we compare the semi-global and global counterfactual exercises. The unit of analysis is an edge. Now, the coefficients on the foreign trade measure are significant and positive for columns (4) to (6). This suggests that the reduction in trade coordinate failure increases the resource reallocation toward the links that are consequential for foreign trade. However, the border frictions on infrastructure resource allocation do not necessarily play significant roles in infrastructure investment along the foreigin trade links in Francophone Africa.

We now analyze the heterogeneity by country. Figures 7 and 8 show the coefficients estimates of equation 2 for each country and border links in Francophone Africa. It is unclear which country experiences under- or over-investment along the existing links that are keys for foreign trade. This suggests that Francophone Africa does not necessarily exhibit large inequality in infrastructure investment along foreign trade links.

5.3 East African Community

Figures A.6, 9, 10 present the status quo and optimal road network as well as the percentage change in infrastructure investment in EAC. Subfigures (a) in figures 9 and 10 suggest the misallocation of infrastructure resources along the links that connect with major economic hubs in each country of the economy block. Subfigures (b) in figures 9 and 10 show that the reduction in trade coordination failure barely affects the reallocation of domestic infrastructure investment in this economy block. However, subfigures (c) in figures 9 and 10 indicate that the social planner of this economy block would reallocate infrastructure resources toward DRC.

Table 5 shows the estimates of equation 1 under road network optimization in EAC. For the outcome variable, we compare the infrastructure investment growth from the status quo to each counterfactual exercise result. The unit of analysis is an edge. The coefficient on the foreign trade measure is significant and positive across all the counterfactual exercises. Thus, links that receive more foreign trade flow are likely to receive more infrastructure investment under road network optimization without political borders both domestically and internationally. This implies that the existing links essential for foreign trade are currently *under-invested*. Similarly, the coefficient on the total trade measure is significantly positive across all the counterfactual exercises. 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. The coefficient on the initial levels of infrastructure investment is negative across all the counterfactual exercises. Thus, edges that initially have a 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

Table 6 shows the estimates of equation 1 in EAC. However, the outcome variable is the infrastructure investment growth from one counterfactual to another. In columns (1), (2), and (3), we compare the status quo and separate counterfactual exercise; in columns (4), (5), and (6), we compare the separate and semi-global counterfactual exercises; in columns (7), (8), and (9), we compare the semi-global and global counterfactual exercises. The unit of analysis is an edge. Now, the coefficients on the foreign trade measure are significant and positive for columns (4) to (6). This suggests that the reduction in trade coordinate failure increases the resource reallocation toward the links that are consequential for foreign trade. However, the border frictions on infrastructure resource allocation do not necessarily play significant roles in infrastructure investment along the foreign trade links in EAC.

We now analyze the heterogeneity by country. Figures 11 and 12 show the coefficients estimates of equation 2 for each country and border links in EAC. The former figure shows that foreign trade links in Rwanda, South Sudan, and Uganda are under-invested across all the counterfactual exercises while Rwanda over-invests along the foreign trade links relative to other countries.

5.4 West African Economic and Monetary Union

Figures A.8, 13, 14 present the status quo and optimal road network as well as the percentage change in infrastructure investment in UEMOA. Subfigures (a) in figures 13 and 14 suggest the misallocation of infrastructure resources along the links that connect with major economic hubs in each country of the economy block. Subfigures (b) in figures 13 and 14 show that the reduction in trade coordination failure barely affects the reallocation of domestic infrastructure investment in this economy block. However, subfigures (c) in figures 13 and 14 indicate that the social planner of this economy block would reallocate infrastructure resources toward coastal economic hubs in Benin, Senegal, and Togo.

Table 7 shows the estimates of equation 1 under road network optimization in UEMOA. For the outcome variable, we compare the infrastructure investment growth from the status quo to each counterfactual exercise result. The unit of analysis is an edge. The coefficient on the foreign trade measure is significant and positive across all the counterfactual exercises. Thus, links that receive more foreign trade flow are likely to receive more infrastructure investment under road network optimization without political borders both domestically and internationally. This implies that the existing links essential for foreign trade are currently *under-invested*. Similarly, the coefficient on the total trade measure is significantly positive across all the counterfactual exercises. 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. The coefficient on the initial levels of infrastructure investment is negative across all the counterfactual exercises. 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

Table 8 shows the estimates of equation 1 in UEMOA. However, the outcome variable is the infrastructure investment growth from one counterfactual to another. In columns (1), (2), and (3), we compare the status quo and separate counterfactual exercise; in columns (4), (5), and (6), we compare the separate and semi-global counterfactual exercises; in columns (7), (8), and (9), we compare the semi-global and global counterfactual exercises. The unit of analysis is an edge. Now, the coefficients on the foreign trade measure are significant and positive for columns (4) to (6) and (9). This suggests that the reduction in trade coordinate failure and the border frictions on infrastructure resources increases the resource reallocation toward the links that are consequential for foreign trade.

We now analyze the heterogeneity by country. Figures 15 and 16 show the coefficients estimates of equation 2 for each country and border links in UEMOA. The former figure shows that foreign trade links in Niger are under-invested across all the counterfactual exercises while Togo over-invests along the foreign trade links relative to other countries.

5.5 Southern African Development Community

Figures A.10, 17, 18 present the status quo and optimal road network as well as the percentage change in infrastructure investment in SADC. Subfigures (a) in figures 17 and 18 suggest the misallocation of infrastructure resources along the links that connect with coastal economic hubs in Angola, Mozambique, South Africa, and Tanzania. Subfigures (b) in figures 17 and 18 show that the reduction in trade coordination failure barely affects the reallocation of domestic infrastructure investment in this economy block. However, subfigures (c) in figures 17 and 18 indicate that the social planner of this economy block would reallocate infrastructure resources from Botswana, South Africa, and Zimbabwe toward DRC, Mozambique, and Tanzania.

Table 9 shows the estimates of equation 1 under road network optimization in SADC. For the outcome variable, we compare the infrastructure investment growth from the status quo to each counterfactual exercise result. The unit of analysis is an edge. The coefficient on the foreign trade measure is significant and negative across all the counterfactual exercises except for column (9). Thus, links that receive more foreign trade flow are likely to receive *less* infrastructure investment under road network optimization without political borders both domestically and internationally. This implies that the existing links essential for foreign trade are currently *over-invested*. In contrast, the coefficient on the total trade measure is significantly positive across all the counterfactual exercises. 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. The coefficient on the initial levels of infrastructure investment is negative across all the counterfactual exercises. 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

Table 10 shows the estimates of equation 1 in SADC. However, the outcome variable is the infrastructure investment growth from one counterfactual to another. In columns (1), (2), and (3), we compare the status quo and separate counterfactual exercise; in columns (4), (5), and (6), we compare the separate and semi-global counterfactual exercises; in columns (7), (8), and (9), we compare the semi-global and global counterfactual exercises. The unit of analysis is an edge. Now, the coefficients on the foreign trade measure is significant and positive for columns (6) and (9). This suggests that the reduction in trade coordinate failure and the border frictions on infrastructure resources increases the resource reallocation toward the links that are consequential for foreign trade.

We now analyze the heterogeneity by country. Figures 19 and 20 show the coefficients estimates of equation 2 for each country and border links in SADC. The former figure shows that foreign trade links in DRC, Mozambique, Zambia, and Zimbabwe are under-invested across all the counterfactual exercises.

6 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 still remains 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 important blocks of African countries from the period of "scramble for Africa" to contemporary free-trade areas and planned currency unions. We make progress on 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 set of countries as one economic block and compare the status quo and optimal infrastructure investment along the links that are consequential for international trade.

We find that the existing foreign trade links are *under-invested* in EAC and UEMOA relative to the optimal road network in the absence of international borders. In contrast, the existing foreign trade links are not necessarily *under-invested* but trade links in general are *under-invested* in Anglophone and Francophone Africa. Our preliminary results provide significant policy tools to understand the implications of various trade block configurations. 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 is one of 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 (SADC). Our study aims to 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. We next plan to understand the implications of certain frozen and ongoing conflicts as well a single block of all 55 member states of the African Union.

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, 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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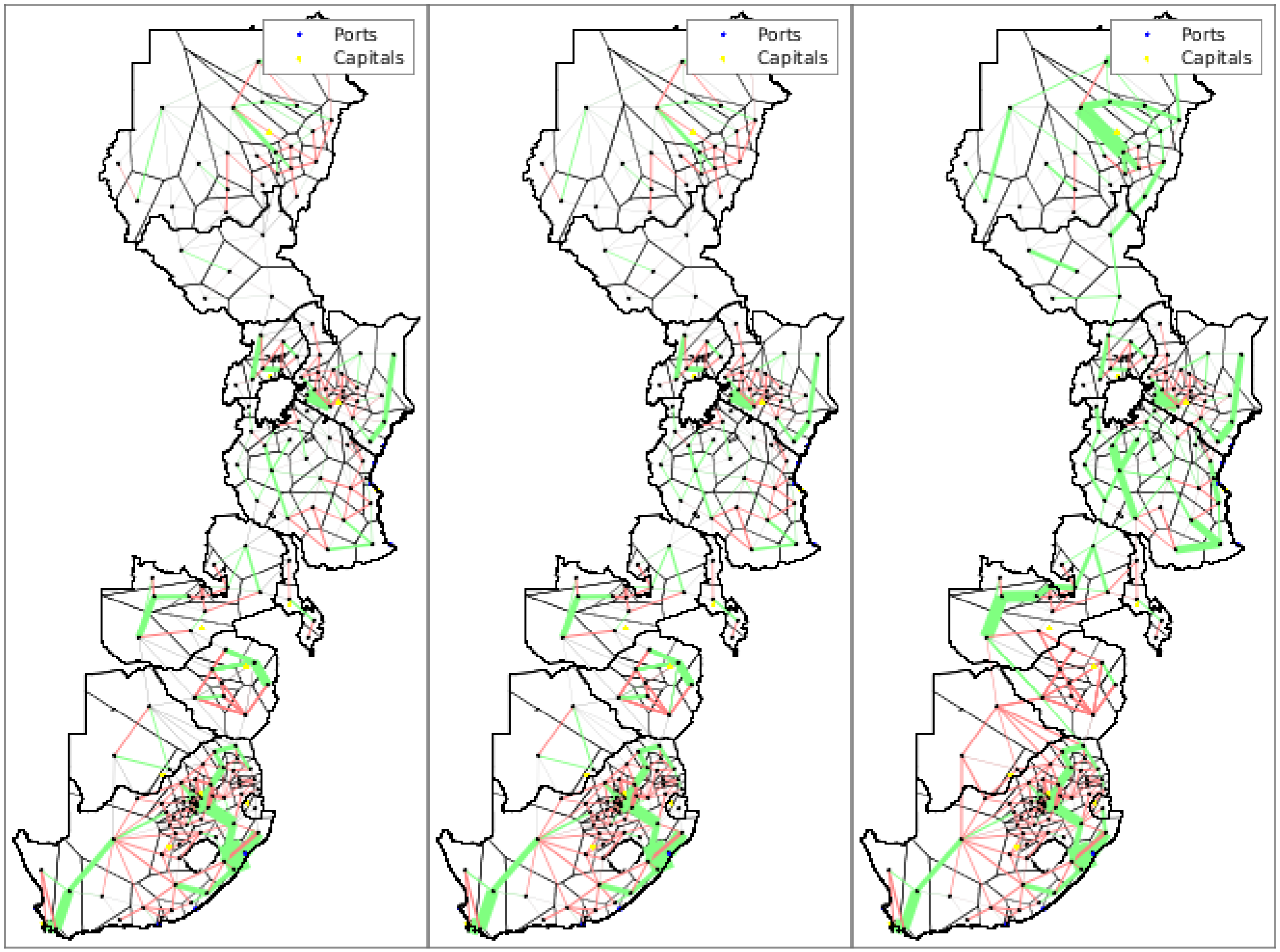
Figure 1: Infrastructure Investment Growth in Anglophone Africa

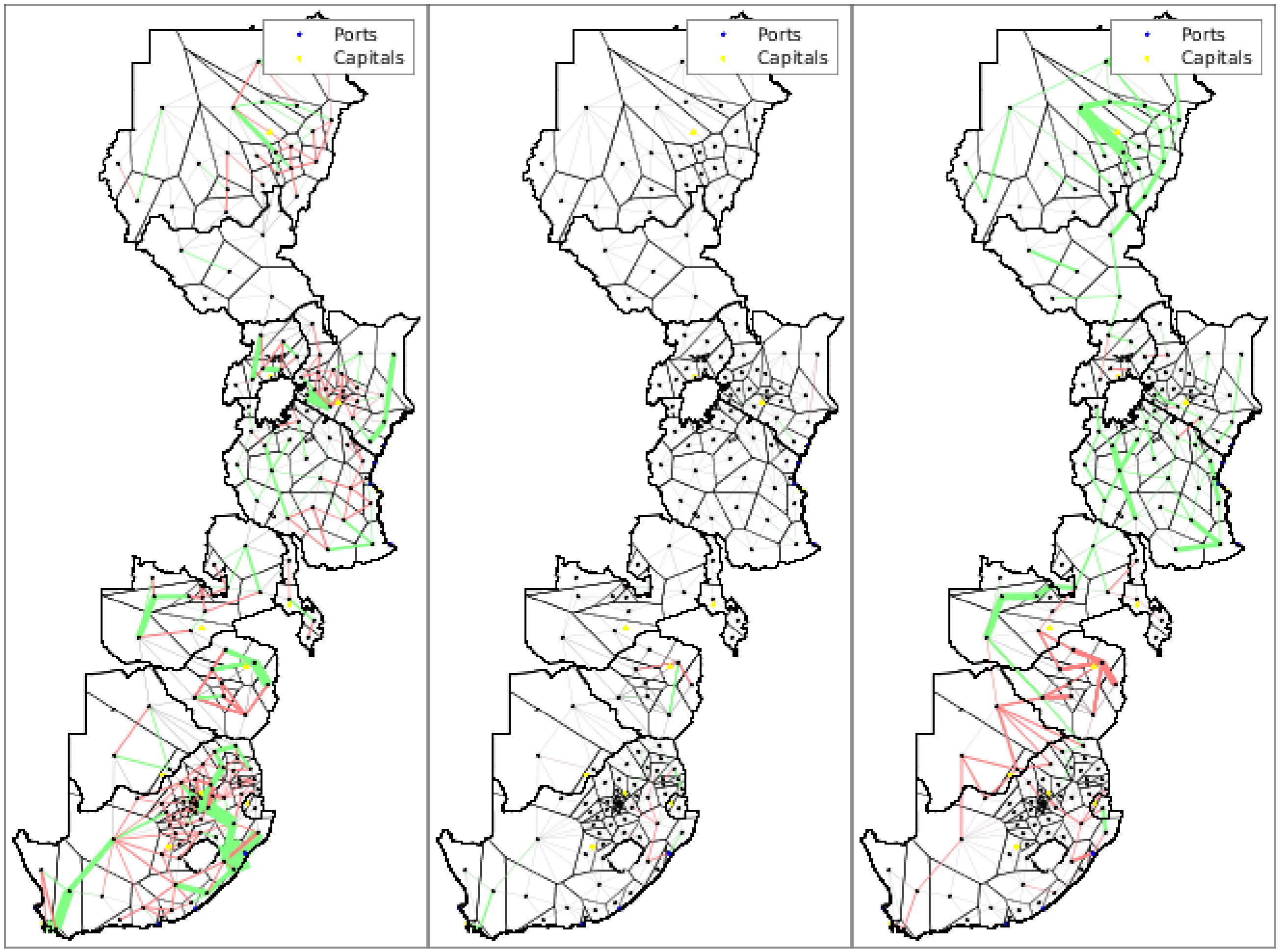
(a) Separate Counterfactual (b) Semi-Global Counterfactual (c) Global Counterfactual



