Policy Research Working Paper 9855

Corridors without Borders in West Africa

Mathilde Lebrand

WORLD BANK GROUP
Infrastructure Chief Economist Office
November 2021

Policy Research Working Paper 9855

Abstract

This paper estimates the welfare gains from upgrading several major regional corridors in West Africa. It uses a quantitative economic geography framework with trade within and across countries and mobility of people within countries to assess the economic impacts of the reduction in trade costs from road and border infrastructure investments. The findings show that the upgrade of Dakar-Lagos regional road corridor brings sizable economic benefits relative to investment costs, with a benefit-cost ratio estimated around 3. The economic benefits of road corridor upgrades are doubled and more widely spread when combined with measures to reduce current massive border delays. The benefits are negligible for Nigeria, but large for small fragile states (Guinea-Bissau, Liberia, and Sierra Leone). The gains are highest for corridors connecting large economies, and smaller and more fragile countries gain proportionally more from accessing larger markets. Finally, regional investments, including border time reduction policies, will reduce spatial inequality in the whole region but might increase inequality in some countries.

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

Corridors without Borders in West Africa

Mathilde Lebrand *

Keywords: regional corridors, trade facilitation, spatial general equilibrium, Africa
JEL Classification:R12, R13, R40, F15, O18, N17

*World Bank (E-mail: mlebrand@worldbank.org). I thank Michele Ruta for his helpful comments, Vivien Foster and Daniel Benitez for their guidance. This work benefited from discussions with Anca Dumitrescu and Aiga Stokenberga.

1 Introduction

West Africa has experienced episodes of trade liberalization in the last three decades with the establishment of a common market and free trade area in the Economic Community of West African States (ECOWAS). But the success of translating reduced tariffs into increased international trade has been limited and geographically unbalanced (Donaldson et al., 2017). In addition, West African trade has done poorly in terms of regional integration, despise the potential gains from more regional trade in the region (Calderon et al., 2015). Several factors can explain the lack of regional trade: the structure of the productive base, the presence of non-tariff barriers and other border frictions, poor transport infrastructure and services resulting in high transport costs, the high rate of informality, and the rise in conflicts that has affected the region in the last years. This paper focuses on the impacts of high land transport and trade costs due to poor infrastructure and border delays. It quantifies the economic impacts of major regional corridor upgrades and complementary actions to reduce border delays.

Intra-national and regional transport costs have been shown to be high and impede regional trade in West Africa (Atkin and Donaldson, 2015; Teravaninthorn and Raballand, 2009). Costs of moving goods are incurred both when transporting goods over long distances and when clearing the goods at border posts. History and the lack of investments explain the limited availability and quality of roads in the region. The regional road network remains distorted towards access to the main ports at the expense of regional connectivity (Bonfatti et al., 2019). Decades of colonization have shaped the transport network towards exports of raw resources towards the rest of the world. Little was done to increase regional connectivity outside of the corridors reaching the sea; regional corridors remains suboptimal for the geography and distribution of comparative advantages of current economies (Bonfatti et al., 2019). Road checkpoints and border frictions also increase the costs of moving goods (OCDE, 2019).[1] Travel time between cities has been shown to be less dependent on the average speed at which a truck operates than on border delays (Teravaninthorn and Raballand, 2009). More important than slow speed is the time a truck is idling while waiting for administrative procedures to be performed (at borders or at the terminals during loading or unloading).

The paper uses a quantitative spatial general-equilibrium model to estimate the gains from five regional corridors and complementary border investments in West Africa. The Dakar-Lagos corridor, also called Trans-West African Coastal Highway, is a transnational highway project to link 12 West African coastal countries. Most of the corridor is paved but the quality of the roads remains suboptimal for large regional trade flows (ADB, 2007). Four other regional corridors

[1]Checkpoints add to the cost of moving goods but are not included in the paper's analysis. For example, numerous checkpoints along the Ghana-Togo-Benin coastal corridor constitute obstacles to an effective implementation of the Abidjan-Lagos transport corridor as planned (AfDB-UEMOA, 2017).

in West Africa are evaluated. Better roads improve driving conditions but many hours remain lost around land borders and at final destinations for goods to reach the final customers. Reducing border frictions matters as goods have to transit up to 11 borders. Transit delays incurred by trucks crossing borders on their way are distinguished from final border delays incurred at destination.

Several findings emerge from the simulations. The upgrade of Dakar-Lagos regional road corridor brings sizable economic benefits relative to investment costs, with a Benefit-Cost Ratio estimated around 3. The economic benefits of road corridor upgrades are doubled and more widely spread when combined with measures to reduce current massive border delays. Income gains are larger for coastal western countries (+10-20%) than landlocked and eastern countries (+5-10%). The benefits are negligible for Nigeria, but large for small fragile states (Guinea-Bissau, Liberia, Sierra Leone). The projects benefit economic activity both along the corridors and, to a certain extent, more distant locations through geographic spillovers. The policy implication is that main road corridor investments are best complemented with measures to reduce border delays to amplify economic impact.

This paper relies on a well-developed tradition of spatial quantitative general-equilibrium models used to provide counterfactuals of transport and border investments. This paper uses the geographic granularity allowed by such models to estimate the sub-national, national and regional impacts of large transport and border investments. The model relies on previous work done by Redding (2016), and follows a growing literature on the spatial impacts of transport such as Fajgelbaum and Redding (2014) for Argentina, Donaldson (2018) for India, Lall and Lebrand (2020) and Bird et al. (2020) for the Belt and Road Initiative in Central Asia, Balboni (2020) for Vietnam, and Herrera Dappe and Lebrand (2019) and Herrera Dappe et al. (2021) for Bangladesh and India. We assume that large corridor investments will significantly improve driving speed. Major upgrades of regional roads are expected to improve road quality, reduce some traffic constraints (slow vehicles, density along the roads, congestion around gateways, etc), and therefore increase driving speed. The current driving speed is assumed to be low along most West African roads (Teravaninthorn and Raballand, 2009). The paper does not speak to the issues related to inefficiencies in the trucking sector (high mark-ups, poor fleet quality, intermediaries). Finally, the use of a structural model is motivated by missing data on domestic and cross-border trade in the region. Little is known about internal trade, formal trade per land border, and informal cross-border trade while informal trade is known to be ubiquitous in the region. The model generates trade linkages between districts and provinces that come from gravity properties between population centers. Given the geographic, cultural, ethnic, and language proximity of most countries, we can assume that these trade linkages are potentially significant, while not fully observed in national and international trade data.

The rest of the paper is organized as follows. Section 2 motivates the research question. Section 3 describes the theoretical framework. Section 4 discusses the results of the counterfactuals.

2 Transport and border infrastructure in West Africa

2.1 Transport infrastructure

Road infrastructure is improving but is doing so from a low base. Since the 1960s, the network of paved or partially improved road has progressively expanded as shown on Figure A1 in the Appendix. The road network is structured by two East-West arteries: the trans-Sahel route connecting Dakar to Niamey and the coastal Abidjan-Lagos route, with South-North connections between the main ports. The large majority of roads in West Africa are poorly maintained and a significant number - less than 20 percent - are paved. Poor-quality roads and weak transport infrastructure remain an issue for African trade, and are considered prime reasons for the continent's low level of competitiveness (Donaldson et al., 2017).

A wide range of factors other than a deteriorated road network can also generate high regional trade costs. Congestion and numerous roadside checks considerably reduce the average speed of vehicles traveling on the main transport corridors (OCDE, 2019).[2] For example, the route connecting Abidjan to Lagos crosses through the most densely populated region in West Africa. Thousands of trucks travel along this corridor daily and the numerous roadblocks set up by customs, immigration and police services add to traffic density further slowing the pace of economic exchanges, especially between Cotonou and Nigeria. And so, for some travelers, the 60-kilometer trip between Badagry - on the outskirts of Lagos - and the economic capital of Benin can take up to half a day, whereas under optimal transport conditions it would take 90 minutes.

The paper considers five West African corridors, the Dakar-Lagos highway corridor, the longest and most ambitious, and four other corridors along the Western part of the region. The Dakar-Lagos corridor is part of the Trans-West African Coastal Highway, which a transnational highway project to link 12 West African coastal nations, from Mauritania to Nigeria, with feeder roads to two landlocked countries, Mali and Burkina Faso. It follows mostly the coastal line along more than 4000 kilometers, and connects the capitals of the countries involved.

The economic impacts of the Dakar-Lagos corridor are expected to be diverse. Along the Northern section between Dakar and Abidjan, road improvements are expected to enable the transit of agricultural production from Senegal towards neighboring countries including The Gambia, Guinea-Bissau, and Guinea. In Liberia, better regional connectivity will reduce the

[2] In the paper, we will consider a low speed for most of the existing transport network which varies only across road types. The lack of regional data on road surface condition and maintenance limits the precision of our baseline.

isolation of rural areas and improve the economic integration with Côte d'Ivoire. The southern part of the corridor between Abidjan and Lagos connects the most densely populated and economically active parts of the sub-region and interconnects with a rail network, major ports and airports. The corridor currently supports approximately 75% of trade activities of the sub-region and is considered as the spine for multi-modal trade logistics. The four other corridors, connecting Bamako to Conakry, Bamako to Monrovia, Conakry to Abidjan, and Dakar to Conakry, complement the coastal Dakar-Lagos corridor by providing feeder roads for more isolated areas and non-capital cities, and by improving connectivity between non-coastal areas that have traditionally not been a priority at the regional level.

2.2 Border frictions

The Economic Community of West African States (ECOWAS) is meant to be a free trade and customs union. Since 1993, the union has envisaged a common market and a free trade area through the abolition of tariff and non-tariff barriers (such as quotas and prohibitions). Two decades after, implementation remains poor and there still exists an extensive list of exceptions.[3] While tariffs have been reduced, effective integration also requires addressing non-tariff measures (NTMs) that remain high (UNCTAD, 2018). NTMs are policy measures other than tariffs that can potentially hinder trade. They refer to regulations whose primary objective is to protect health and the environment such as Sanitary and Phytosanitary (SPS) measures, Technical Barriers to Trade (TBTs), pre-shipment inspections and export-related measures (UNCTAD, 2018). The presence and complexity of such trade barriers and involved procedures require trucks to stop, go through the different procedures, provide the adequate papers, all that takes time.

Along most West African corridors, border procedures take time. Doing Business Indicators report estimates of the time and cost associated with the logistical process of exporting and importing goods.[4] Border compliance captures the time and cost associated with compliance with the economy's customs regulations and with regulations relating to other inspections that are mandatory in order for the shipment to cross the economy's border, as well as the time and cost for handling that takes place at its port or border. Delays at a land border are available only for the three landlocked countries. They range between 48 hours to export in Niger to 102 hours to import in Burkina Faso. All West African countries are poorly ranked in terms of easiness of crossing borders.

The main reported reasons for border delays in West Africa, as observed in the World Bank (2013) report, include: lack of regular supply of electricity and IT networks, lengthy procedures at scanners, informal payments and negotiations, lack of space and inefficient distribution of administrative offices, and transshipment at the border. Many border posts are located in

[3] https://www.economist.com/middle-east-and-africa/2016/02/27/tear-down-these-walls

[4] Table A1 in the Appendix reports border delays from the Doing Business Indicators for several West African countries.

border cities creating congestion, pollution and large delays that impact both local citizens and international transport companies (OCDE, 2019). Various types of investments can help. Border delays, especially in densely populated areas, has led countries to plan new infrastructure in place with a view to facilitating trade and reducing corruption at the borders, and one-stop border posts (OSBPs) have been prioritized. At the moment, few OSBP border posts are currently operational in West Africa, meaning high delays and border frictions around the borders (Figures A2 and A3 in the Appendix).

This paper considers the gains from better road and border infrastructures.