Subfigures (a), (b), and (c) present the percentage change from the status quo to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment from the status quo to optimal level. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

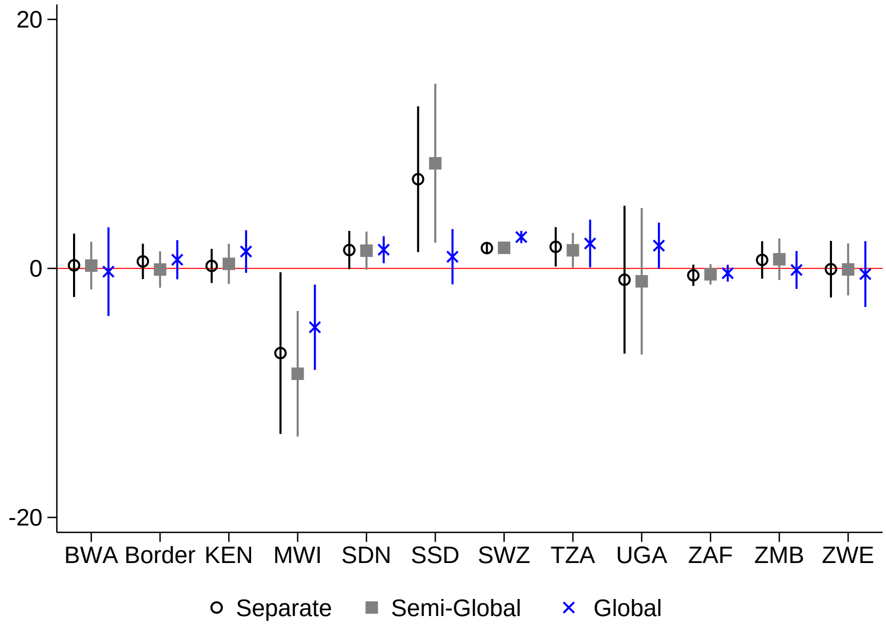
Figure 2: Infrastructure Investment Growth in Anglophone Africa

(a) Status Quo vs Separate (b) Separate vs Semi-Global (c) Semi-Global vs Global



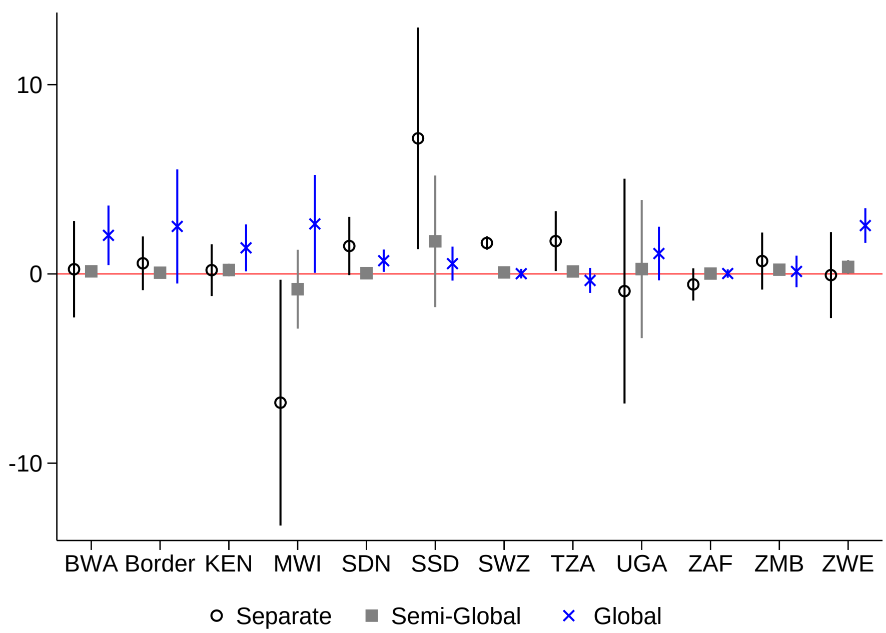
Subfigures (a), (b), and (c) present the percentage change of optimal infrastructure investment under one counterfactual exercise to another. Subfigure (a) compares the status quo to the separate counterfactual exercise; subfigure (b) compares the separate and semi-global counterfactual exercises; and subfigure (c) compares the semi-global and global counterfactual exercises. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment under these counterfactual exercises. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 3: Foreign Trade Link and Infrastructure Investment Growth in Anglophone Africa



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in Anglophone Africa. "Border" indicates the edges that cross international boundaries.

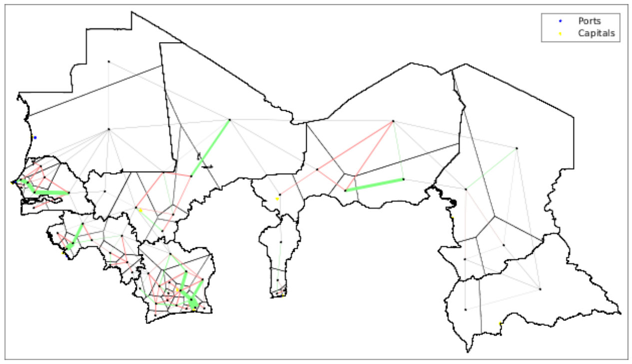
Figure 4: Foreign Trade Link and Infrastructure Investment Growth in Anglophone Africa



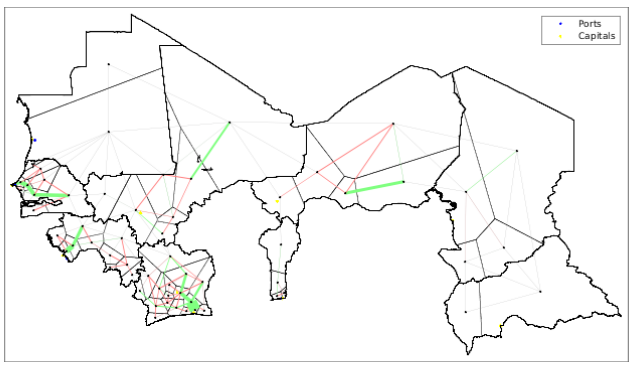
This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in Anglophone Africa. "Border" indicates the edges that cross international boundaries.

Figure 5: Infrastructure Investment Growth in Francophone Africa

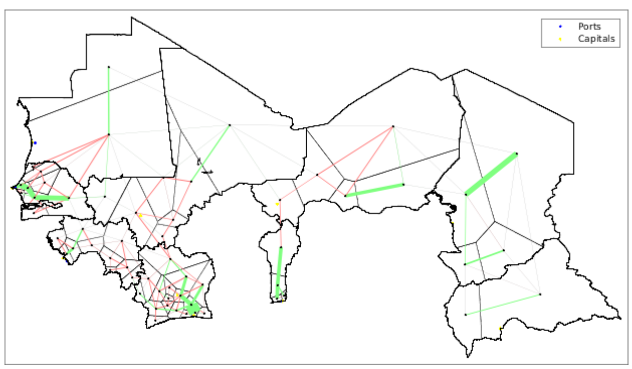
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



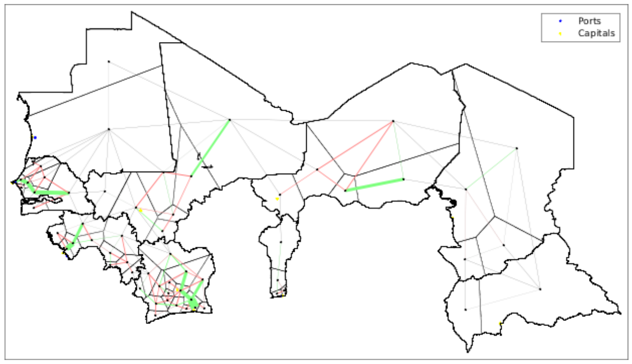
(c) Global Countefactual



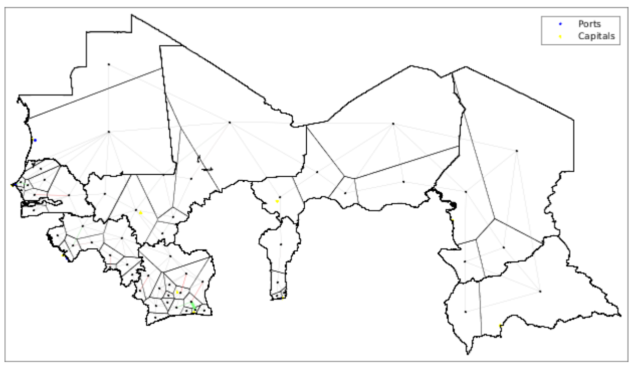
Subfigures (a), (b), and (c) present the percentage change from the status quo to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment from the status quo to optimal level. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 6: Infrastructure Investment Growth in Francophone Africa

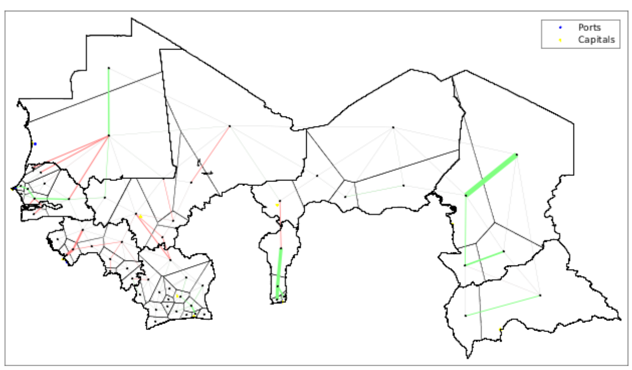
(a) Separate Counterfactual



(b) Semi-Global Counterfactual

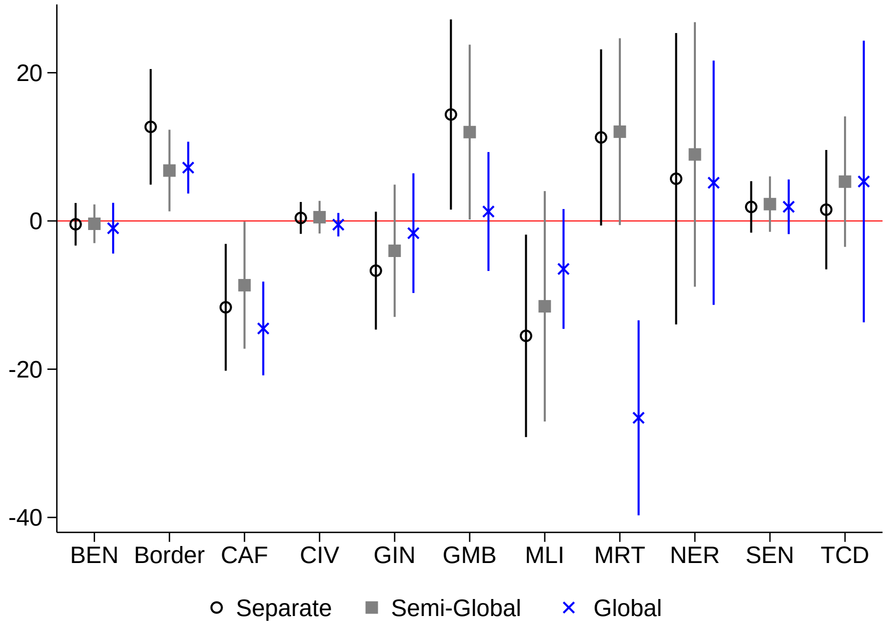


(c) Global Countefactual



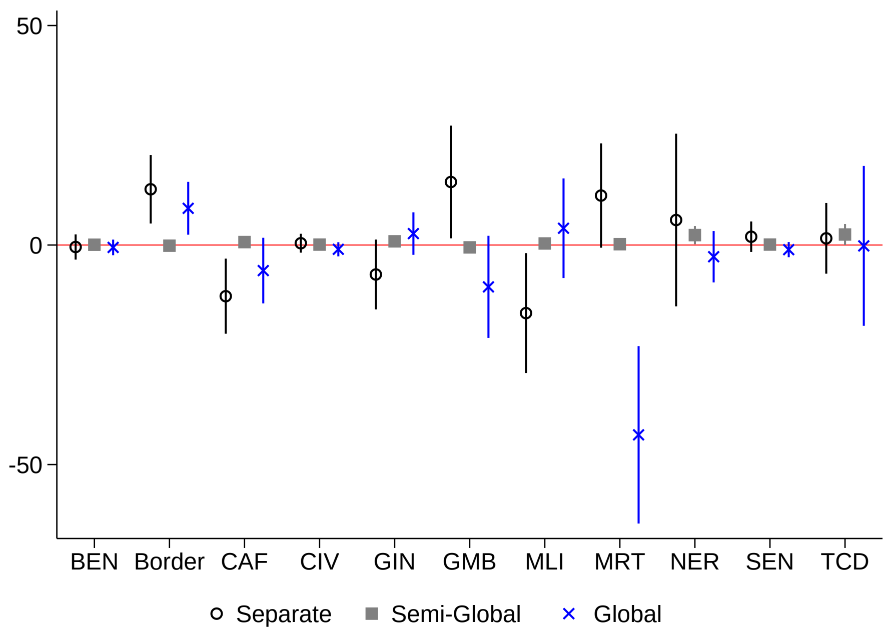
Subfigures (a), (b), and (c) present the percentage change of optimal infrastructure investment under one counterfactual exercise to another. Subfigure (a) compares the status quo to the separate counterfactual exercise; subfigure (b) compares the separate and semi-global counterfactual exercises; and subfigure (c) compares the semi-global and global counterfactual exercises. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment under these counterfactual exercises. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 7: Foreign Trade Link and Infrastructure Investment Growth in Francophone Africa



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in Francophone Africa. "Border" indicates the edges that cross international boundaries.

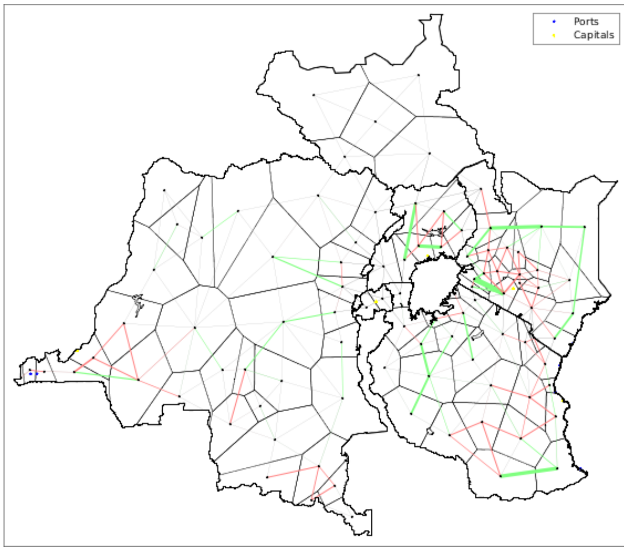
Figure 8: Foreign Trade Link and Infrastructure Investment Growth in Francophone Africa



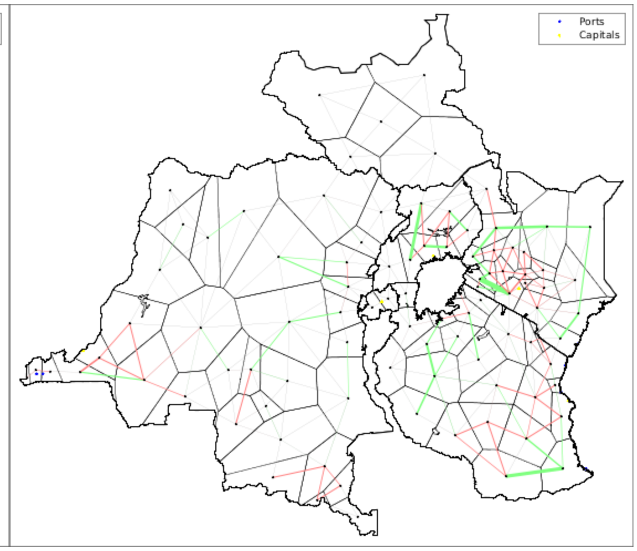
This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in Francophone Africa. "Border" indicates the edges that cross international boundaries.

Figure 9: Infrastructure Investment Growth in EAC

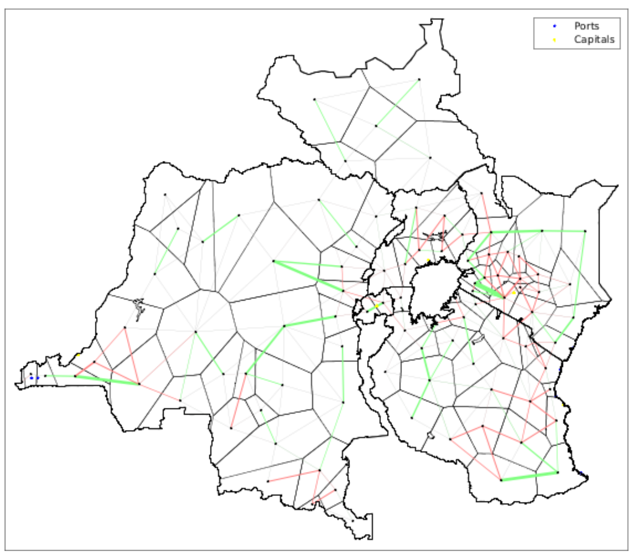
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



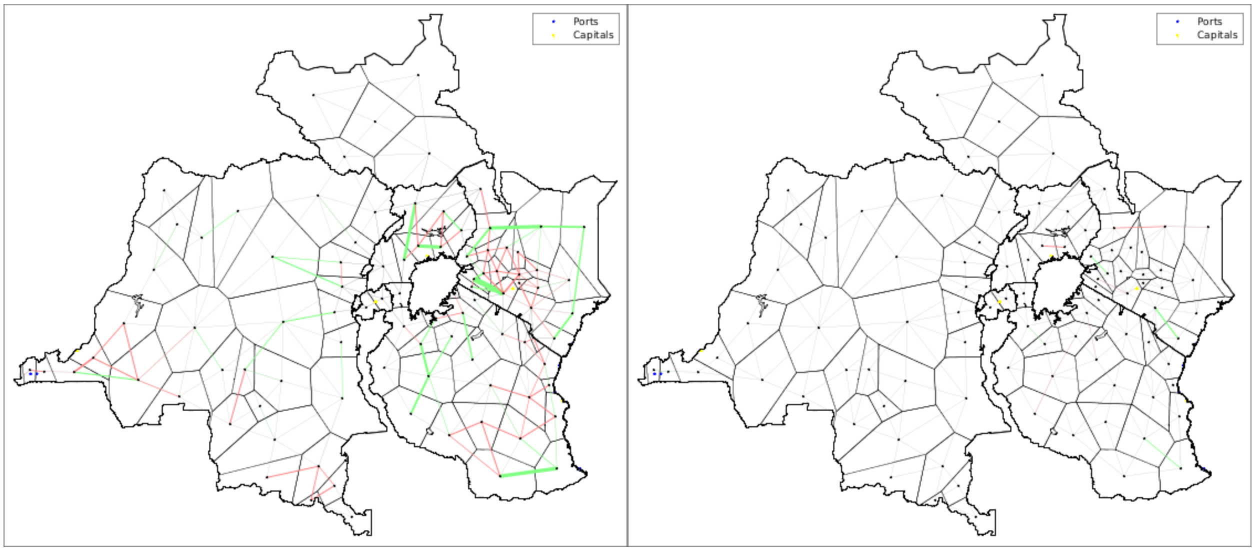
(c) Global Counterfactual



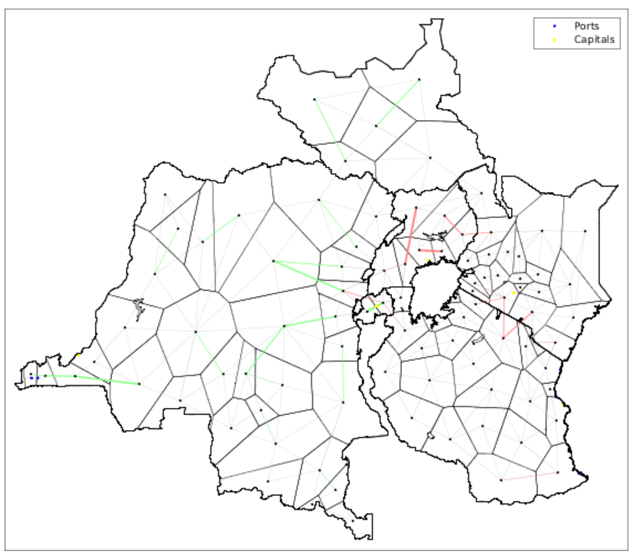
Subfigures (a), (b), and (c) present the percentage change from the status quo to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment from the status quo to optimal level. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 10: Infrastructure Investment Growth in EAC

(a) Status Quo vs Separate (b) Separate vs Semi-Global

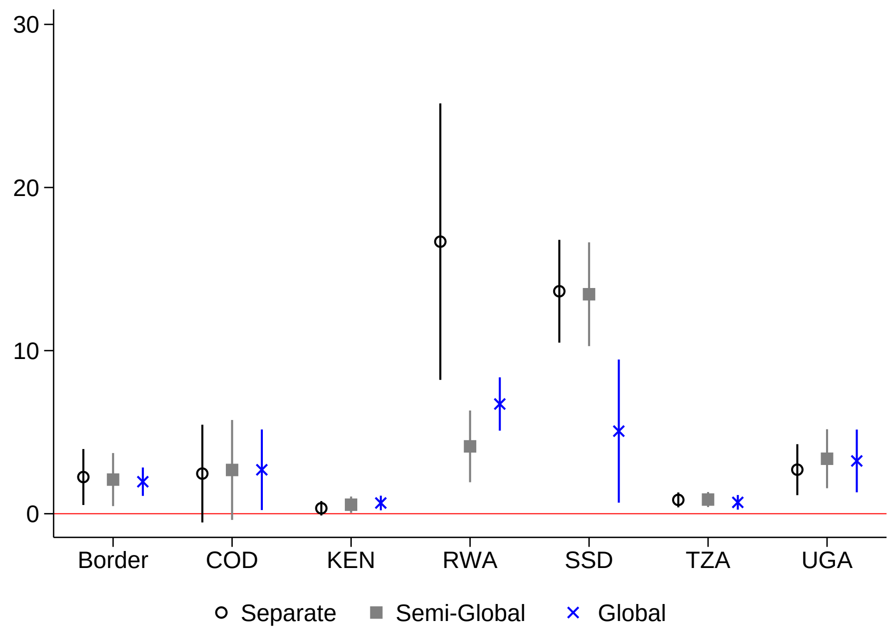


(c) Semi-Global vs Global



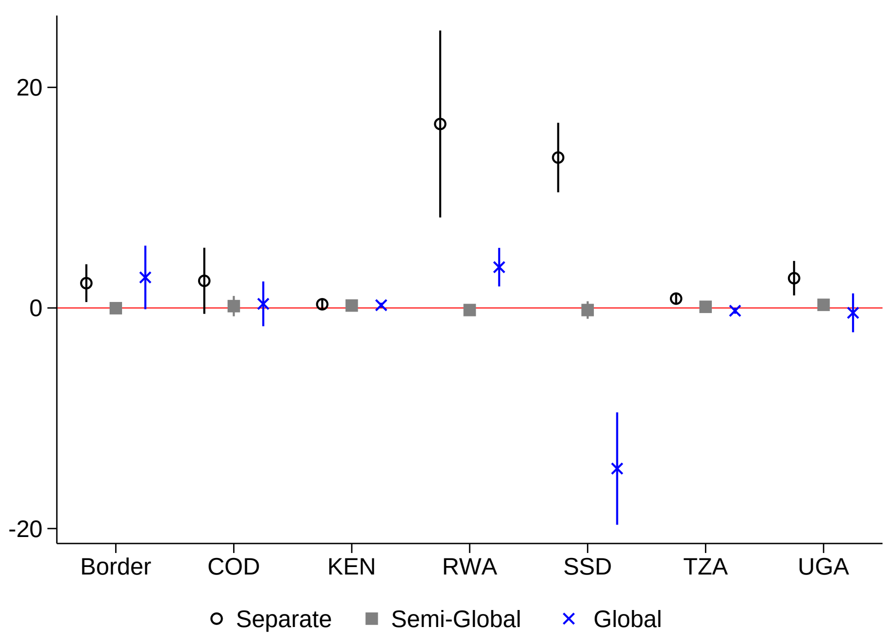
Subfigures (a), (b), and (c) present the percentage change of optimal infrastructure investment under one counterfactual exercise to another. Subfigure (a) compares the status quo to the separate counterfactual exercise; subfigure (b) compares the separate and semi-global counterfactual exercises; and subfigure (c) compares the semi-global and global counterfactual exercises. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment under these counterfactual exercises. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 11: Foreign Trade Link and Infrastructure Investment Growth in EAC



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in EAC. "Border" indicates the edges that cross international boundaries.

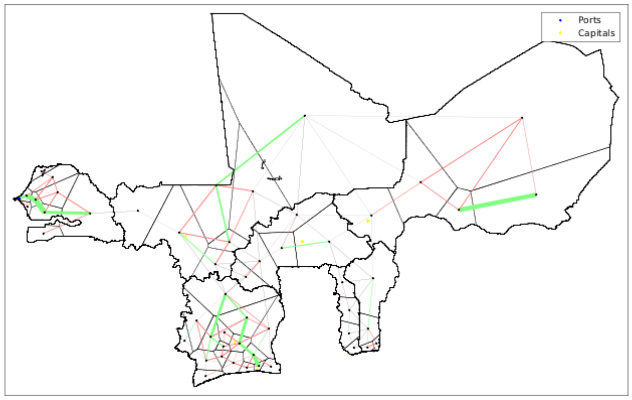
Figure 12: Foreign Trade Link and Infrastructure Investment Growth in EAC



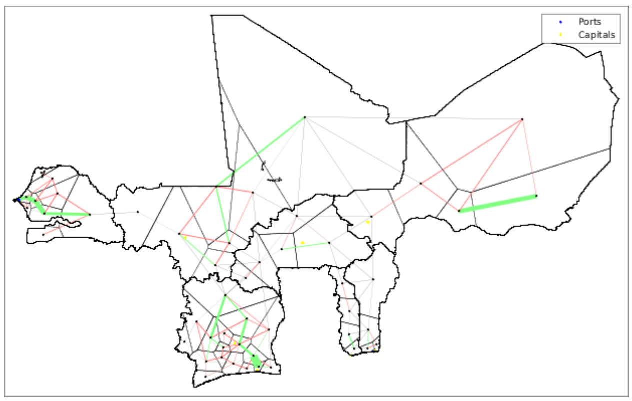
This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in EAC. "Border" indicates the edges that cross international boundaries.