3 Quantifying the wider economic benefits of corridors

3.1 Theoretical framework

We use the theoretical framework from Redding (2016) applied to 662 locations in 16 countries in West Africa: Benin (76 districts), Nigeria (37 provinces), The Gambia (6 districts), Senegal (46 districts), Mauritania (44 districts), Guinea-Bissau (9 districts), Mali (50 districts), Togo (21 districts), Ghana (137 districts), Cameroon (58 districts), Niger (36 districts), Burkina Faso (45 districts), Côte d'Ivoire (34 districts), Liberia (15 districts), Sierra Leone (14 districts), and Guinea (34 districts). Each location is indexed by i. Locations differ from one another in terms of land supply, productivity, amenities and their geographical location relative to one another. Bilateral trade costs for goods are assumed to take the iceberg form, such that d_{ni} units of a good must be shipped from location i for one unit to arrive in location n, where $d_{ni} > 1$ for $n \neq i$ and $d_{nn} = 1$. Land and labor are the two factors of production. Workers are mobile across locations within country but not across countries. They have idiosyncratic draws for preferences for each location within their own country.

Consumer preferences Preferences for a worker in location n depend on goods consumption (C_n), residential land use (H_n) and an idiosyncratic amenity shock to the utility from residing in that location:

$$U_n = B_n\left(\frac{C_n}{\alpha}\right)^{\alpha}\left(\frac{H_n}{1-\alpha}\right)^{1-\alpha}, \quad 0 < \alpha < 1 \tag{3.1}$$

The goods consumption index (C_n) is defined over consumption of a fixed continuum of goods $j \in [0,1]$:

$$C_n = \left[\int_0^1 c_n(j)^{\rho} dj\right]^{\frac{1}{\rho}}, \tag{3.2}$$

The price index for goods consumption (P_n) is:

$$P_n = \left[\int_0^1 p_n(j)^{1-\sigma} dj\right]^{1-\rho}, \sigma = \frac{1}{1-\rho} \tag{3.3}$$

The idiosyncratic amenity shocks capture the idea that workers have heterogeneous preferences for living in each location. These amenity shocks are drawn independently across locations and workers from a Fréchet distribution:

$$G_n(b) = e^{-B_n b^{-\varepsilon}} \tag{3.4}$$

where the scale parameter B_n determines average amenities for location n and the shape parameter ε controls the dispersion of amenities across workers for each location. Each worker is endowed with one unit of labor that is supplied inelasticity with zero disutility.

Each location draws an idiosyncratic productivity z for each good j. Productivity is independently drawn across goods and locations from a Fréchet distribution:

$$F_i(z) = e^{-A_n z^{-\omega}} \tag{3.5}$$

where the scale parameter A_n determines average amenities for location n and the shape parameter ω controls the dispersion of amenities across workers for each location.

Goods are homogeneous and produced with labor under perfect competition according to a linear technology. The price of one unit of good j bought in location n from location i is therefore:

$$p_{ni}(j) = \frac{d_{ni}\omega_i}{z_i(j)}, \tag{3.6}$$

where ω_i denotes the wage in location i.

Expenditure shares and price indices The representative consumer in location n sources each good from the lowest-cost supplier to that location. Using the properties of the Fréchet distribution, the share of expenditure of location n on goods produced by location i is:

$$\pi_{ni} = \frac{A_i(d_{ni}\omega_i)^{-\omega}}{\sum_{l\in N} A_l(d_{nl}\omega_l)^{-\omega}} \tag{3.7}$$

where the elasticity of trade with respect to trade costs is the Fréchet shape parameter for productivity h.

Residential choices and income Given the specification of consumer preferences (Eq. 3.2), the corresponding indirect utility function is:

$$U_n = B_n \frac{b_n v_n}{P_n^{\alpha} r_n^{1-\alpha}} \tag{3.8}$$

where r_n is the land rent for location n and v_n is income in location n, which include the wage and redistributed land rents.

Each worker chooses the location that offers her the highest utility. Indirect utility is a monotonic function of the amenity draw, and too has a Fréchet distribution. The probability that a worker chooses to live in location $n \in N$ is:

$$\frac{L_n}{\bar{L}} = \frac{B_n(v_n/P_n^{\alpha} r_n^{1-\alpha})^{\varepsilon}}{\sum_{k \in N} B_k(v_k/P_k^{\alpha} r_k^{1-\alpha})^{\varepsilon}}, \tag{3.9}$$

where the elasticity of population with respect to real income is determined by the Fréchet shape parameter for amenities ε.

Expected utility for a worker across locations is:

$$\bar{U} = \delta\Big[\sum_{k \in N} B_k(v_k/P_k^{\alpha} r_k^{1-\alpha})^{\varepsilon}\Big]^{\frac{1}{\varepsilon}}, \tag{3.10}$$

where $\delta = \Gamma((\varepsilon - 1)/\varepsilon)$ and $\Gamma(.)$ denotes the Gamma function.

Expenditure on land in each location is redistributed lump sum to the workers. Total income equals wages plus expenditure on residential land:

$$v_n L_n = \omega_n L_n + (1-\alpha) v_n L_n \tag{3.11}$$

Labor income in each location equals expenditure on goods produced in that location:

$$\omega_i L_i = \sum_{n \in N} \pi_{ni} \omega_n L_n \tag{3.12}$$

General equilibrium The general equilibrium of the model can be represented by the measure of workers (L_n) in each location $n \in N$, the share of each location's expenditure on goods produced in other locations (p_{ni}) and the wage in each location (ω_n). The equilibrium triple $\{L_n, \pi_{ni}, \omega_n\}$ solves the following system of equations for all i, $n \in N$. Each location's income must equal expenditure on the goods produced in that location (Eq. 3.12). Location expenditure shares and residential chocies are well defined (Eqs. 3.7 and 3.9). The proof of uniqueness of the equilibrium is given in Redding (2016).

3.2 Counterfactuals

Recover productivities and amenities For a given set of model parameters $\{\alpha, \omega, \varepsilon\}$, bilateral trade costs $\{d_{ni}\}$ and data on populations, wages and land supplies, there exist unique values of amenities (B_n) and productivities (A_n) that are consistent with the data. To solve for them, we use the recursive structure of the model following Redding (2016). We obtain amenity and producivity estimates for each region.

Compute the counterfactuals The system of equations that define the general equilibrium (Eqs. 3.12, 3.7 and 3.9) can be used to undertake model-based counterfactuals for new trade costs, new productivity or new amenity levels that uses only parameters and the values of endogenous variables in the initial equilibrium. We use the hat notation such that $\hat{x} = x'/x$ with x' the counterfactual value. The system of equations for the counterfactual equilibrium (Eqs. 3.12, 3.7 and 3.9) can be re-written as follows:

$$\hat{\omega}_i \hat{\lambda}_i Y_i = \sum_{n \in N} \in N \hat{\pi_{ni}} \pi_{ni} \hat{\omega}_n \hat{\lambda}_n Y_n \tag{3.13}$$

$$\hat{\pi_{ni}} \pi_{ni} \frac{\pi_{ni} \hat{A}_i (\hat{d_{ni}} \hat{\omega}_i)^{-\theta}}{\sum_{k \in N} \pi_{nk} \hat{A}_k (\hat{d_{nk}} \hat{\omega}_k)^{-\theta}} \tag{3.14}$$

$$\hat{\lambda}_i \lambda_i = \frac{\hat{B}_n \hat{B}_n^{\frac{\alpha\varepsilon}{\theta}} \hat{\pi_{nn}}^{\frac{\alpha\varepsilon}{\theta}} \hat{\lambda}_n^{\varepsilon(1-\alpha)} \lambda_n}{\sum_{k \in N} \hat{B}_k \hat{B}_k^{\frac{\alpha\varepsilon}{\theta}} \hat{\pi_{kk}}^{\frac{\alpha\varepsilon}{\theta}} \hat{\lambda}_k^{\varepsilon(1-\alpha)} \lambda_k} \tag{3.15}$$

where $Y_i = \omega_i L_i$ denotes labor income and $\lambda_n = L_n/\bar{L}$ denotes the population share of each location in the initial equilibrium. Given the observed variables in the initial equilibrium $\{\lambda_n, Y_n, \pi_{ni}\}$ and an assumed comparative static for trade costs.

4 New transport and trade investments

4.1 Calibration of the model

The information needed to calibrate the model comes from traditional data sources and satelite images. Four types of data at the state and district level are used: residential land size, labor force, wages, and transport costs. Labor force includes active population as calculated by GHSL for 2015 (Figure A5 in the Appendix). All wages are monthly and expressed in dollars based on estimates from Tilottama et al. (2010) (Figure A7 in the Appendix). Land covers urban areas using CIESIN data (Figure A6 in the Appendix).

We assume labor mobility within country but not across countries. Following Redding (2016) and the residential choice Equation 3.9, workers can move in a location with higher wages, lower consumption and housing prices depending on their initial preferences across the amenities that are offered across locations. Such assumptions smooth the movement of workers across locations, otherwise all workers would move to the locations with the highest purchasing power.

Transport costs are measured as a function of the travel time to reach other locations from the center of each location. The travel time, which is calculated using GIS network techniques, is the shortest time given all the possible routes in the road network (Figure A8 in the Appendix). Travel times are based on categories of roads from Open Street Map (primary, secondary, tertiary and the rest) with assumptions assigned for each category. For the main roads in the baseline, 35 km per hour is assumed on the primary network, and 20 km per hour for the rest of the main network (secondary and tertiary roads). While trucks may move faster on certain segments than others, the overall limited quality of the roads as well as activities along side the roads slow down land-based freight movement.

In addition, frictions at the border increase travel time between pairs of locations. Delays are added at the border in two ways: a transit time for crossing countries which are neither the origin or the destination, and a final delay when reaching the country of destination. Delays for transiting a country are assumed to be 20 hours for each border crossing. A same time is assumed across all borders, given the lack of consistent data for time delays at borders in West Africa. Delays when reaching the country of destination are assumed to be 50 hours, which represent the time needed to go through the administrative trading processes, not included in the transit time. The choice of the transit and final border times is motivated by Table A1 which provides cross-country time estimates, but given the unreliability of some numbers across different sources, we settle on a same number across all countries and pairs of countries. No additional delay is assumed for trade within countries.

In the counterfactuals, we increase the driving speed to 80 km per hour on the upgraded segments.[5] In complementary scenarios, transit delays are reduced to zero and final border delays are halved.

4.2 Scenarios

We consider three types of scenarios that we incrementally implement to compare the differential effects of each policy.

Transport investments The nature of the upgrades along the corridors vary across segments. Upgrading existing roads consist in either increasing the number of lanes, improving road quality, or removing obstacles on the road. Some sections require little additional investments while other sections categorized into secondary or tertiary roads are to be completely rebuilt. The construction of bridges or other infrastructure than roads are not considered. Figures 1 and 2 shows the location of the new transport segments included in the corridor investments.

[5] While this speed is relatively high, it is the driving speed for trucks observed in richer economies and expected on newly renovated segments.