Figure 13: Infrastructure Investment Growth in UEMOA

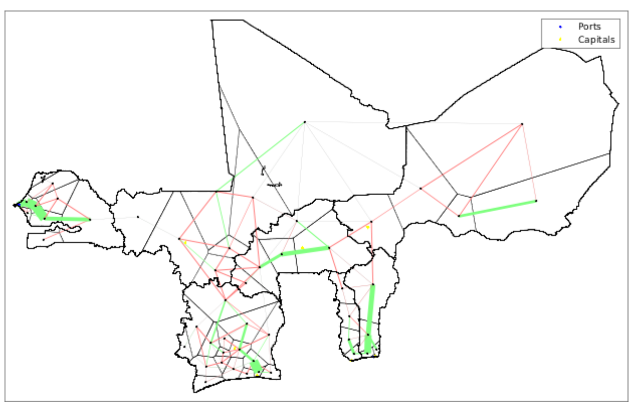
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



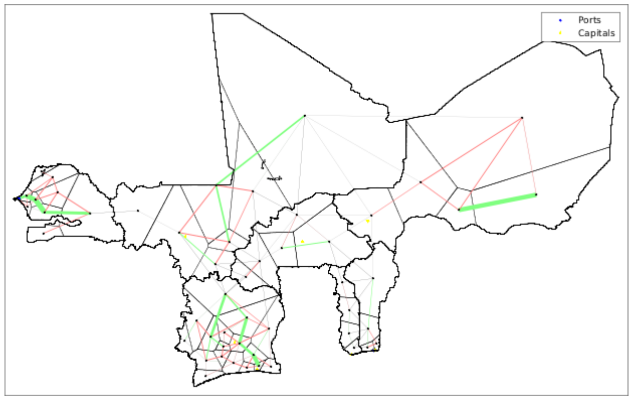
(c) Global Counterfactual



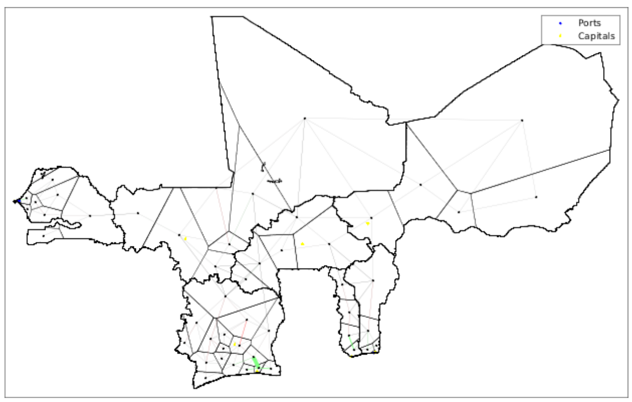
Subfigures (a), (b), and (c) present the percentage change from the status quo to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment from the status quo to optimal level. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 14: Infrastructure Investment Growth in UEMOA

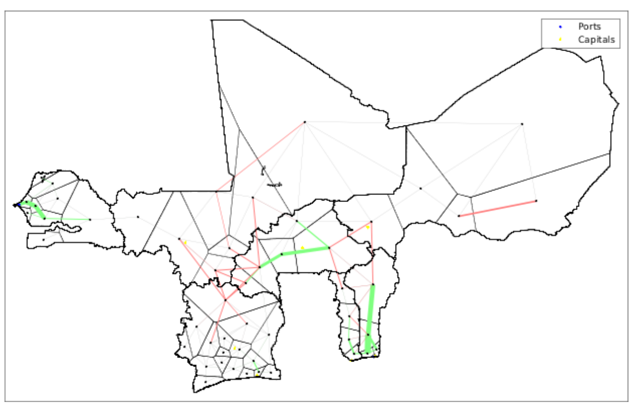
(a) Status Quo vs Separate



(b) Separate vs Semi-Global

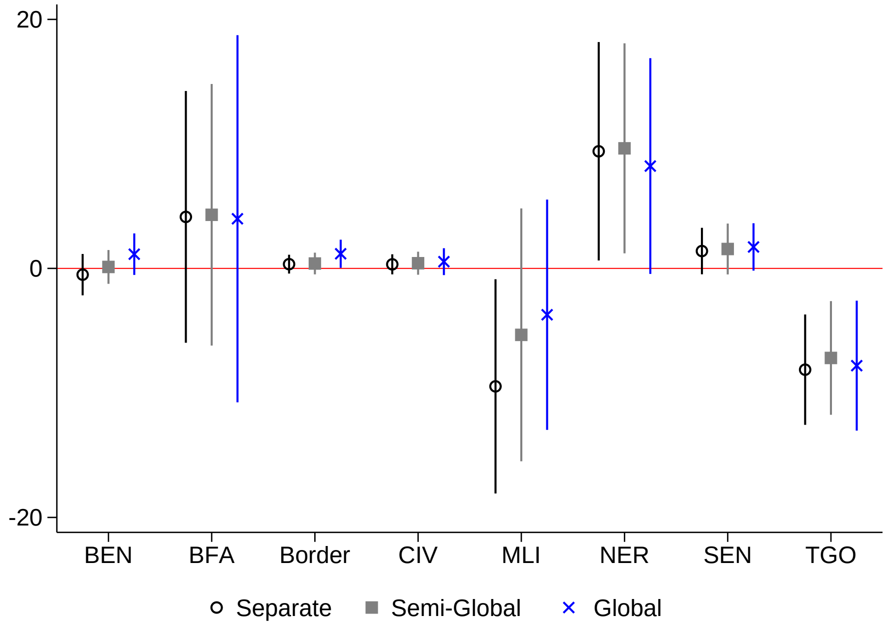


(c) Semi-Global vs Global



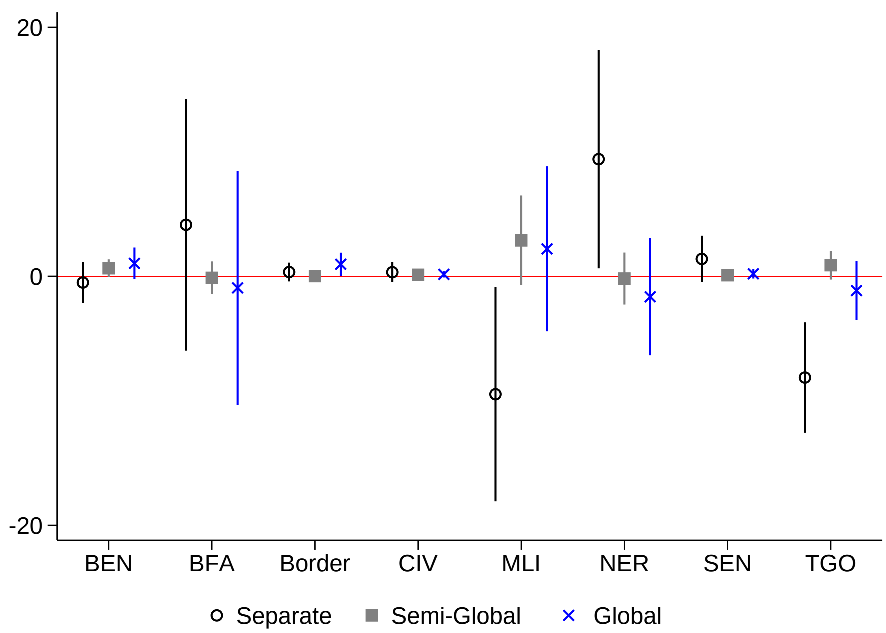
Subfigures (a), (b), and (c) present the percentage change of optimal infrastructure investment under one counterfactual exercise to another. Subfigure (a) compares the status quo to the separate counterfactual exercise; subfigure (b) compares the separate and semi-global counterfactual exercises; and subfigure (c) compares the semi-global and global counterfactual exercises. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment under these counterfactual exercises. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 15: Foreign Trade Link and Infrastructure Investment Growth in UEMOA



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in UEMOA. "Border" indicates the edges that cross international boundaries.

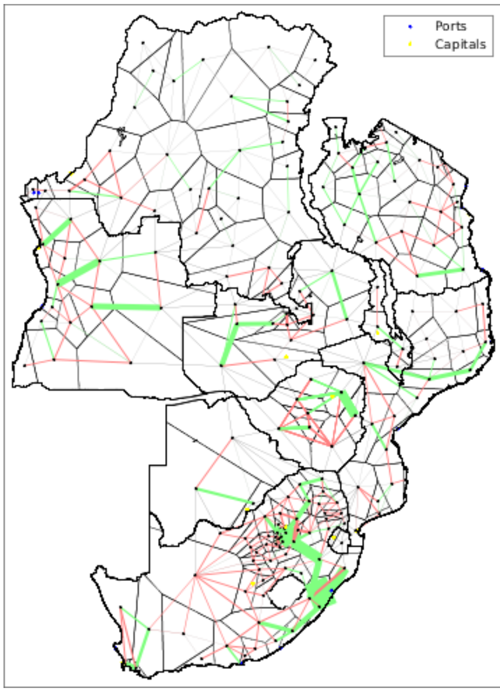
Figure 16: Foreign Trade Link and Infrastructure Investment Growth in UEMOA



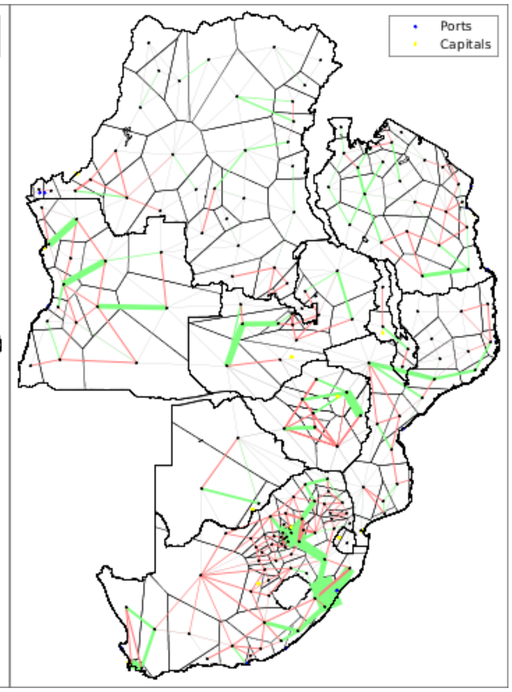
This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in UEMOA. "Border" indicates the edges that cross international boundaries.

Figure 17: Infrastructure Investment Growth in SADC

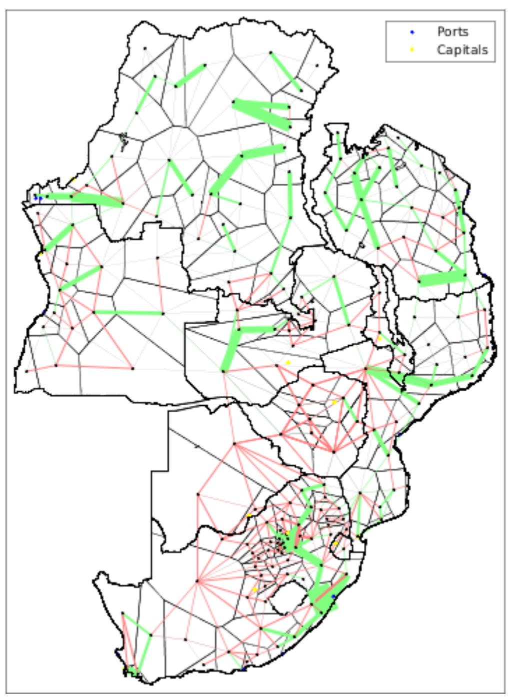
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



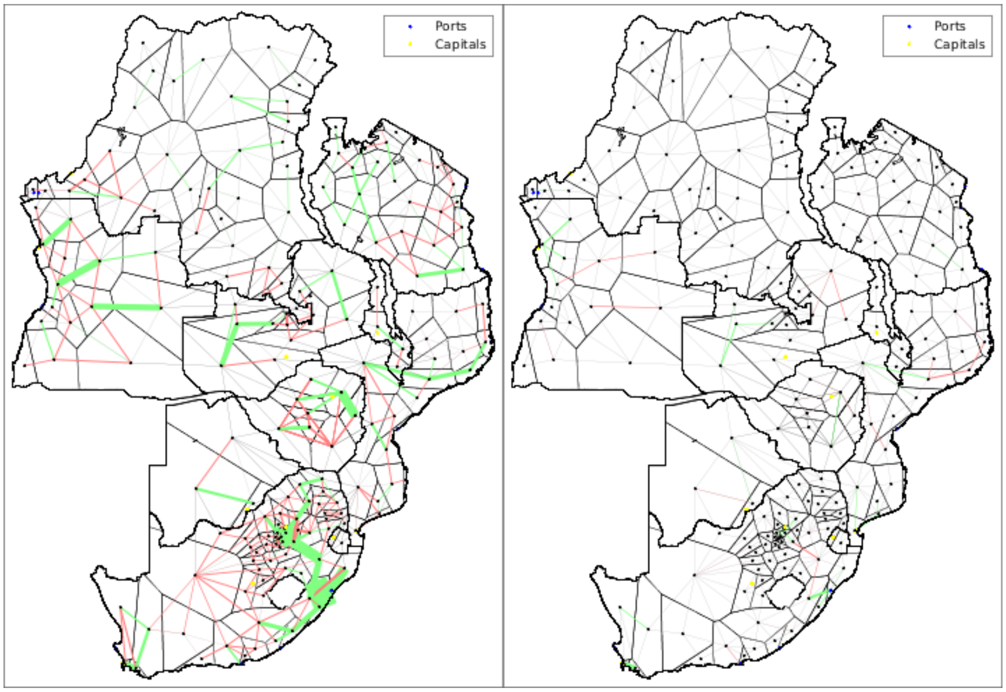
(c) Global Counterfactual



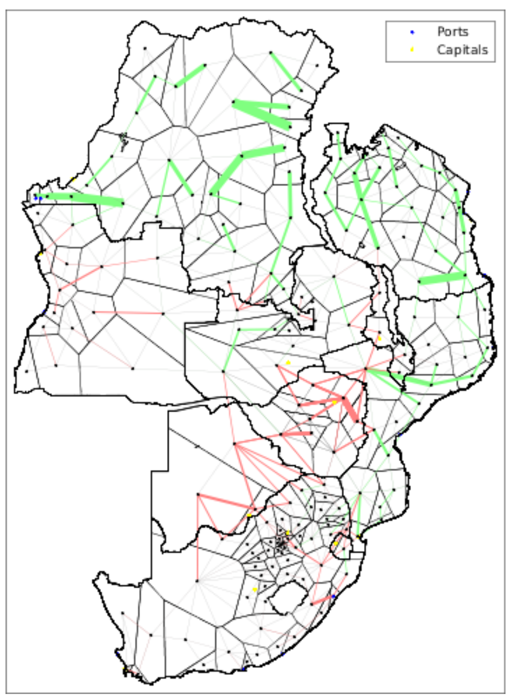
Subfigures (a), (b), and (c) present the percentage change from the status quo to optimal infrastructure investment. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment from the status quo to optimal level. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 18: Infrastructure Investment Growth in SADC