Figure 1: Dakar-Lagos corridor

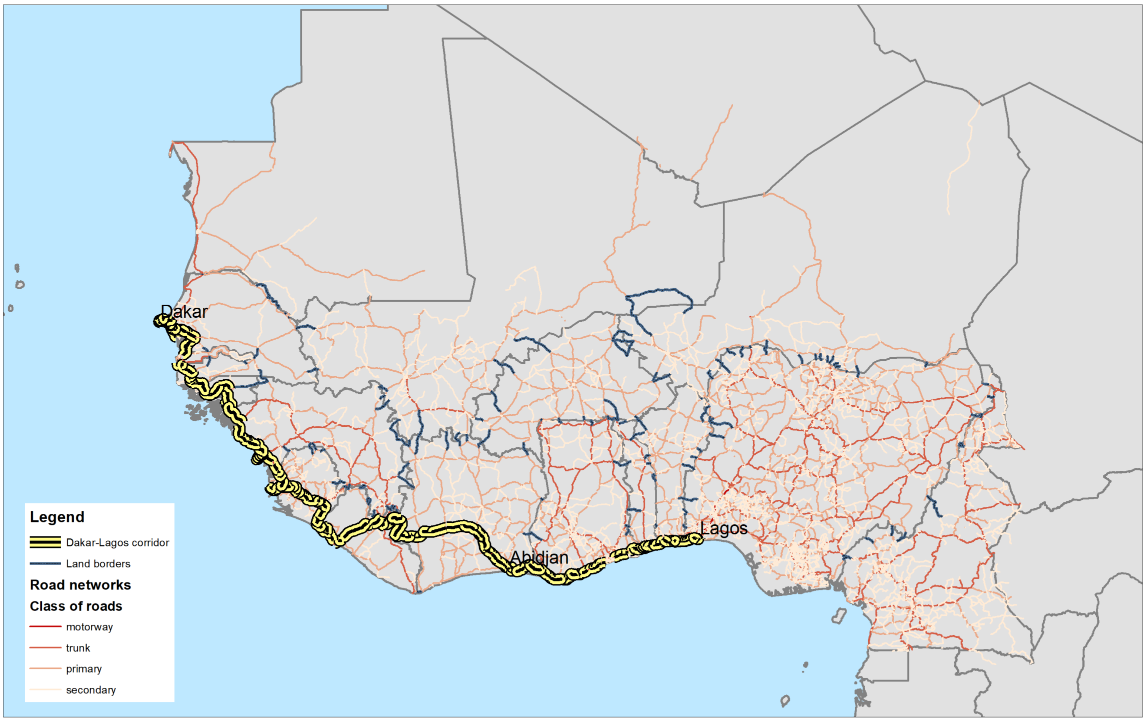
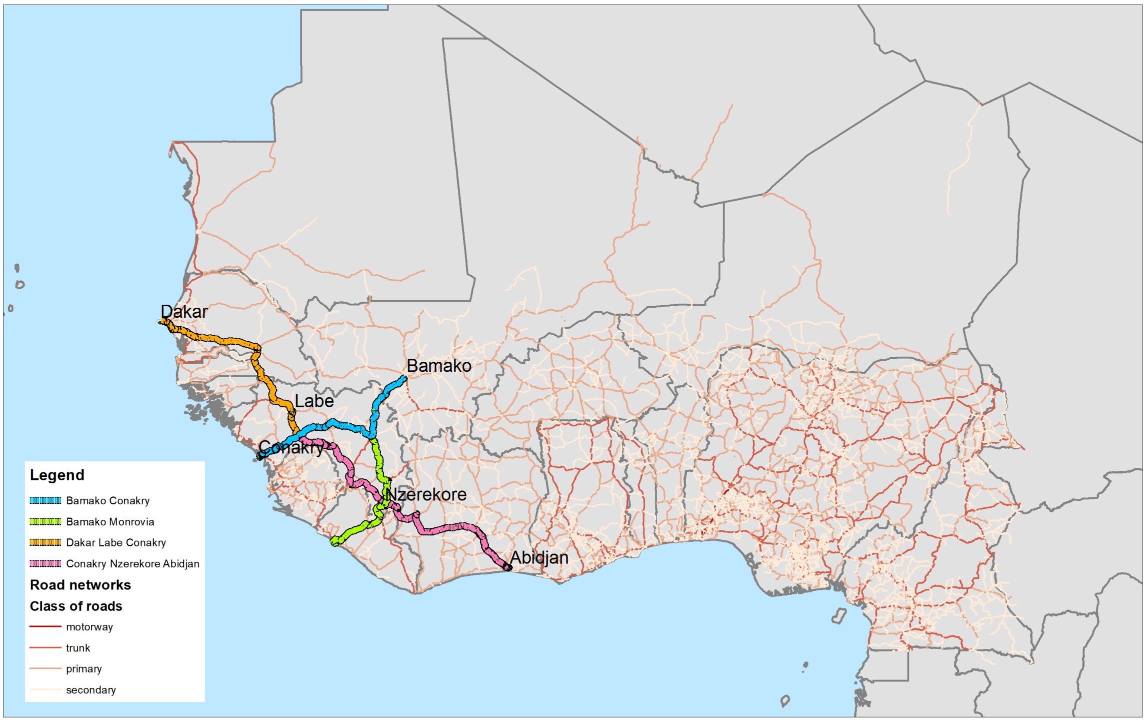


Figure 2: Other regional West-African corridors



Transit delays Transit delays, assumed to be 20 hours in the baseline case, happen at every land border. Policies that would facilitate transit traffic are multiple and could bring large benefits. In the case of the Dakar-Lagos corridor, trucks have to drive through 11 land borders before reaching their final destination. Figure 1 shows the location of the transport segments crossing a border. Delays are added at every border segment in the network to be taken into account by the shorter route algorithm to find the optimal route. The optimal routes between Origin/Destination pairs might change when road conditions and border delays are modified.

Trade delays An additional time of 50 hours is assumed for traders which add up to the transit time delays and represents the time needed to load and go through the final procedures in the final country.

We consider the following series of scenarios starting from the baseline, which models the current situation with no investment in the new corridors, high transit time delays, and high final border delays. Table 1 reports the list of scenarios applied for each corridor.

Table 1: Summary of counterfactual scenarios

Scenario	Transport investments	Removal of Transit time across countries: 20 h	Border improvement: half border time
Baseline	No investment	No	No
1	No investment	Yes	No
2	No investment	Yes	Yes
3	New investment	No	No
4	New investment	Yes	No
5	New investment	Yes	Yes

4.3 Main channels

Transport infrastructure investments will impact the spatial distribution of economic activity through different channels: the movement of goods within and across countries as well the movement of people within country. The different channels through which the economic benefits will materialize are the following.

Corridor improvements are expected to reduce the cost for domestic trade. Keeping high border crossing times, the model generates new trade shares between all locations in the model, being within and across countries. Traders benefit from lower transport costs along the corridor to increase internal trade. At the equilibrium, it is not clear whether domestic trade will relatively increase compared to regional trade as transport costs to reach international locations also decrease.

There are spillovers along the corridor and in the hinterland. Transport investments have direct benefits for locations along the corridors and indirect effects through the transport network effects and general equilibrium properties of the model. Distant locations whose trade goes through the renovated corridors and locations that trade with the directly impacted locations are impacted. The general-equilibrium model, consider all these effects, and add mobility of goods and economic activities across locations. The final impacts are not clear and depend on the outcomes of all other locations.

There are spillovers in neighboring countries. After considering the indirect effects, we also consider the effects of investments in one location, being a district or a province, on trade from and to other locations within and across countries. Similarly, the effects for one location can be positive of negative if there is diversion of trade. The general-equilibrium model considers all these effects and quantifies the income effects for all locations across all countries.

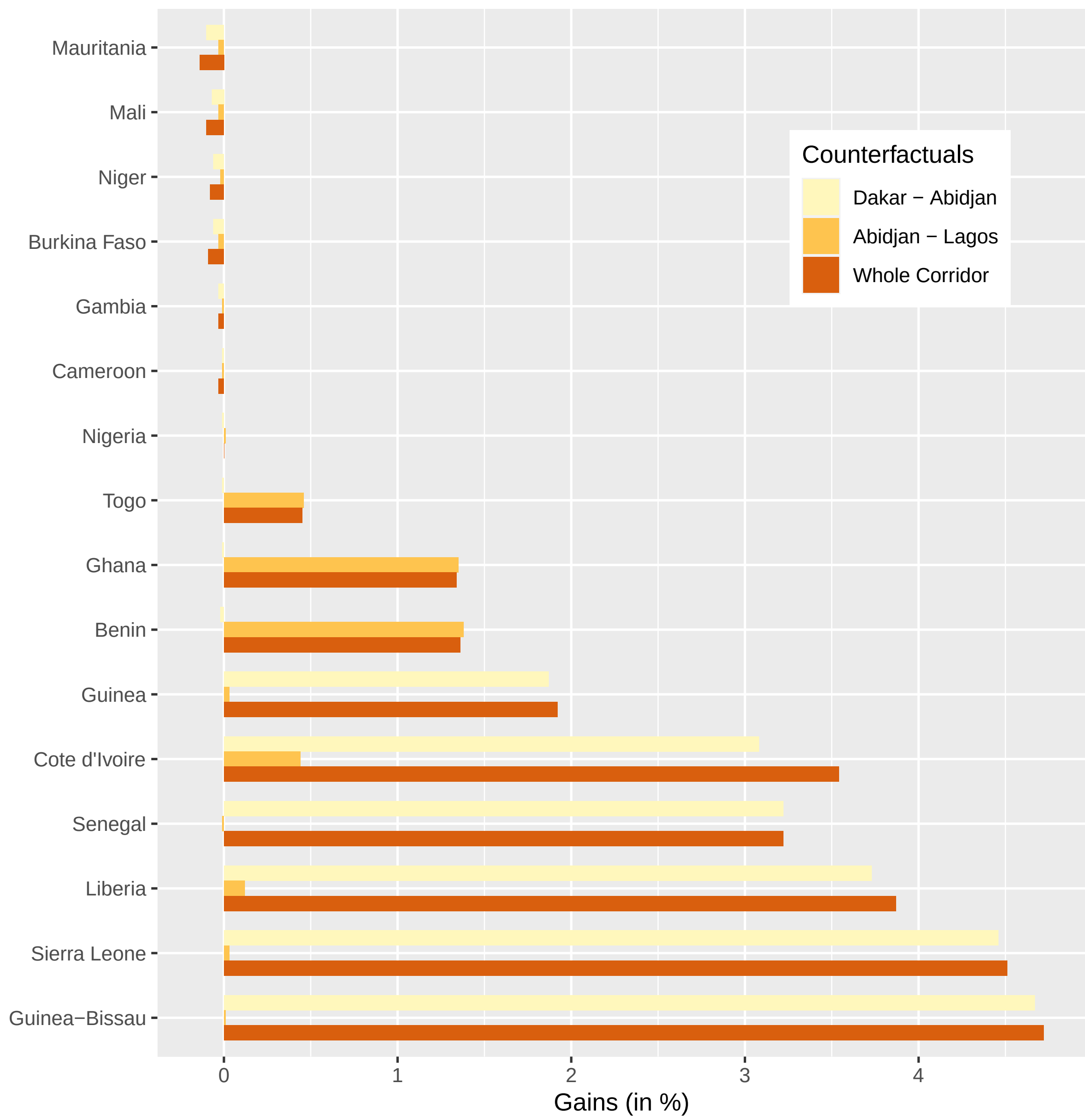
4.4 Welfare gains from road and border investments along the Dakar-Lagos corridors

4.4.1 Gains at the country level

Investments along the Dakar-Lagos corridor will reduce trade costs, lower prices and translate into welfare gains for most countries. Tables A2, A3, A4, and A5 report all income gains per country from all the simulations. Figure 3 reports the gains in real wages from improving the roads first along the Dakar-Abidjan section, second along the Abidjan-Lagos section, and finally for the whole corridor. Guinea, Côte d'Ivoire, Senegal, Liberia, Sierra Leone and Guinea-Bissau benefit from large real income gains due to the improvement of the Dakar-Abidjan road corridor. The gains range from almost 2% for Guinea to more than 4.5% for Guinea-Bissau. Togo, Ghana, and Benin benefit mostly from the Abidjan-Lagos section. The gains range from almost 0.5% for Togo to more than 1% for Benin. Côte d'Ivoire is the only country that will significantly benefit from both sections. The simulated distribution of benefits shows that countries benefit more from lower transport costs within their country and with neighboring locations, and less from trading with more distant locations.

Some countries slightly lose from the Dakar-Lagos corridor upgrade. Countries including Mauritania, Mali, Niger, Burkina Faso, The Gambia, and Cameroon that are not directly located along the corridor lose because of their relative decline in comparative advantage. The reduction in real incomes ranges from 0.25% in Mauritania to almost null for The Gambia. Fewer consumers will buy from these locations, turning towards locations from where it is cheaper to buy from. In this context, Nigeria will not gain from the new corridor investments because most trade is happening within its already large market. The new corridor only gives Nigeria a better access to much smaller neighboring markets in the presence of large border frictions as assumed in this scenario.

Figure 3: Gains in real wages from the Dakar-Lagos corridor investment

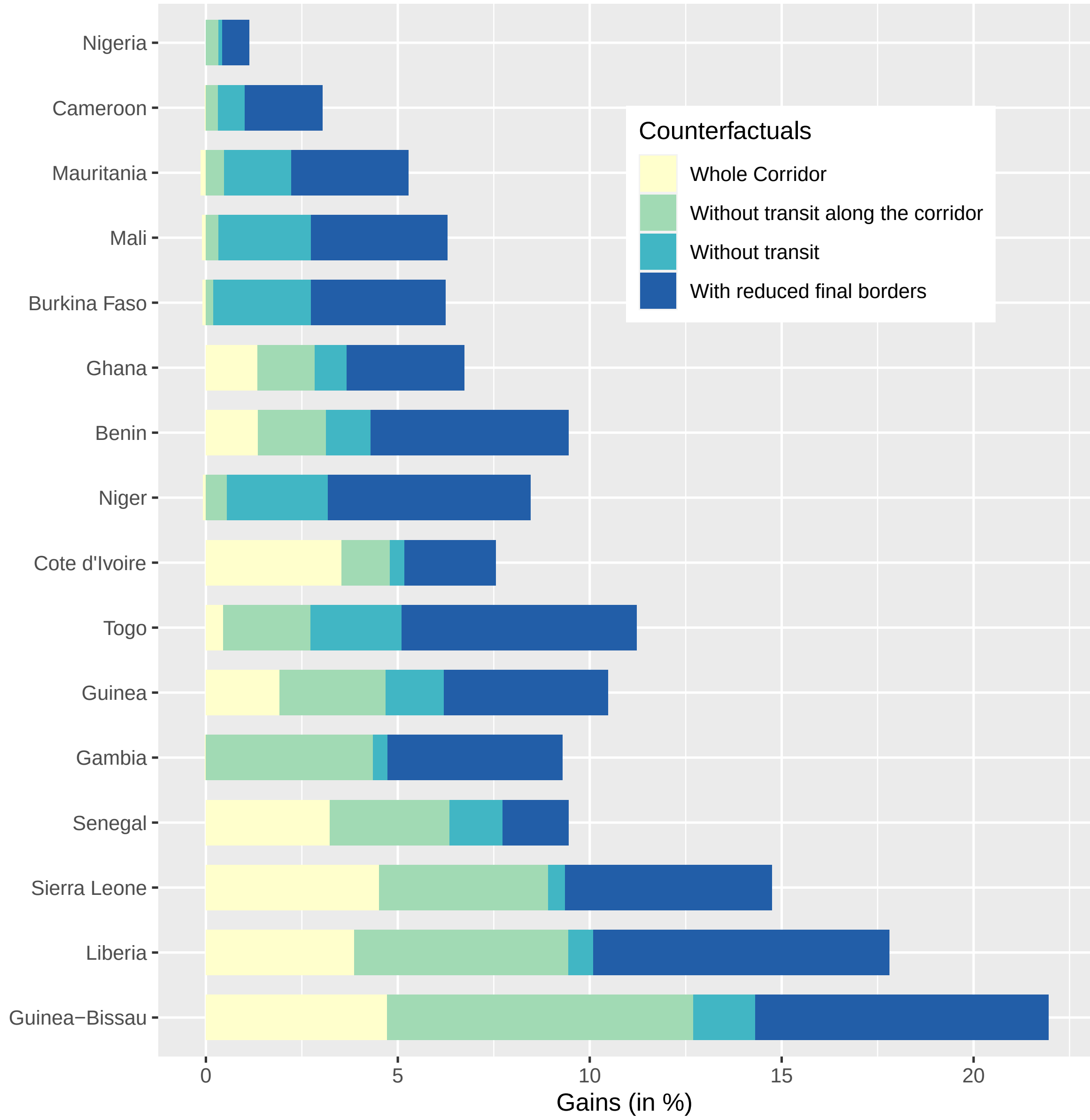


Source: Authors' calculations.

Complementary investments in reducing border delays will yield large additional gains. Figure 4 reports the gains from (1) investing in the road corridor, (2) from additionally removing transit delays only along the corridor, (3) from additionally removing all transit delays in the region, and finally (4) from reducing by half final border delays. While some countries were losing from investing in roads only, complementary investments from all scenarios 2, 3, and 4 lead to positive income gains for all countries. The maximum gains from reducing border frictions are substantial and range from 0.5% for Nigeria to more than 20% for Guinea-Bissau. Countries located in the middle of the whole corridor, such as Guinea-Bissau, Liberia, and Sierra Leone, tend to win the most from the combined investments.

Smaller countries gain the most from accessing bigger markets. While Benin and Togo gain a lot from a better access to Nigeria, Nigeria gains little from the new road investments. Regional trade from or to Nigeria in the context of high border costs is small when compared to its internal trade flows. Reducing transit and border delays bring larger benefits to Nigeria. Traders can import from cheaper locations and benefit from a larger more accessible market. Discrepancy in market sizes explains why larger economies including Nigeria benefit relatively little from these investments.

Figure 4: Gains in real wages from complementary investments along the Dakar-Lagos corridor



Source: Authors' calculations. Each category represents the additional percentage gains compared to the previous scenario.

4.4.2 Net gains at the regional level

We then subtract the investment costs from the GDP gains to obtain the net benefits from the corridor. A first cost estimate is provided by the PIDA website, which assess the CAPEX cost of a 2x3 1052km-long highway from Abidjan to Lagos through Accra, Lomé and Cotonou to be 3,000 million USD, hence US$ 3M per kilometer.[6] Given that not all segments of the corridors will be upgraded into 6L roads, we choose a lower estimate as a lower bound, US$ 2M per kilometer. We compare this low bound estimate with other estimates provided from international comparisons. We use the 2018-updated Road Costs Knowledge System (ROCKS) database which was designed to obtain average and range of unit costs based on historical data to improve the reliability of new cost estimates. It relies on all WBG-financed projects with a road component that were completed between the years 2000 and 2017, as well as some road-related projects financed by the African and Asian Development Banks. Based on the ROCKS database, the average unit costs per km for a 4L expressway are US$ 5.26M. Unit costs differ across geographic regions and whether we consider estimates or actual numbers which include observed cost overruns. Actual unit costs for a km of 4L expressway range from US$ 3.55 in South Asia to US$8 in Middle-East and North America. There is no estimate for a km of 4L or 6L expressway available for Sub-Saharian Africa. We therefore compare the results using two unit cost estimates: a low-bound of US$ 2M per km and a high-bound of US$ 5.26M per km. Our estimates do not include maintenance costs.

In order to use the investments' cost estimates in the context of our static model, we cannot simply use the total costs computed above and compare those to a single year of annual gain. Following de Soyres et al. (2020), we use an annualized cost, which allows us to compare one year of income to one yearly equivalent of the investment cost. We assume that the costs are paid overtime with interest rate r, assuming an interest rate r of 5 percent. The equivalent annualized cost A for a total investment cost C is given by:

$$C = \sum_{t=1}^{\infty} \frac{A}{(1+r)^t} \Rightarrow A = r \times C \tag{4.1}$$

Using Eq. 4.1, the low-bound annualized cost for the whole corridor Dakar-Lagos is estimated at US$400M and the high-bound annualized cost is estimated at US$1052M. We then compute the GDP gains net of investment costs by subtracting the annualized cost to the equilibrium annual GDP gains. The annual GDP gain is computed by using the estimated income gains from Table A3 and the 2019 GDPs (constant 2010 US$ from the World Bank) of all West African countries.

Table 2 provides the estimated net gains using the low and high-bound estimated annualized

[6] https://www.au-pida.org/view-project/2002/

costs and the gains from Table A3. We consider the total net gains for the region and do not consider the case when each country would have to pay for the number of kms crossing its territory. Using the low-bound cost estimates, the net gains for the region range from 0.52% when considering only the countries along the corridors to 0.44% when considering all countries. Using the high-bound cost estimates, the net gains for the region range from 0.07% when considering only the countries along the corridors to 0.05% when considering all countries. When only investing in the road corridor, the net gains are almost null, and possibly negative when including maintenance costs.

The net gains increase when including reduction in transit delays along the corridor only. We assume that the costs of such interventions is negligible compared to the estimated cost of the Dakar-Lagos corridor. Using the low-bound cost estimates, the net gains for the region range from 1.28% when considering only the countries along the corridors to 0.83% when considering all countries. Using the high-bound cost estimates, the net gains for the region range from 1.16% when considering only the countries along the corridors to 0.76% when considering all countries. Additional investments in border infrastructure are therefore necessary to get a positive return on investment for the whole corridor. Larger gains are expected with further removals of border frictions.

The Dakar-Lagos corridor can benefit all countries in the region. We consider the net gains from reducing transit delays for all countries as well as reducing by half final border time. The net gains become much larger when significantly reducing border frictions.

Table 2: Net gains from investing along the Dakar-Lagos corridor (in %)

(1) From road investments only				
Costs	Total welfare gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.66	0.57	0.60	0.51
High bound	0.66	0.57	0.50	0.42

(2) With reduction of border transit delays along the Dakar-Lagos corridor				
Costs	Total welfare gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	1.45	1.31	1.39	1.25
High bound	1.45	1.31	1.29	1.16

(3) With reduction of border transit delays for all countries				
Costs	Total welfare gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	1.74	1.31	1.68	1.87
High bound	1.74	1.31	1.58	1.78

(4) With additional reduction in final border delays				
Costs	Total welfare gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	3.17	3.63	3.11	3.49
High bound	3.17	3.63	3.01	3.49

Note: Authors' calculations.

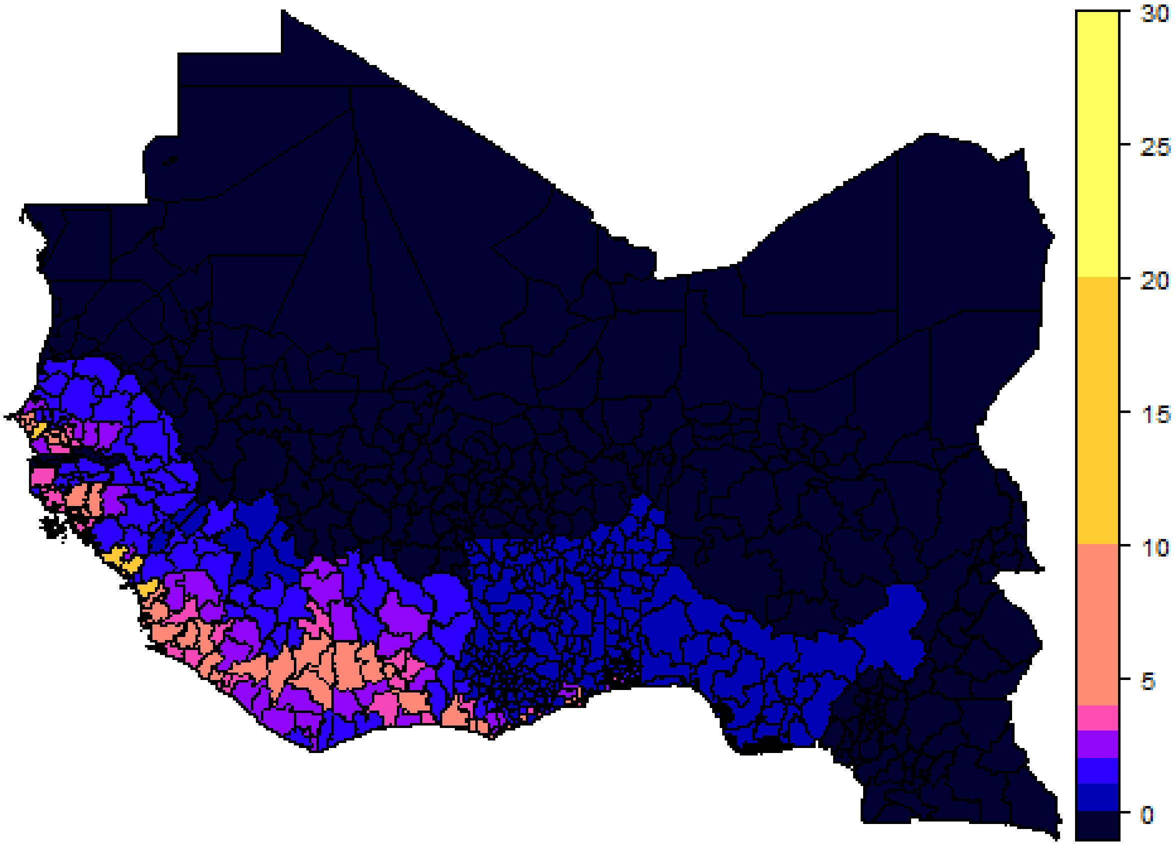
4.4.3 Gains at the sub-national level

The simulations allow to present income gains at the sub-national levels. Figure 5 shows the sub-national gains for investing in the whole Dakar-Lagos corridor. Figure 6 shows the gains for additionally removing transit delays along the corridor only. Figure 7 shows the gains from removing all transit delays and reducing final border delays by half.