(a) Status Quo vs Separate (b) Separate vs Semi-Global

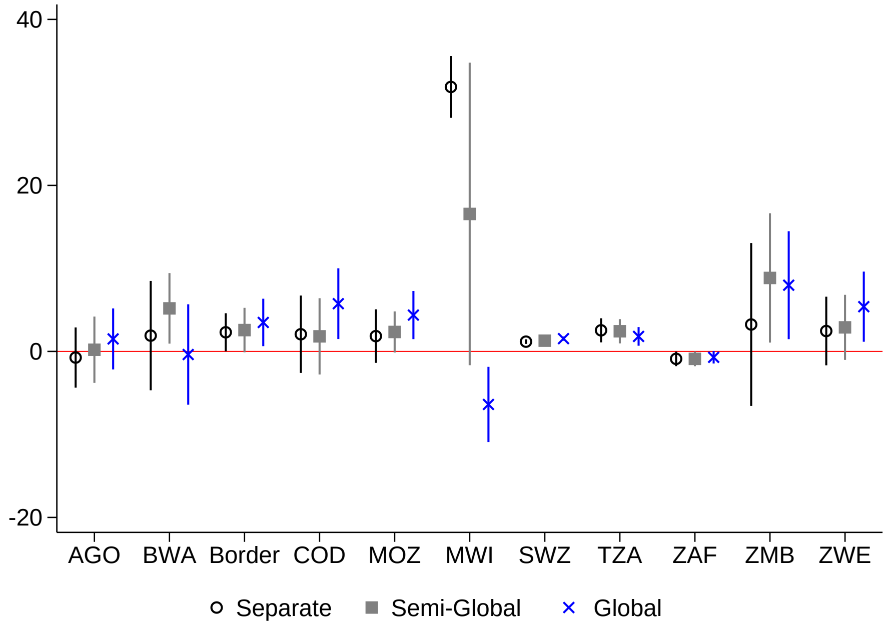


(c) Semi-Global vs Global



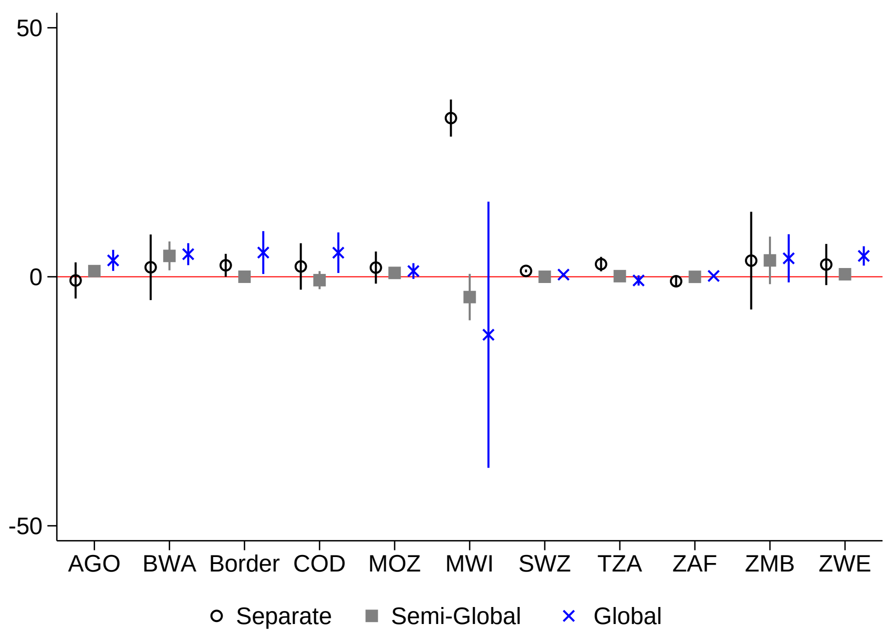
Subfigures (a), (b), and (c) present the percentage change of optimal infrastructure investment under one counterfactual exercise to another. Subfigure (a) compares the status quo to the separate counterfactual exercise; subfigure (b) compares the separate and semi-global counterfactual exercises; and subfigure (c) compares the semi-global and global counterfactual exercises. Green edge corresponds to infrastructure gains while red edge corresponds to infrastructure loss. The black edge indicates no change in infrastructure investment under these counterfactual exercises. The wider edge corresponds to the greater gain/loss of infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure 19: Foreign Trade Link and Infrastructure Investment Growth in SADC



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in SADC. "Border" indicates the edges that cross international boundaries.

Figure 20: Foreign Trade Link and Infrastructure Investment Growth in SADC



This figure presents the coefficients on the interaction term between the country indicator and the optimal foreign trade measure for each country in SADC. "Border" indicates the edges that cross international boundaries.

Table 1: Optimal Infrastructure Investment in Anglophone Africa

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-0.912	-0.888	-0.379	-0.773	-0.746	-0.237	-0.087	-0.037	0.068
	(0.585)	(0.590)	(0.404)	(0.580)	(0.586)	(0.381)	(0.646)	(0.655)	(0.333)
Optimal total trade	2.768***	2.727***	2.280***	2.753***	2.704***	2.252***	2.564***	2.525***	2.134***
	(0.609)	(0.620)	(0.351)	(0.611)	(0.623)	(0.353)	(0.611)	(0.621)	(0.300)
Border	1.044***	0.965**	-0.342	1.080***	0.985**	-0.350	1.195	1.123	-0.442
	(0.355)	(0.394)	(0.663)	(0.368)	(0.404)	(0.663)	(1.083)	(1.097)	(0.572)
Population		0.273	-0.137		0.290	-0.120		0.675*	0.163
		(0.345)	(0.239)		(0.344)	(0.239)		(0.372)	(0.239)
Income		-0.223	0.220		-0.160	0.290		-1.391*	-0.739
		(0.692)	(0.498)		(0.709)	(0.505)		(0.811)	(0.463)
Infrastructure			-0.735***			-0.736***			-0.918***
			(0.036)			(0.036)			(0.033)
Observations	482	482	482	482	482	482	482	482	482
Adjusted R-squred	0.12	0.12	0.62	0.13	0.13	0.62	0.13	0.13	0.73

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the status quo to optimal infrastructure investment. Optimal foreign (total) trade 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: Optimal Infrastructure Investment in Anglophone Africa

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-0.912	-0.888	-0.379	0.049**	0.051**	0.051**	0.601***	0.612***	0.634***
	(0.585)	(0.590)	(0.404)	(0.019)	(0.020)	(0.021)	(0.204)	(0.210)	(0.201)
Optimal total trade	2.768***	2.727***	2.280***	0.022	0.014	0.014	-0.193*	-0.170	-0.252
	(0.609)	(0.620)	(0.351)	(0.025)	(0.028)	(0.029)	(0.114)	(0.123)	(0.153)
Border	1.044***	0.965**	-0.342	0.105**	0.089	0.088	0.188	0.235	-0.097
	(0.355)	(0.394)	(0.663)	(0.048)	(0.054)	(0.057)	(1.036)	(1.036)	(0.884)
Population		0.273	-0.137		0.009	0.009		0.356**	0.248*
		(0.345)	(0.239)		(0.061)	(0.062)		(0.152)	(0.148)
Income		-0.223	0.220		0.083	0.083		-1.284***	-1.146***
		(0.692)	(0.498)		(0.161)	(0.163)		(0.448)	(0.414)
Infrastructure			-0.735***			0.000			-0.194***
			(0.036)			(0.006)			(0.028)
Observations	482	482	482	482	482	482	482	482	482
Adjusted R-squred	0.12	0.12	0.62	0.01	0.01	0.01	0.03	0.05	0.20

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change of optimal infrastructure investment from one counterfactual exercise to another. Columns (1), (2), and (3) compare the status quo and separate counterfactual exercise results; columns (4), (5), and (6) compare the separate and semi-global counterfactual exercise results; and columns (7), (8), and (9) compare the semi-global and global counterfactual exercise results. Optimal foreign (total) trade 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 3: Optimal Infrastructure Investment in Francophone Africa

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-0.005	0.150	0.172	0.125	0.287	0.265	0.202	0.462	0.221
	(0.688)	(0.721)	(0.614)	(0.744)	(0.786)	(0.647)	(0.828)	(0.868)	(0.535)
Optimal total trade	1.993***	1.801***	1.770***	1.940***	1.735***	1.720***	2.096***	1.878***	1.827***
	(0.554)	(0.550)	(0.332)	(0.563)	(0.564)	(0.337)	(0.591)	(0.545)	(0.325)
Border	2.734***	1.804*	-0.050	2.709***	1.778*	-0.059	4.841***	3.168**	-1.144
	(0.638)	(0.931)	(1.108)	(0.630)	(0.939)	(1.121)	(1.493)	(1.563)	(0.827)
Population		0.062	1.071		0.187	1.194		-1.260	1.156*
		(0.793)	(0.776)		(0.787)	(0.763)		(1.305)	(0.685)
Income		1.239*	-0.865		1.166	-0.936		3.014**	-1.930***
		(0.730)	(0.765)		(0.752)	(0.768)		(1.311)	(0.712)
Infrastructure			-0.463***			-0.460***			-1.070***
			(0.106)			(0.106)			(0.064)
Observations	134	134	134	134	134	134	134	134	134
Adjusted R-squred	0.18	0.19	0.40	0.18	0.20	0.40	0.15	0.19	0.76

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the status quo to optimal infrastructure investment. Optimal foreign (total) trade 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 4: Optimal Infrastructure Investment in Francophone Africa

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-0.005	0.150	0.172	0.038***	0.034**	0.034**	-0.005	0.119	-0.020
	(0.688)	(0.721)	(0.614)	(0.008)	(0.015)	(0.015)	(0.179)	(0.197)	(0.296)
Optimal total trade	1.993***	1.801***	1.770***	-0.023	-0.031	-0.031	0.179	0.157	0.127
	(0.554)	(0.550)	(0.332)	(0.032)	(0.034)	(0.035)	(0.141)	(0.157)	(0.403)
Border	2.734***	1.804*	-0.050	-0.027	0.000	0.003	2.151	1.362	-1.133
	(0.638)	(0.931)	(1.108)	(0.083)	(0.108)	(0.117)	(1.366)	(1.352)	(1.199)
Population		0.062	1.071		0.140	0.138		-1.436	-0.038
		(0.793)	(0.776)		(0.103)	(0.106)		(1.036)	(0.795)
Income		1.239*	-0.865		-0.120	-0.116		1.922	-0.938
		(0.730)	(0.765)		(0.093)	(0.086)		(1.176)	(0.998)
Infrastructure			-0.463***			0.001			-0.619***
			(0.106)			(0.007)			(0.117)
Observations	134	134	134	134	134	134	134	134	134
Adjusted R-squred	0.18	0.19	0.40	0.00	0.01	0.01	0.04	0.07	0.48

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change of optimal infrastructure investment from one counterfactual exercise to another. Columns (1), (2), and (3) compare the status quo and separate counterfactual exercise results; columns (4), (5), and (6) compare the separate and semi-global counterfactual exercise results; and columns (7), (8), and (9) compare the semi-global and global counterfactual exercise results. Optimal foreign (total) trade 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 5: Optimal Infrastructure Investment in EAC

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	0.357	0.738*	0.889***	0.415	0.806*	0.989***	0.251	0.819*	0.867***
	(0.467)	(0.444)	(0.230)	(0.460)	(0.432)	(0.220)	(0.476)	(0.449)	(0.197)
Optimal total trade	2.985***	3.097***	2.244***	2.988***	3.114***	2.233***	3.093***	3.129***	1.996***
	(0.442)	(0.414)	(0.233)	(0.446)	(0.417)	(0.242)	(0.450)	(0.407)	(0.215)
Border	-0.546	1.735**	-1.042	-0.539	1.707**	-1.130	0.229	3.202**	-0.396
	(0.553)	(0.786)	(1.015)	(0.569)	(0.799)	(1.011)	(1.578)	(1.501)	(0.591)
Population		-3.146***	-0.200		-3.088***	-0.082		-4.213***	-0.412
		(0.816)	(0.536)		(0.839)	(0.549)		(0.899)	(0.461)
Income		5.850***	-1.865**		5.858***	-2.017**		8.162***	-1.608***
		(0.947)	(0.805)		(0.977)	(0.823)		(1.002)	(0.617)
Infrastructure			-0.798***			-0.813***			-1.017***
			(0.044)			(0.045)			(0.034)
Observations	222	222	222	222	222	222	222	222	222
Adjusted R-squred	0.21	0.33	0.75	0.20	0.32	0.75	0.16	0.35	0.88

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the status quo to optimal infrastructure investment. Optimal foreign (total) trade 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 6: Optimal Infrastructure Investment in EAC

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	0.357	0.738*	0.889***	0.127***	0.119***	0.122***	-0.158	0.022	0.032
	(0.467)	(0.444)	(0.230)	(0.025)	(0.026)	(0.028)	(0.150)	(0.152)	(0.172)
Optimal total trade	2.985***	3.097***	2.244***	-0.010	-0.014	-0.030	0.181	0.189	-0.041
	(0.442)	(0.414)	(0.233)	(0.026)	(0.026)	(0.027)	(0.182)	(0.182)	(0.196)
Border	-0.546	1.735**	-1.042	0.046	-0.003	-0.057	0.821	1.749	1.019
	(0.553)	(0.786)	(1.015)	(0.067)	(0.085)	(0.083)	(1.495)	(1.487)	(1.303)
Population		-3.146***	-0.200		0.073	0.130*		-1.299***	-0.528
		(0.816)	(0.536)		(0.077)	(0.077)		(0.480)	(0.460)
Income		5.850***	-1.865**		-0.096	-0.247*		2.623***	0.640
		(0.947)	(0.805)		(0.140)	(0.127)		(0.635)	(0.748)
Infrastructure			-0.798***			-0.016***			-0.206***
			(0.044)			(0.005)			(0.042)
Observations	222	222	222	222	222	222	222	222	222
Adjusted R-squred	0.21	0.33	0.75	0.03	0.04	0.06	0.01	0.09	0.19

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change of optimal infrastructure investment from one counterfactual exercise to another. Columns (1), (2), and (3) compare the status quo and separate counterfactual exercise results; columns (4), (5), and (6) compare the separate and semi-global counterfactual exercise results; and columns (7), (8), and (9) compare the semi-global and global counterfactual exercise results. Optimal foreign (total) trade 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 7: Optimal Infrastructure Investment in UEMOA

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	0.505**	0.589**	0.593**	0.670**	0.742**	0.738**	0.902**	1.116**	1.031**
	(0.236)	(0.273)	(0.272)	(0.287)	(0.329)	(0.324)	(0.370)	(0.484)	(0.417)
Optimal total trade	1.612***	1.564***	1.683***	1.631***	1.556***	1.682***	1.649***	1.745***	1.978***
	(0.449)	(0.489)	(0.398)	(0.455)	(0.502)	(0.406)	(0.441)	(0.507)	(0.397)
Border	2.986***	2.720***	1.460	3.108***	2.756***	1.436	1.413	1.464	-0.772
	(0.690)	(0.973)	(0.973)	(0.721)	(1.035)	(1.024)	(1.398)	(1.554)	(0.770)
Population		-0.219	1.167		-0.032	1.426		-1.583	0.920
		(1.103)	(1.037)		(1.117)	(1.037)		(1.497)	(1.047)
Income		1.031	-1.748		0.976	-1.944		2.243	-2.775**
		(1.892)	(1.522)		(1.875)	(1.468)		(2.111)	(1.352)
Infrastructure			-0.559***			-0.586***			-0.994***
			(0.135)			(0.137)			(0.084)
Observations	109	109	109	109	109	109	109	109	109
Adjusted R-squred	0.15	0.16	0.39	0.16	0.16	0.40	0.11	0.12	0.62

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the status quo to optimal infrastructure investment. Optimal foreign (total) trade 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 8: Optimal Infrastructure Investment in UEMOA

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	0.505**	0.589**	0.593**	0.148**	0.138**	0.138**	0.194	0.318	0.283
	(0.236)	(0.273)	(0.272)	(0.057)	(0.054)	(0.054)	(0.158)	(0.213)	(0.185)
Optimal total trade	1.612***	1.564***	1.683***	0.027	-0.001	0.005	0.154**	0.325**	0.422**
	(0.449)	(0.489)	(0.398)	(0.042)	(0.063)	(0.064)	(0.065)	(0.152)	(0.167)
Border	2.986***	2.720***	1.460	0.126	0.037	-0.025	-1.580	-1.150	-2.077**
	(0.690)	(0.973)	(0.973)	(0.119)	(0.210)	(0.193)	(1.207)	(1.182)	(0.841)
Population		-0.219	1.167		0.199	0.267*		-1.484	-0.446
		(1.103)	(1.037)		(0.158)	(0.160)		(1.046)	(0.840)
Income		1.031	-1.748		-0.062	-0.199		1.088	-0.994
		(1.892)	(1.522)		(0.262)	(0.307)		(0.955)	(0.836)
Infrastructure			-0.559***			-0.027**			-0.413***
			(0.135)			(0.013)			(0.116)
Observations	109	109	109	109	109	109	109	109	109
Adjusted R-squred	0.15	0.16	0.39	0.05	0.06	0.08	0.06	0.09	0.39

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change of optimal infrastructure investment from one counterfactual exercise to another. Columns (1), (2), and (3) compare the status quo and separate counterfactual exercise results; columns (4), (5), and (6) compare the separate and semi-global counterfactual exercise results; and columns (7), (8), and (9) compare the semi-global and global counterfactual exercise results. Optimal foreign (total) trade 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 9: Optimal Infrastructure Investment in SADC

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-1.906***	-1.905***	-0.938**	-1.788***	-1.788***	-0.819*	-1.547***	-1.547***	-0.319
	(0.390)	(0.390)	(0.414)	(0.419)	(0.417)	(0.438)	(0.478)	(0.470)	(0.470)
Optimal total trade	3.611***	3.604***	2.749***	3.561***	3.547***	2.677***	3.571***	3.524***	2.257***
	(0.456)	(0.461)	(0.296)	(0.452)	(0.456)	(0.289)	(0.439)	(0.440)	(0.245)
Border	1.344***	1.364***	-0.392	1.329***	1.343***	-0.462	2.147**	2.143**	-0.563
	(0.330)	(0.350)	(0.515)	(0.333)	(0.355)	(0.520)	(0.964)	(0.977)	(0.483)
Population		0.329	-0.334		0.433	-0.247		0.880**	-0.088
		(0.360)	(0.277)		(0.361)	(0.272)		(0.442)	(0.257)
Income		-0.758	-0.066		-0.913	-0.203		-1.635*	-0.611
		(0.823)	(0.579)		(0.825)	(0.559)		(0.980)	(0.560)
Infrastructure			-0.629***			-0.642***			-0.943***
			(0.031)			(0.031)			(0.028)
Observations	536	536	536	536	536	536	536	536	536
Adjusted R-squred	0.20	0.20	0.60	0.19	0.19	0.61	0.14	0.15	0.76

The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change from the status quo to optimal infrastructure investment. Optimal foreign (total) trade 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 10: Optimal Infrastructure Investment in SADC

Dependent Variable:	Infrastructure Growth								
Counterfactual:	Separate			Semi-Global			Global		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Optimal foreign trade	-1.906***	-1.905***	-0.938**	0.036	0.036*	0.056**	0.121	0.121	0.523***
	(0.390)	(0.390)	(0.414)	(0.022)	(0.022)	(0.027)	(0.124)	(0.120)	(0.157)
Optimal total trade	3.611***	3.604***	2.749***	-0.010	-0.016	-0.034	0.055	0.028	-0.387***
	(0.456)	(0.461)	(0.296)	(0.026)	(0.028)	(0.034)	(0.070)	(0.076)	(0.122)
Border	1.344***	1.364***	-0.392	-0.007	-0.010	-0.047	0.788	0.783	-0.102
	(0.330)	(0.350)	(0.515)	(0.054)	(0.059)	(0.070)	(0.896)	(0.902)	(0.705)
Population		0.329	-0.334		0.100*	0.086		0.479*	0.163
		(0.360)	(0.277)		(0.056)	(0.054)		(0.272)	(0.246)
Income		-0.758	-0.066		-0.167	-0.152		-0.865	-0.530
		(0.823)	(0.579)		(0.146)	(0.145)		(0.527)	(0.496)
Infrastructure			-0.629***			-0.013*			-0.309***
			(0.031)			(0.007)			(0.029)
Observations	536	536	536	536	536	536	536	536	536
Adjusted R-squred	0.20	0.20	0.60	0.00	0.01	0.02	0.01	0.01	0.26

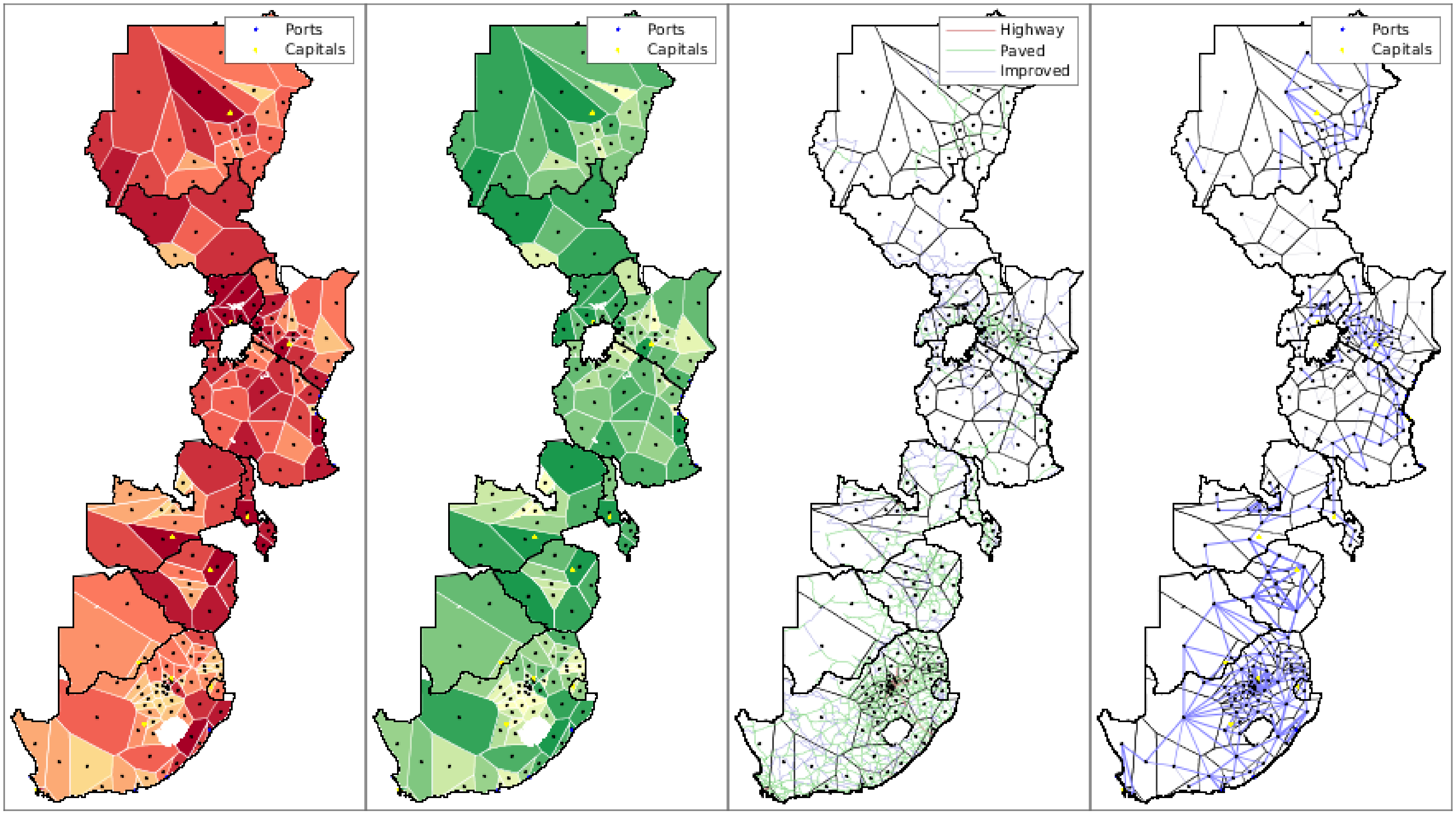
The unit of analysis is an edge. Dependent variable is infrastructure growth, which denotes the percentage change of optimal infrastructure investment from one counterfactual exercise to another. Columns (1), (2), and (3) compare the status quo and separate counterfactual exercise results; columns (4), (5), and (6) compare the separate and semi-global counterfactual exercise results; and columns (7), (8), and (9) compare the semi-global and global counterfactual exercise results. Optimal foreign (total) trade 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%.

Appendices

A Figures

Figure A.1: Population, GDP, and Road Network in Anglophone Africa

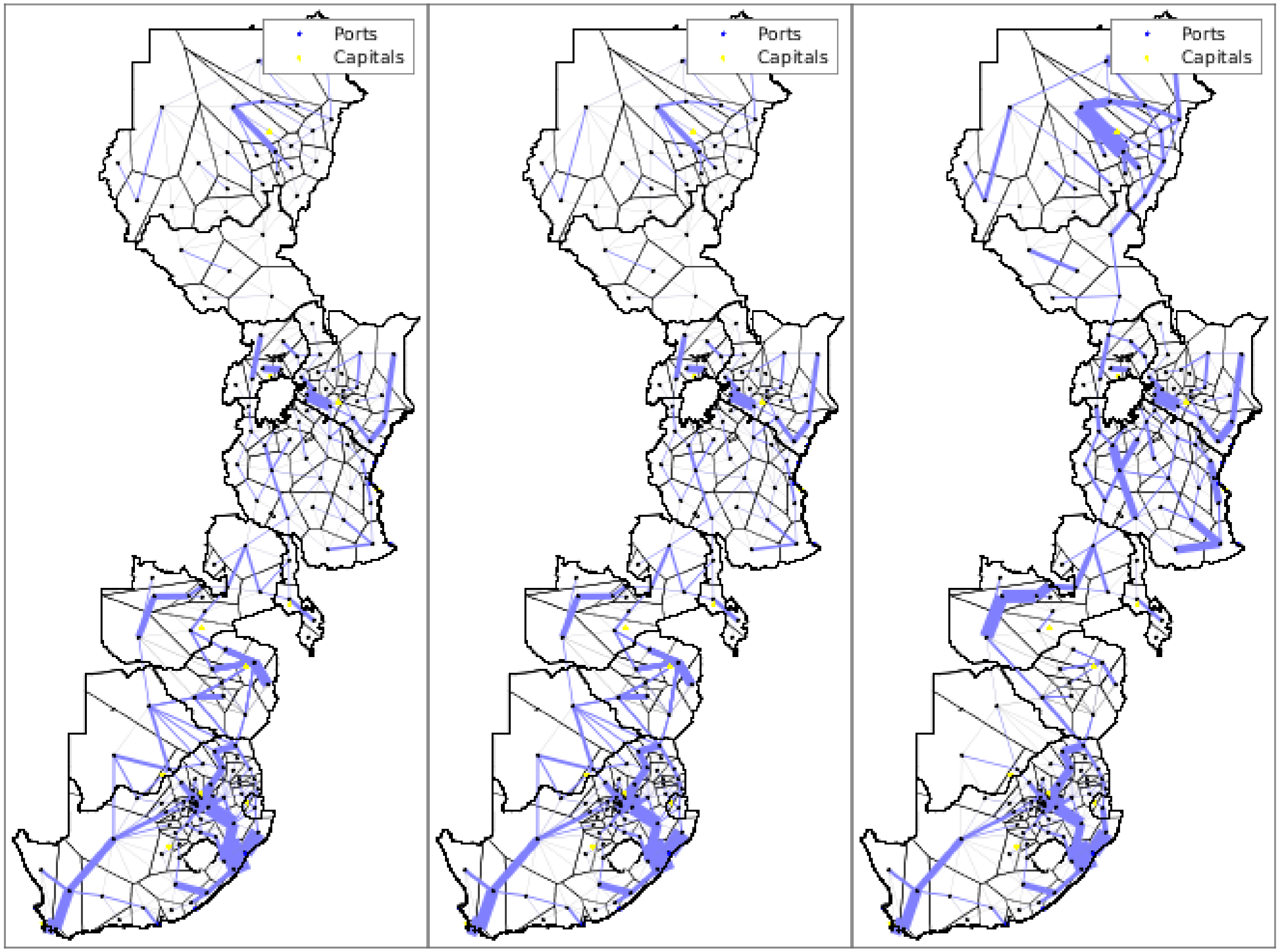
(a) Population (b) GDP (c) Actual Road (d) Discretized Road



Subfigures (a) and (b) display the population and GDP data in Anglophone Africa. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Subfigures (c) and (d) depict the actual and discretized road network in Anglophone Africa. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads in the actual road network. The width of each edge denotes the intensity of infrastructure investment in the discretized road network: The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots are national capitals and international ports, respectively.