Improving a section of the transport network will translate into lower costs for more regions than those directly located along the corridor. Using GIS methods to compute new times between all pairs of locations allows to consider the indirect impacts of corridor improvement all sub-national locations in the region. Figure 5 shows that the locations that gain the most are those located along the corridors. However not all of them do, and some distant locations also benefit from lower transport costs. The model includes both direct and indirect impacts when simulating the welfare gains.

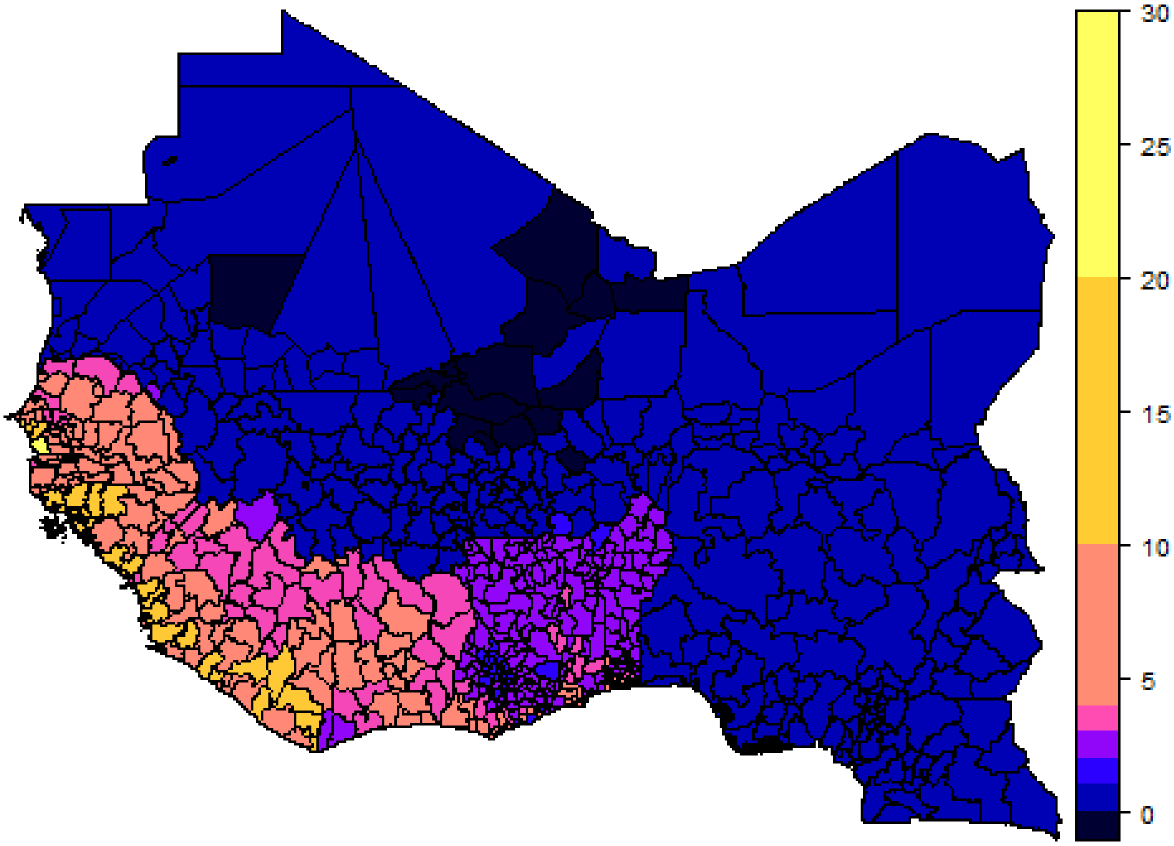
Reducing transit delays along the corridor brings large income gains for most locations along the new corridor (Figure 6). Not only are the gains larger for the locations along the corridor but the indirect gains are also larger for the more distant ones. Removing all transit delays in West Africa and reducing by half final border delays bring income gains for all in West Africa, even the most distant locations (Figure 7). There are two mains factors that affect the gains: the distance to the corridor, and the size of the internal market. More distant and isolated locations in the Sahel benefit little from all infrastructure investments happening along the corridor and borders. Locations in Nigeria also benefit relatively little from all these investments. The large size of the internal market explains the small gains from better regional connectivity.

Figure 5: Spatial Gains in real wages from the Dakar-Lagos corridor (in %)



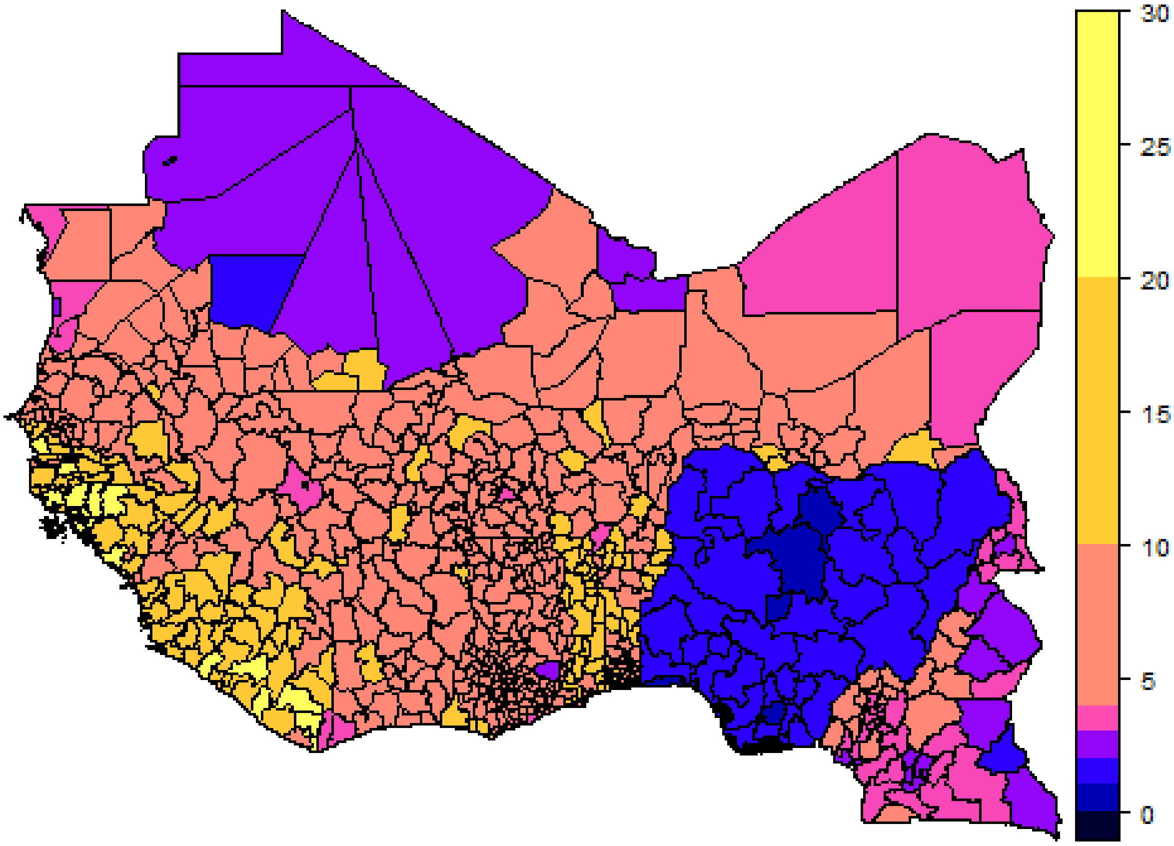
Source: Authors' calculations.

Figure 6: Spatial gains in real wages from additionally removing transit delays along the Dakar-Lagos corridor (in %)



Source: Authors' calculations.

Figure 7: Spatial gains in real wages from removing all transit and border delays (in %)



Source: Authors' calculations.

4.5 Comparing corridors in West Africa

This section compares the gains of the Dakar-Lagos corridor and four other regional corridors of interest.

4.5.1 Welfare gains

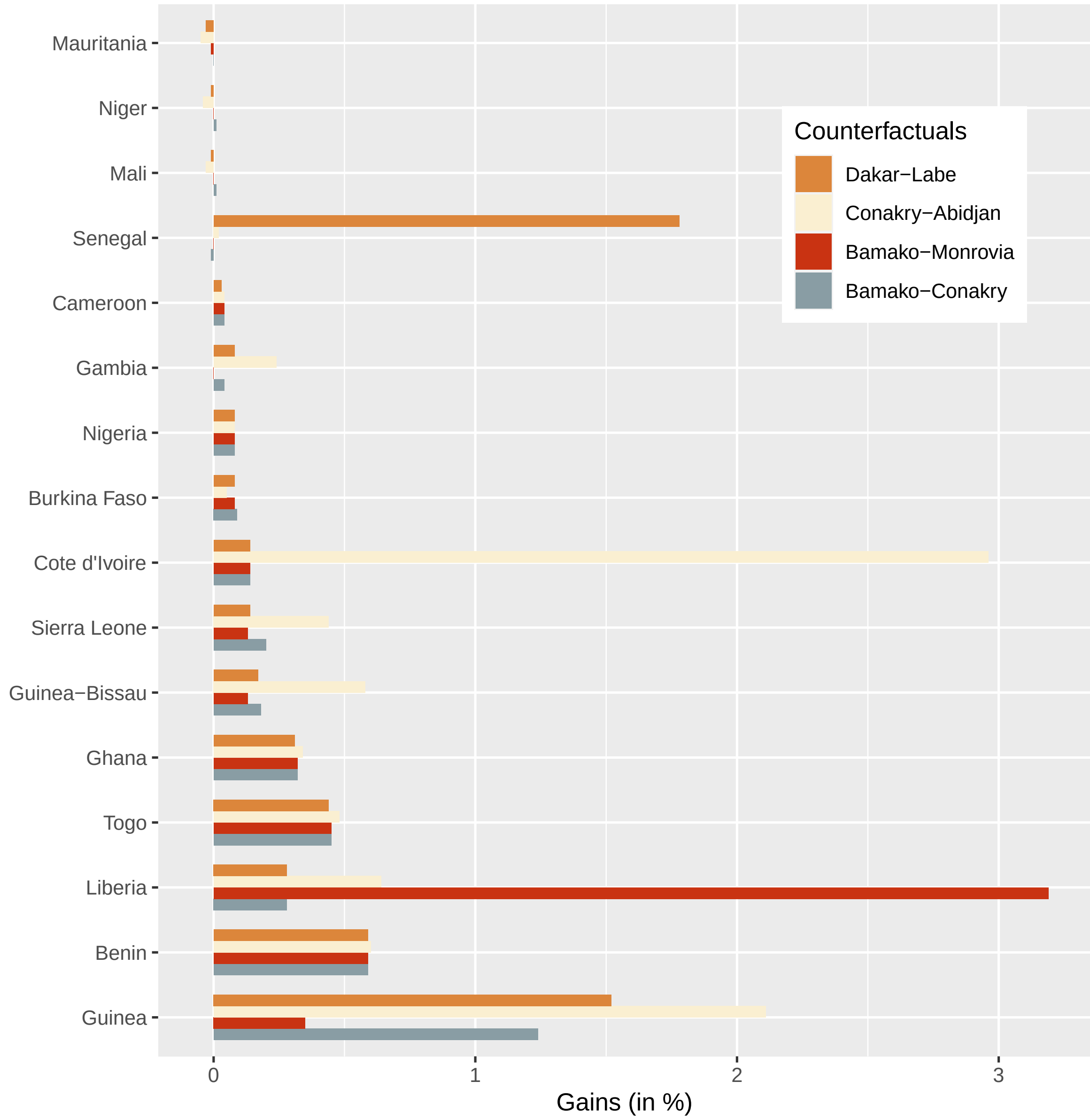
The gains depend on the location of the corridor and the size of the indirect network effects. Figure 8 reports the real income gains for each corridor per country in the scenario of no transit and border improvement. Each corridor benefits the most the countries which are directly located along the new road. The Dakar-Labe-Conakry corridor benefits the most Senegal and Guinea;

the Conakry-Abidjan corridor benefits the most Guinea and Côte d'Ivoire. Other countries also benefit from these investments. Sierra Leone and Guinea Bissau are two small countries that do not directly benefit from a road improvement in their country but gain from investments in neighboring countries. Togo and Benin are also two examples of countries that benefit from distant investments in road corridors.

Some countries relatively lose from these investments by losing in terms of relative comparative advantage and as economic activities move across space. Isolated and landlocked countries tend to gain less or even lose from these further investments. Mauritania, Niger, Mali experience loses in real incomes from these new investments. Cameroon and Burkina Faso would gain very little from such investments.

Complementary investments to remove transit delays and reduce final border delays bring large income gains. Figure A9 shows the real income gains when removing transit delays for all countries in addition to the road investments. Figure A10 shows the real income gains when additionally reducing final border delays by half. The gains become much larger when including reduction in border delays. Such findings support the idea that as or more important than slow speed is the time a truck is idling while waiting for administrative procedures to be performed (at borders or at the terminals during loading or unloading) (Teravaninthorn and Raballand, 2009). The gains from reducing border delays would magnify the gains of necessary road upgrades. Both upgraded roads and more fluid borders are complementary investments to increase domestic and regional trade.

Figure 8: Gains in real wages from road corridor investments



Source: Authors' calculations.

4.5.2 Comparing the net gains across corridors

Table 3 presents the gross and net gains for six corridors when subtracting the construction costs following the method used for Table 2. We compare the gains for following corridors: (1) Dakar-Abidjan, (2) Abidjan-Lagos, (3) Bamako-Conakry, (4) Bamako-Monrovia, (5) Conakry-Abidjan, and (6) Dakar-Labe-Conakry. We compare the total gains and net gains for the countries along the corridor only, and for all countries in the region. Each cost assessment is made using a lower bound (USD2M per kilometer) and a higher bound (USD5.6M per kilometer).[7]

The corridors that bring the largest net gains for the countries along the corridor are the

[7]The costs are estimated average costs for the whole corridor and we do not include additional maintenance costs.

Dakar-Abidjan corridor and the Conakry-Abidjan corridor. These corridors connect smaller economies with larger markets in Côte d'Ivoire and Senegal. Other corridors mostly interconnect smaller economies and therefore bring smaller gains.

We include cross-border spillovers in Table 3 with indirect gains for most countries in the region. While the total gains are relatively larger for the countries along the corridor, including the gains from other countries increase the benefits and make some projects more cost effective. The corridors between Bamako and Monrovia and between Bamako and Conakry both have low or negative net total gains for their direct beneficiaries depending on the cost scenario that is preferred. Liberia, and its capital Monrovia, are relatively small economies to be connected to which do not bring sufficient benefits given the high costs of road upgrades. Connecting Bamako to Conakry brings slightly larger gains because of the larger size of the Guinean market but not sufficient to compensate both countries for the construction costs. However, including the indirect benefits from other countries increase the total gains such that the annual gains are larger than the annualized costs. Depending on which countries bear the costs of new cross-border corridors in the regions, some corridors can bring either net loses or net gains. If only transit countries finance such large regional corridors, some corridors might become too expensive. If additional indirect countries also finance the corridor given their expected gains, all corridors pass our cost-benefit analysis.

Table 3: Net gains from investing along the different corridors (in %)

Dakar-Abidjan (~3000 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	3.85	0.46	3.53	0.42
High bound	3.85	0.46	2.99	0.35

Abidjan-Lagos (~1000 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.13	0.10	0.12	0.09
High bound	0.13	0.10	0.09	0.07

Bamako Conakry (~980 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.47	0.12	0.10	0.11
High bound	0.47	0.12	-0.49	0.09

Bamako Monrovia (~1150 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.77	0.14	0.38	0.12
High bound	0.77	0.14	-0.24	0.10

Conakry Abidjan (~2210 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	1.75	0.23	1.36	0.20
High bound	1.75	0.23	0.72	0.15

Dakar-Labe (~1140 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	1.78	0.19	1.48	0.18
High bound	1.78	0.19	0.98	0.15

Note: Authors' calculations.

4.5.3 Adding maintenance costs

While investing in new roads is necessary, poor maintenance leaves part of the existing infrastructure in disrepair. In Africa around 2010, half of the African countries surveyed were found not to devote adequate resources to maintenance of the main road network, and about half of these are not even spending enough to meet routine maintenance requirements (Gwilliam, 2011). There is great variation in spending for maintenance across countries, but under spending is conspicuous in low-income countries (Gwilliam, 2011). We therefore include maintenance costs to the analysis. Maintenance of the road network includes both routine maintenance to preserve the condition of the road and periodic maintenance to resurface paved roads to account for that lost due to vehicle usage. For the projects of interest, we assume an average annual maintenance cost (recurrent/routine maintenance as well as periodic maintenance) over the life of the assets of 3 percentage of capital cost range.[8]

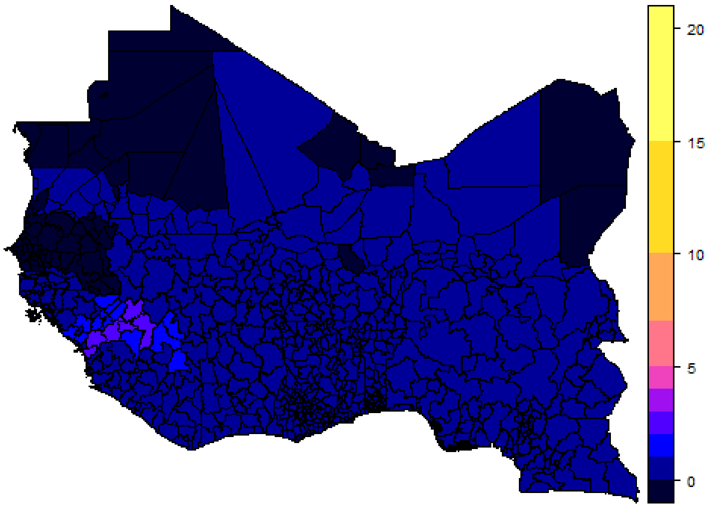
Table A16 reports the results of the net gains when including the maintenance costs. Adding maintenance costs reduce the net gains but the reduction is small for all corridors. The results remain similar to the previous estimation.

4.6 Spatial impacts

Figures 9, 10, 11 and 12 show the gains for all 662 locations for each corridor. The corridor Conakry-Abidjan on Figure 11 brings the largest benefits. The gains are the largest for the locations directly along the corridors that benefit from a significant drop in transport costs. The size of the gains decrease with the distance from the corridors, but the indirect benefits go well beyond the neighboring locations. Therefore reducing transit and border costs should be done not only along the corridor but also in the whole region to maximize the gains.

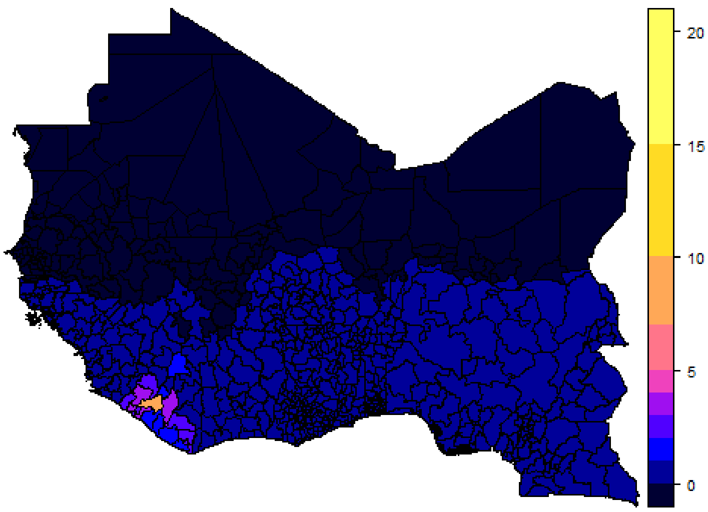
[8]This estimation is commonly used to quantify maintenance costs in cost-benefit analysis. It is higher than an estimation of the average combined cost of routine and periodic maintenance for a typical Sub-Saharan African country. The median value from “Study of Road Infrastructure Costs: Analysis of Unit Costs and Cost Overruns of Road Infrastructure Projects in Africa” published by the African Development Bank in May 2014 is given by 7,500 USD/km for routine maintenance, 160,644 USD/km for periodic maintenance, and 23564 for the combined annual cost. The values are adjusted at 2% annual inflation from 2006 to 2017 since data in US$ are from 2006.

Figure 9: Spatial Gains in real wages from the Bamako-Conakry corridor (in %)



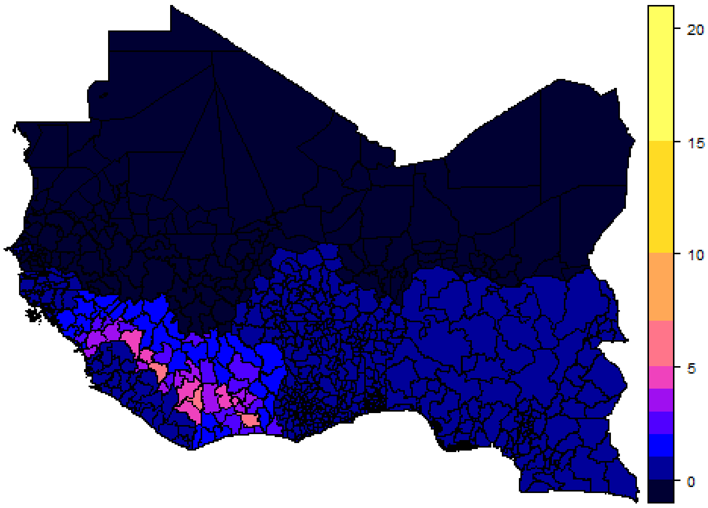
Source: Authors' calculations.

Figure 10: Spatial Gains in real wages from the Bamako-Monrovia corridor (in %)



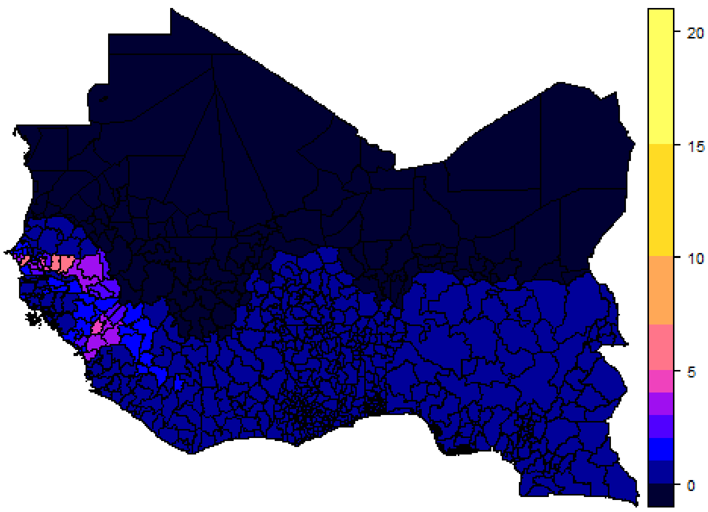
Source: Authors' calculations.