Figure A.2: Optimal Road Network in Anglophone Africa

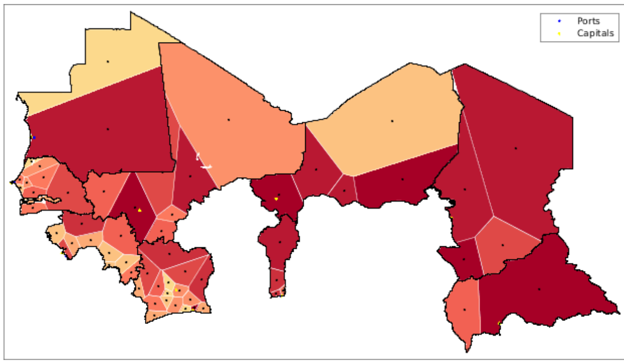
(a) Separate Counterfactual (b) Semi-Global Counterfactual (c) Global Counterfactual



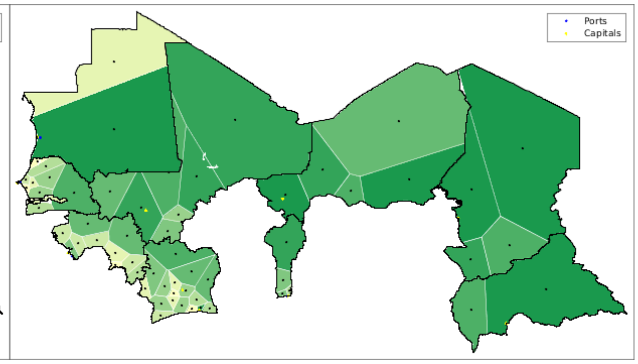
Subfigures (a), (b), and (c) present the optimal road network in Anglophone Africa under separate counterfactual, semi-global counterfactual, and global counterfactual exercises, respectively. The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure A.3: Population, GDP, and Road Network in Francophone Africa

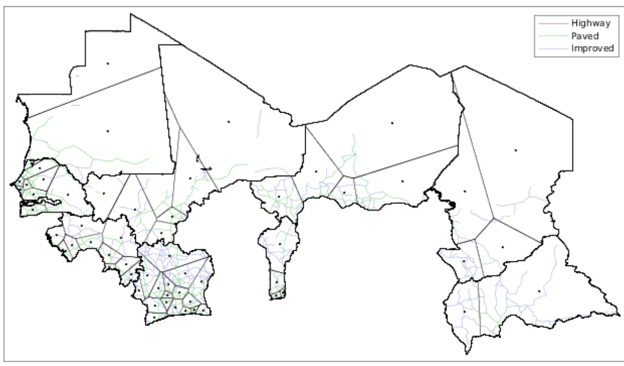
(a) Population



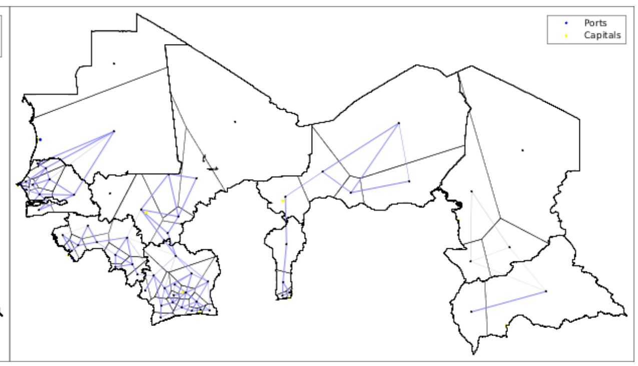
(b) GDP



(c) Actual Road



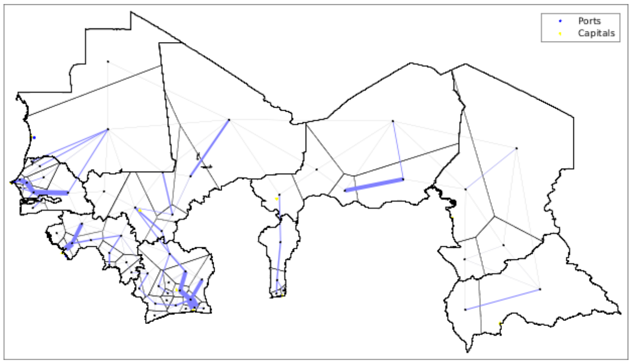
(d) Discretized Road



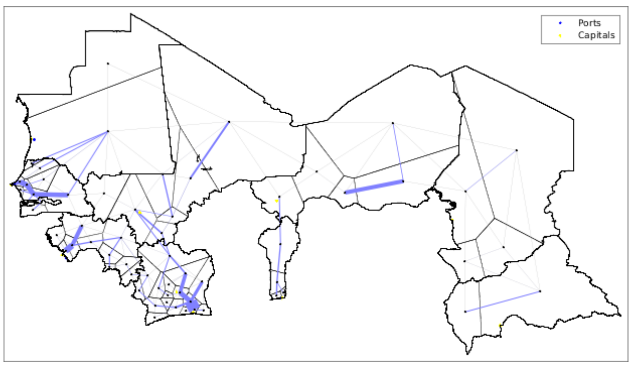
Subfigures (a) and (b) display the population and GDP data in Francophone Africa. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Subfigures (c) and (d) depict the actual and discretized road network in Francophone Africa. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads in the actual road network. The width of each edge denotes the intensity of infrastructure investment in the discretized road network: The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots are national capitals and international ports, respectively.

Figure A.4: Optimal Road Network in Francophone Africa

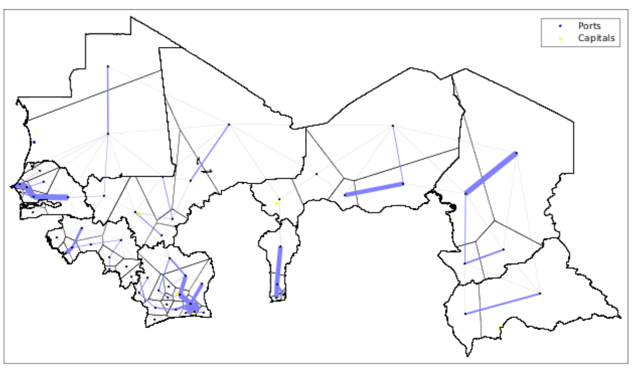
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



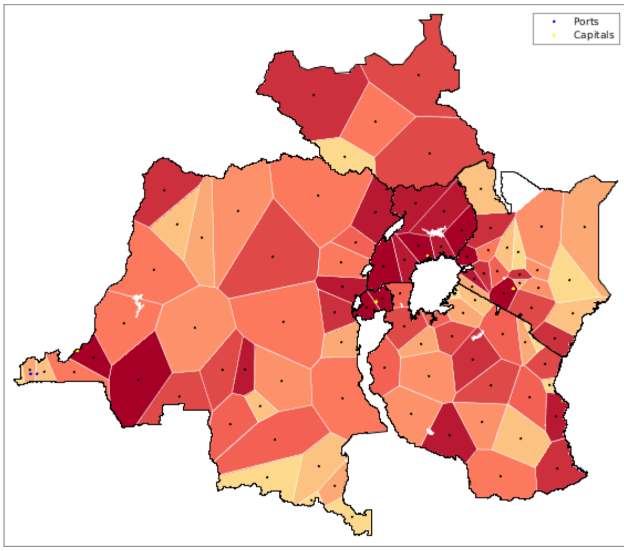
(c) Global Countefactual



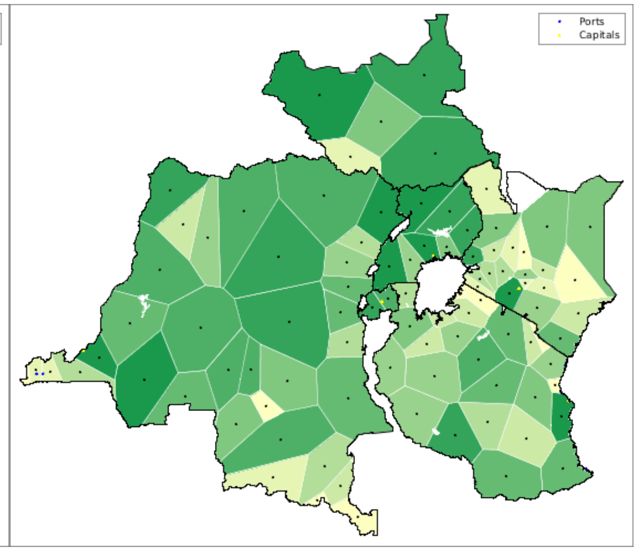
Subfigures (a), (b), and (c) present the optimal road network in Francophone Africa under separate counterfactual, semi-global counterfactual, and global counterfactual exercises, respectively. The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure A.5: Population, GDP, and Road Network in EAC

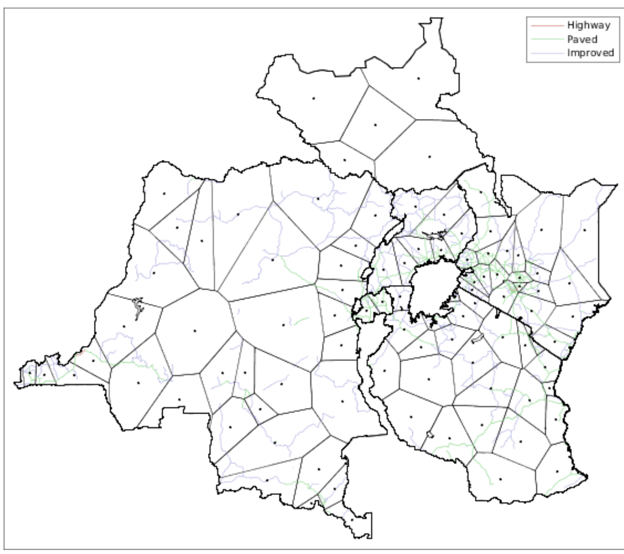
(a) Population



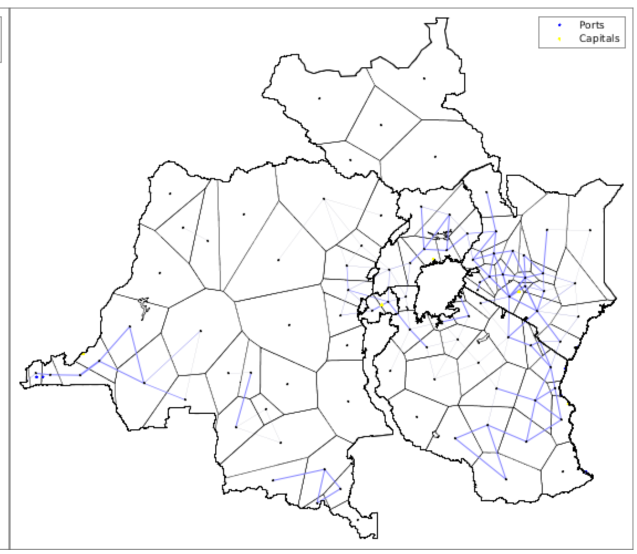
(b) GDP



(c) Actual Road



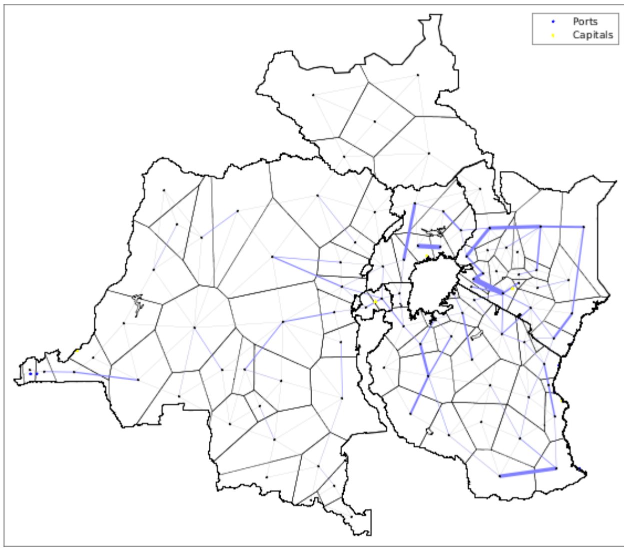
(d) Discretized Road



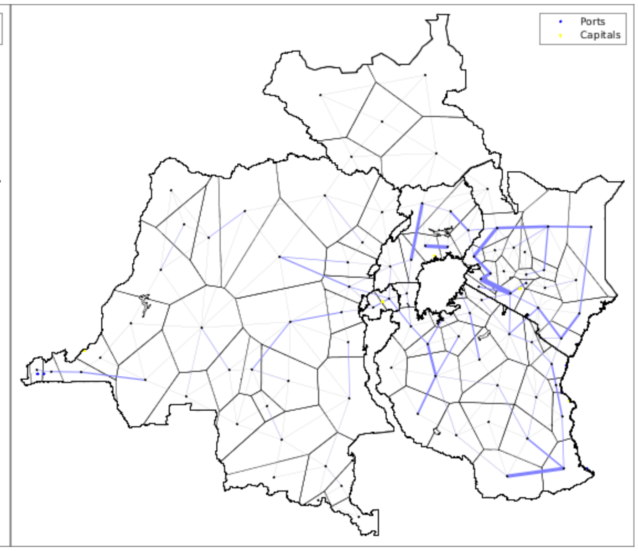
Subfigures (a) and (b) display the population and GDP data in EAC. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Subfigures (c) and (d) depict the actual and discretized road network in EAC. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads in the actual road network. The width of each edge denotes the intensity of infrastructure investment in the discretized road network: The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots are national capitals and international ports, respectively.