Figure 11: Spatial Gains in real wages from the Conakry-Abidjan corridor (in %)



Source: Authors' calculations.

Figure 12: Spatial Gains in real wages from the Dakar-Labe corridor (in %)



Source: Authors' calculations.

4.6.1 Spatial disparities

Transport and border investments reduces the transport and trade costs between locations leading to the relocation of economic activities within and across countries, and the movement of people within countries. The differential impacts of the investments will not only bring different welfare benefits across countries but also affect economic disparities across and within country.

Transport and trade investments can lead to either convergence or divergence at the regional and national levels. We use coefficients of standard deviation to quantify the impacts of the investments on spatial disparities in terms of real wages. The higher the coefficient, the higher the disparities between all the locations. At the regional level of West Africa, the coefficients of standard deviation will drop by 0.08% when investing only in the Dakar-Lagos corridor, by 2.2% when only investing in the road corridor, and by 3.5% when removing transit delays and reducing final border delays by half. For all scenarios, reducing trade costs will reduce spatial inequality in real wages across locations for the whole of West Africa.

Within country, spatial inequality between regions will increase in some countries and decrease in others. Tables A6 and A7 present the changes in the coefficients of standard deviation for each scenario at the country level. Road investments only will reduce spatial inequality in Guinea-Bissau and Sierra-Leone. Additional reductions in trade costs will lead to further reductions in within-country spatial inequality for most countries, but the changes remain small. Similar tables are presented for the four other corridors in the Appendix.

5 Conclusion

This paper estimates the welfare gains from upgrading several major regional corridors in West Africa. It uses the quantitative economic geography framework from Redding (2016) with trade within and across countries, and mobility of people within countries to assess the economic impacts of reduction in trade costs from road and border infrastructure investments. First, we quantify the direct gains for locations along the corridors as well as the indirect spillovers for more distant locations. We find that the upgrade of Dakar-Lagos regional road corridor brings sizable economic benefits relative to investment costs, with a benefit-cost ratio estimated around 3. The economic benefits of road corridor upgrades are doubled and more widely spread when combined with measures to reduce current massive border delays. The benefits are negligible for Nigeria, but large for small, fragile states (Guinea-Bissau, Liberia, and Sierra Leone). The gains are highest for corridors connecting large economies, and smaller and more fragile countries gain proportionally more from accessing larger markets. Finally regional investments, including border time reduction policies, will reduce spatial inequality in the whole region but might increase inequality in some countries.

More work remains to be done to better assess the effects of transport investments. First, the paper relies on strong assumptions on speed and border delays because of the lack of reliable and consistent data for West African countries. Accessing better data would help producing more precise estimates. Second, the paper does not model the transport sector and remains silent on issues of market power, back-haul, and other factors behind high transport costs. While improving road conditions can reduce transport costs, it remains an open question whether such cost reductions will be passed through to final customers or would only benefit trucking companies. Further work should also be done to include the global implications of infrastructure improvements considering the rest of the world while this paper only considers countries in the West African region.

References

AfDB-UEMOA, “"Benin/Togo multinational project to upgrade the Lomé-Cotonou route and facilitate trade and transport on the Abidjan-Lagos corridor",” 2017.

Atkin, David and Dave Donaldson, “Who’s Getting Globalized? The Size and Implications of Intra-national Trade Costs,” NBER Working Papers 21439, National Bureau of Economic Research, Inc July 2015.

Balboni, Clare, “"In Harm’s Way: Infrastructure Investments and the Persistence of Coastial Cities",” 2020.

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

Bonfatti, Roberto, Yuan Gu, and Steven Poelhekke, “Priority Roads: The Political Economy of Africa’s Interior-to-Coast Roads,” Technical Report 2019.

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

de Soyres, François, Alen Mulabdic, and Michele Ruta, “Common transport infrastructure: A quantitative model and estimates from the Belt and Road Initiative,” *Journal of Development Economics*, 2020, *143* (C).

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

_ , Amanda Jinhage, and Eric Verhoogen, “Beyond borders: Making transport work for African trade,” *IGC Growth Brief*, 2017.

Fajgelbaum, Pablo and Stephen J. Redding, “External Integration, Structural Transformation and Economic Development: Evidence From Argentina,” CEP Discussion Papers dp1273, Centre for Economic Performance, LSE June 2014.

Gwilliam, Ken, *Africa’s Transport Infrastructure : Mainstreaming Maintenance and Management* number 2275. In ‘World Bank Publications - Books.’, The World Bank Group, September 2011.

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

_ , _ , and Diana Van Patten, "Bridging India and Bangladesh: Cross-border Trade and the BBIN Motor Vehicles Agreement," 2021.

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

OCDE, "Accessibility and Infrastructure in Border Cities," West African Papers 23, OECD Publishing April 2019.

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

Teravaninthorn, Supee and Gael Raballand, *Transport Prices and Costs in Africa : A Review of the International Corridors* number 6610. In 'World Bank Publications.', The World Bank, November 2009.

Tilottama, Ghosh, R.L. Powell, Christopher Elvidge, K.E. Baugh, Paul Sutton, and Sharolyn Anderson, "Shedding Light on the Global Distribution of Economic Activity," *The Open Geography Journal*, 01 2010, *3*, 147–160.

UNCTAD, *Regional Integration and Non-Tariff Measures in the Economic Community of West African States (ECOWAS)*, United Nations, 2018.

World Bank, *"SSATP Report - Logistics Cost Study of Transport Corridors in Central and West Africa"*, The World Bank, 2013.

Figure A1: The evolution of main paved or partially improved roads in ECOWAS

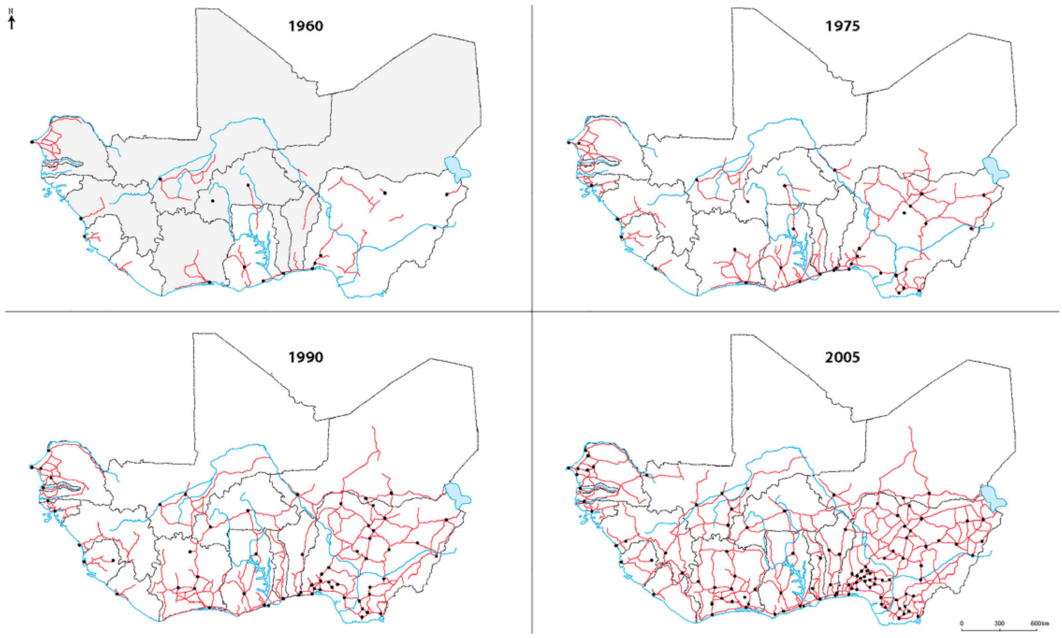


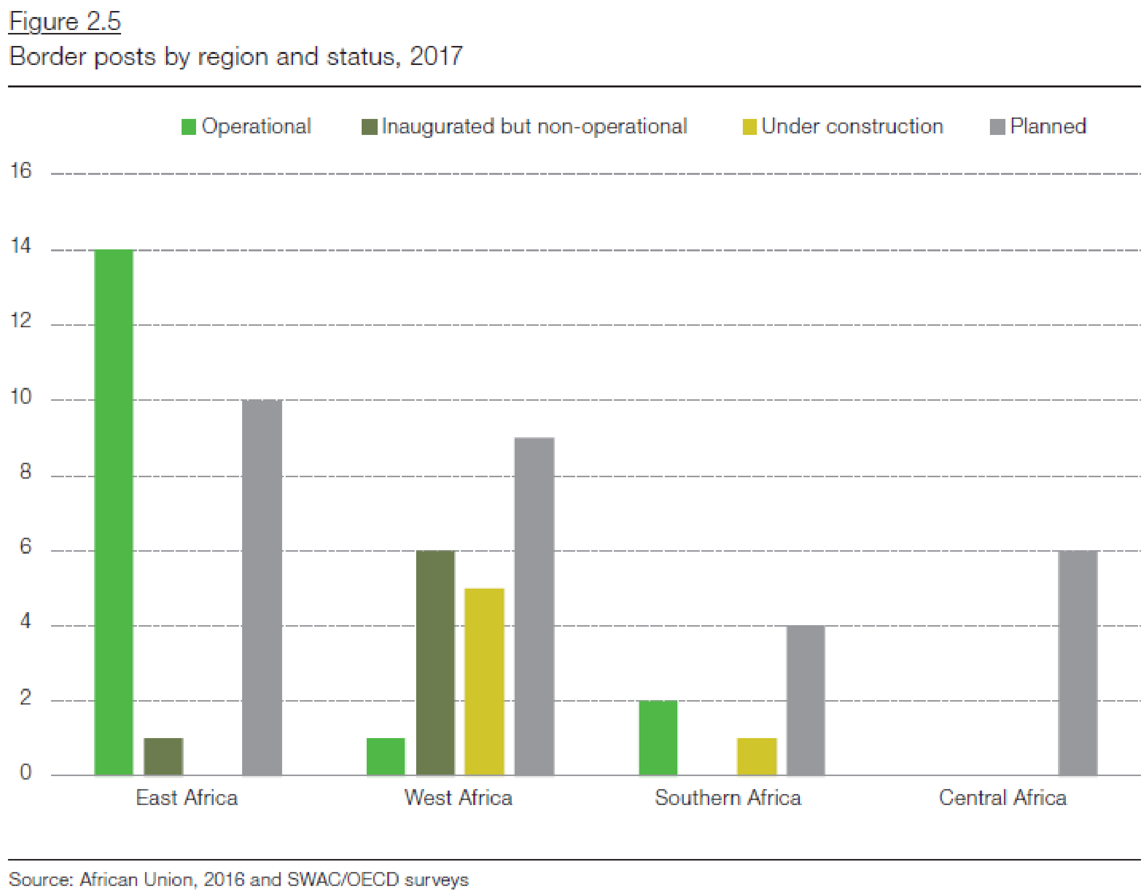
Figure 5. Main paved or partially improved roads within ECOWAS (Economic Community of West African States, 2005).

Source: Economic Community of West African States. (2005).