Figure A.6: Optimal Road Network in EAC

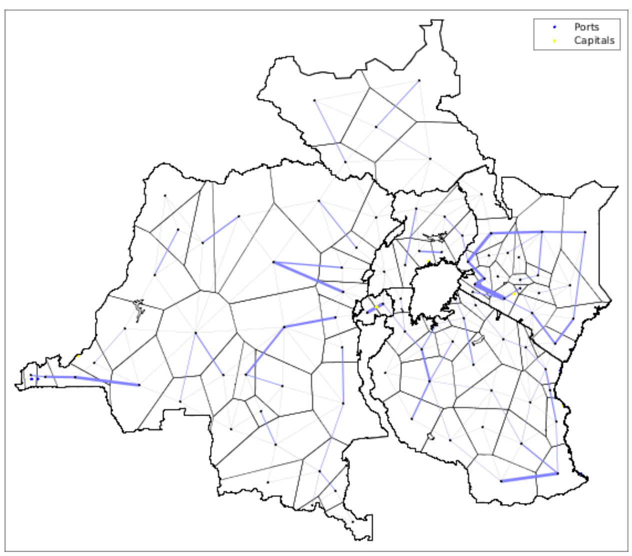
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



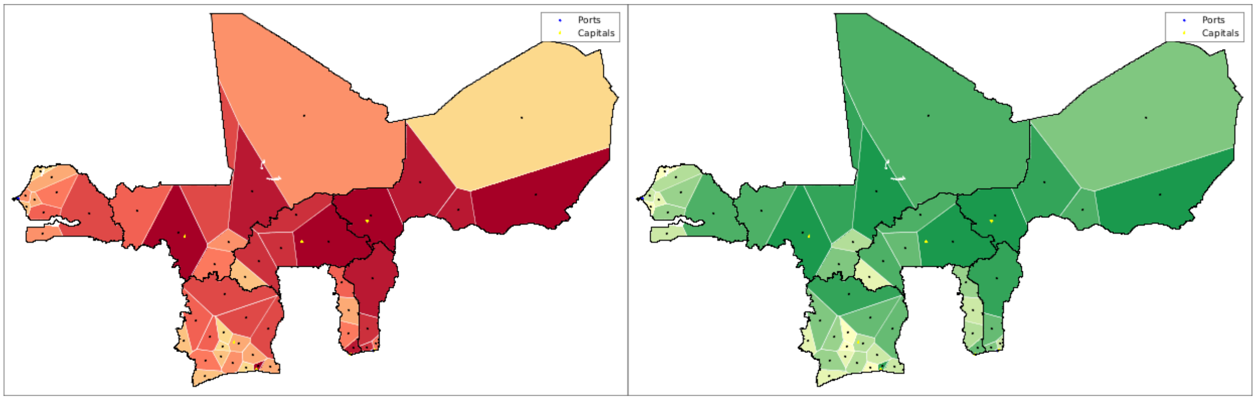
(c) Global Counterfactual



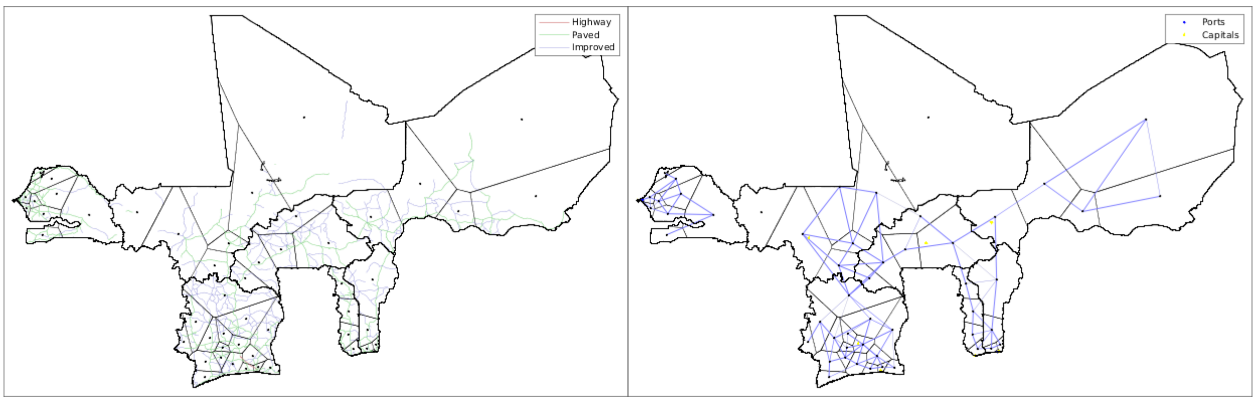
Subfigures (a), (b), and (c) present the optimal road network in EAC under separate counterfactual, semi-global counterfactual, and global counterfactual exercises, respectively. The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure A.7: Population, GDP, and Road Network in UEMOA

(a) Population (b) GDP



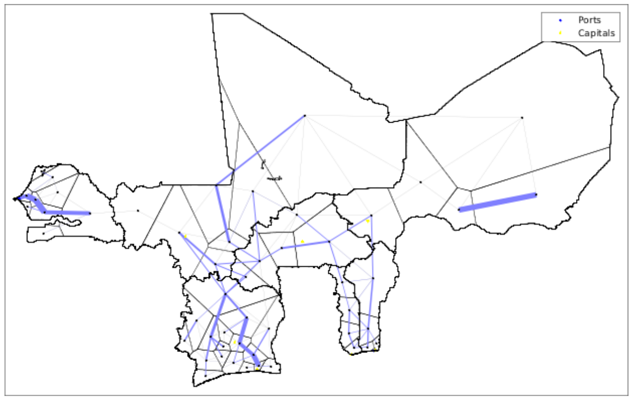
(c) Actual Road (d) Discretized Road



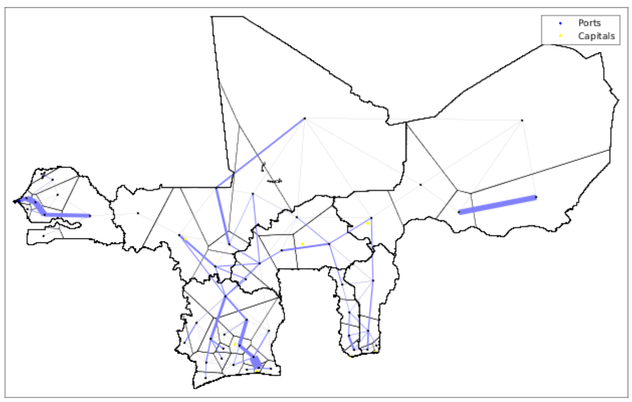
Subfigures (a) and (b) display the population and GDP data in UEMOA. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Subfigures (c) and (d) depict the actual and discretized road network in UEMOA. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads in the actual road network. The width of each edge denotes the intensity of infrastructure investment in the discretized road network: The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots are national capitals and international ports, respectively.

Figure A.8: Optimal Road Network in UEMOA

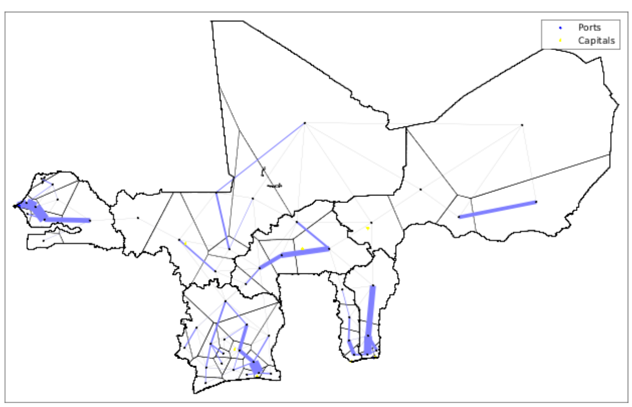
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



(c) Global Counterfactual

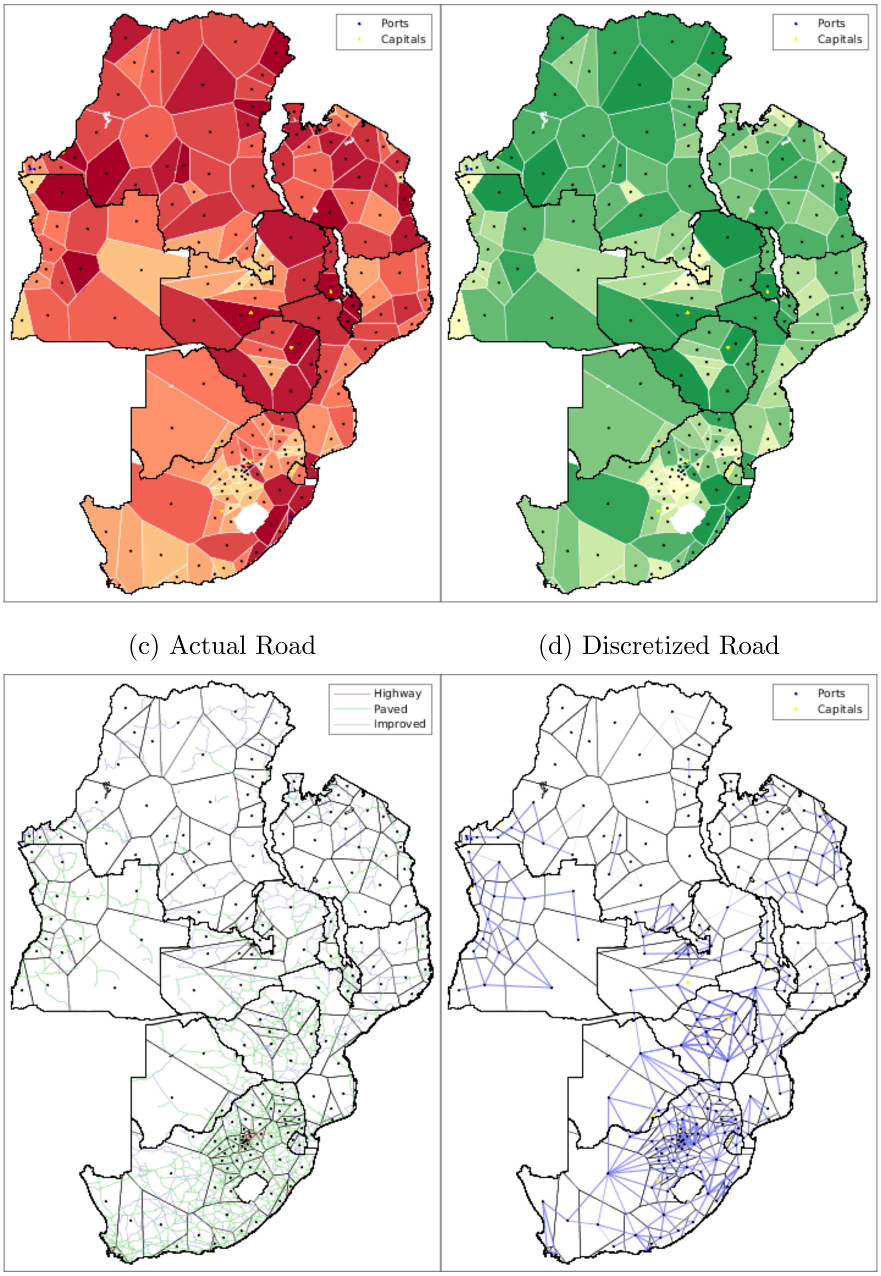


Subfigures (a), (b), and (c) present the optimal road network in UEMOA under separate counterfactual, semi-global counterfactual, and global counterfactual exercises, respectively. The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.

Figure A.9: Population, GDP, and Road Network in SADC

(a) Population (b) GDP

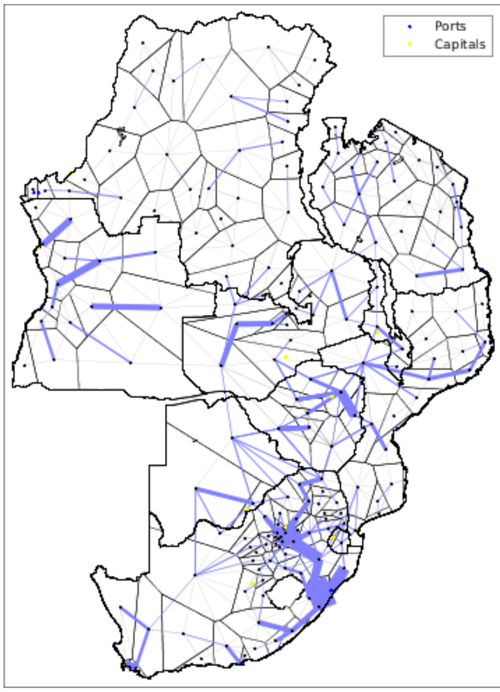
(c) Actual Road (d) Discretized Road



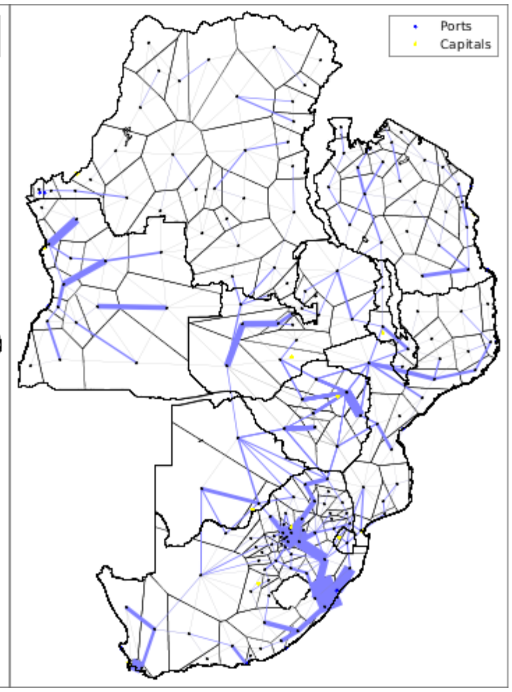
Subfigures (a) and (b) display the population and GDP data in SADC. Darker colors indicate high population and GDP in the cell while lighter color indicate lower population and GDP. Subfigures (c) and (d) depict the actual and discretized road network in SADC. Red lines indicate highway, green lines indicate paved roads, and blue lines indicate improved roads in the actual road network. The width of each edge denotes the intensity of infrastructure investment in the discretized road network: The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots are national capitals and international ports, respectively.

Figure A.10: Optimal Road Network in SADC

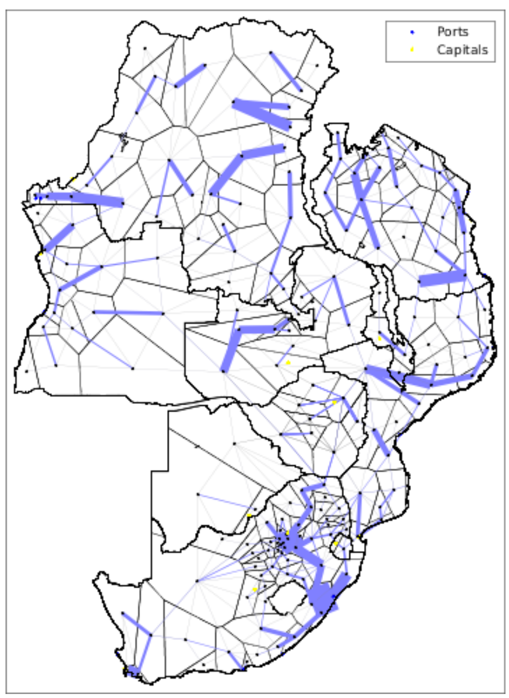
(a) Separate Counterfactual



(b) Semi-Global Counterfactual



(c) Global Counterfactual



Subfigures (a), (b), and (c) present the optimal road network in SADC under separate counterfactual, semi-global counterfactual, and global counterfactual exercises, respectively. The wider edge corresponds to the more intense infrastructure investment. Yellow and blue dots indicate national capitals and international ports, respectively.