Table A1: Doing Business Indicators (2019)

Location	Trading across Borders rank	Trading across Borders score	Export border type	Time to export: Border compliance (hours)	Import border type	Time to import: Border compliance (hours)
Burkina Faso	122	66.6	land	75	land	102
Mali	95	73.3	land	48	land	98
Niger	126	65.4	land	48	land	78
Côte d'Ivoire	163	52.4	port	239	port	125
Equatorial Guinea	175	32	port	132	port	240
Ghana	158	54.8	port	108	port	80
Guinea	167	47.8	port	72	port	79
Guinea-Bissau	146	59.6	port	118	port	84
Nigeria	179	29.2	port	128	port	242
Senegal	142	60.9	port	61	port	53
Gambia, The	115	67.8	port	109	port	87

Figure A2: One-stop Border Posts in Africa



Source: ADB

Figure A3: Map of One-Stop Border Posts in Africa

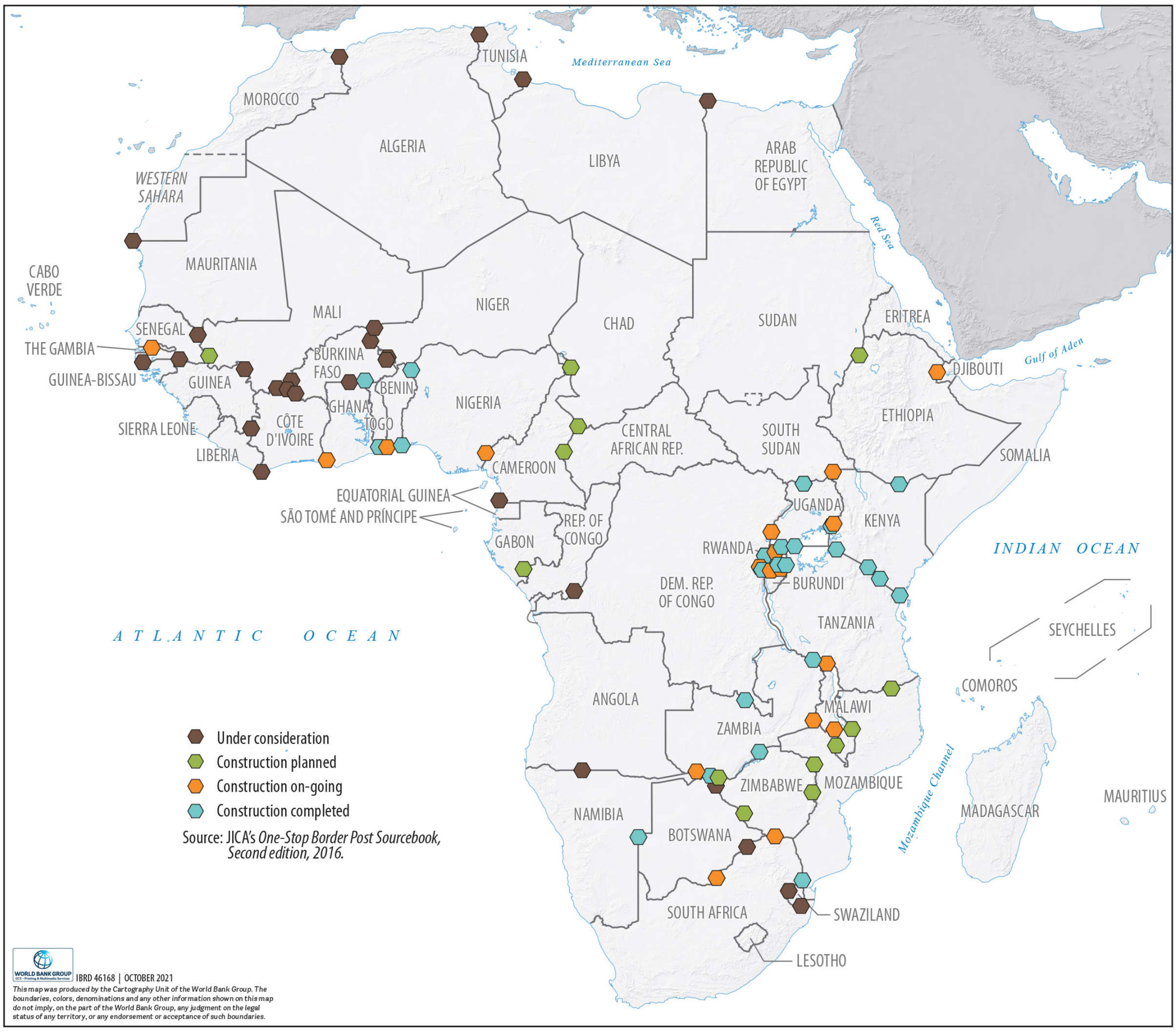
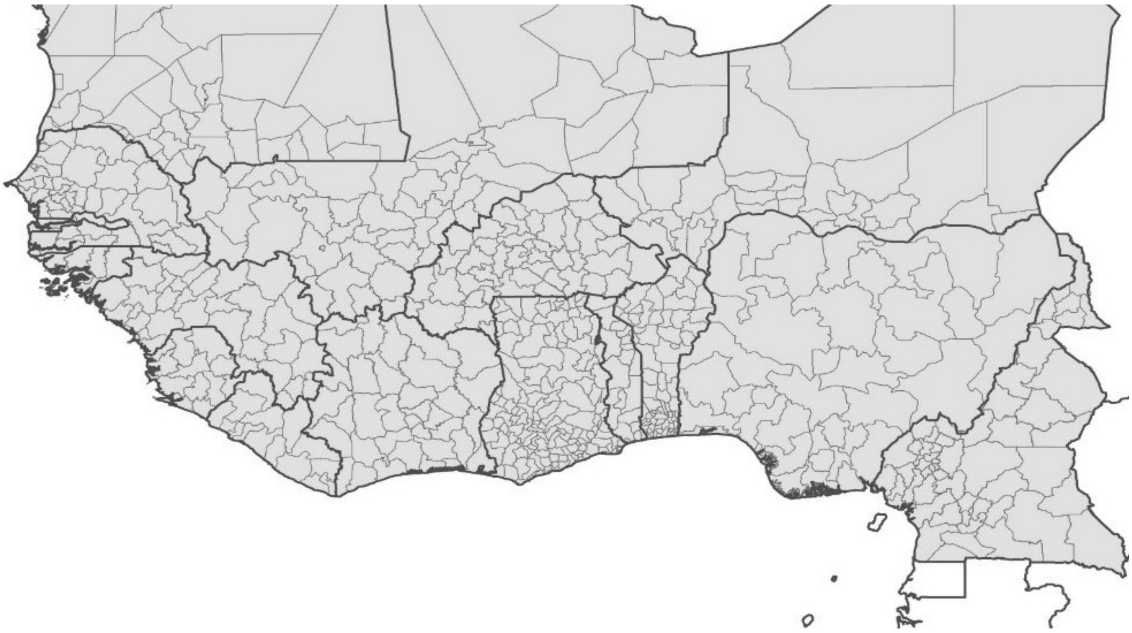
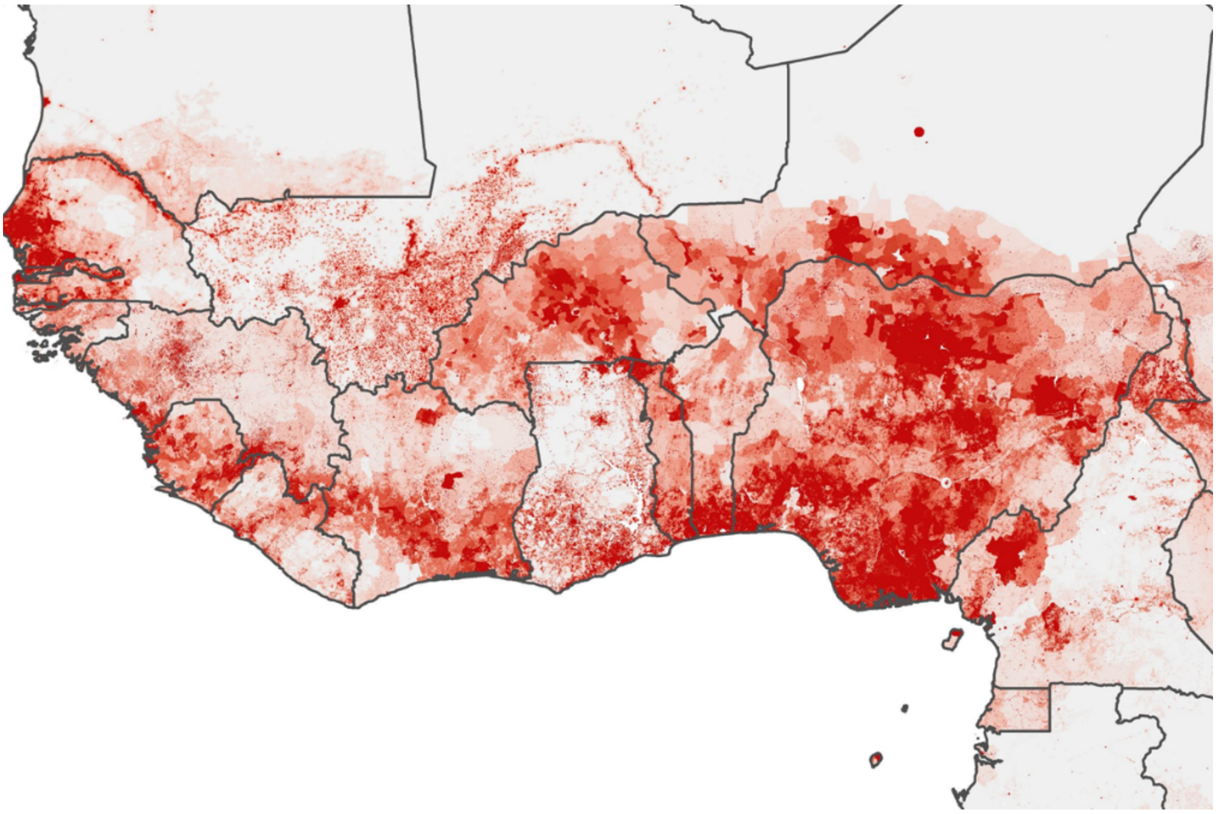


Figure A4: Administrative divisions



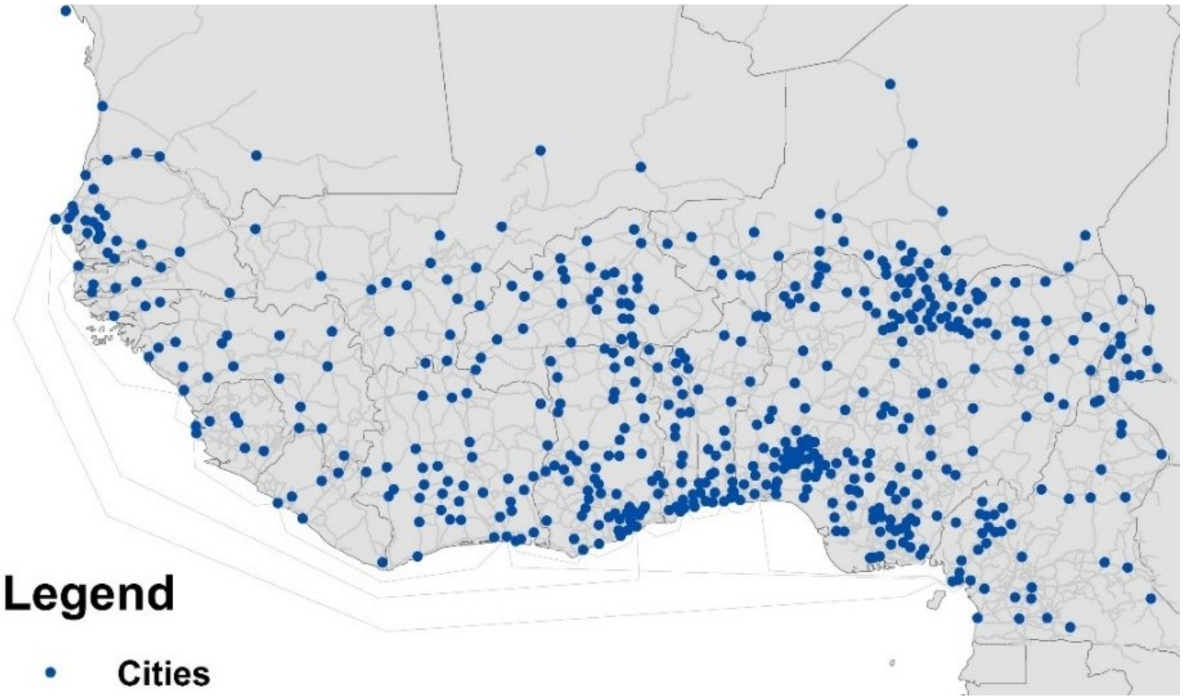
Source: Administrative levels, GADM

Figure A5: Population



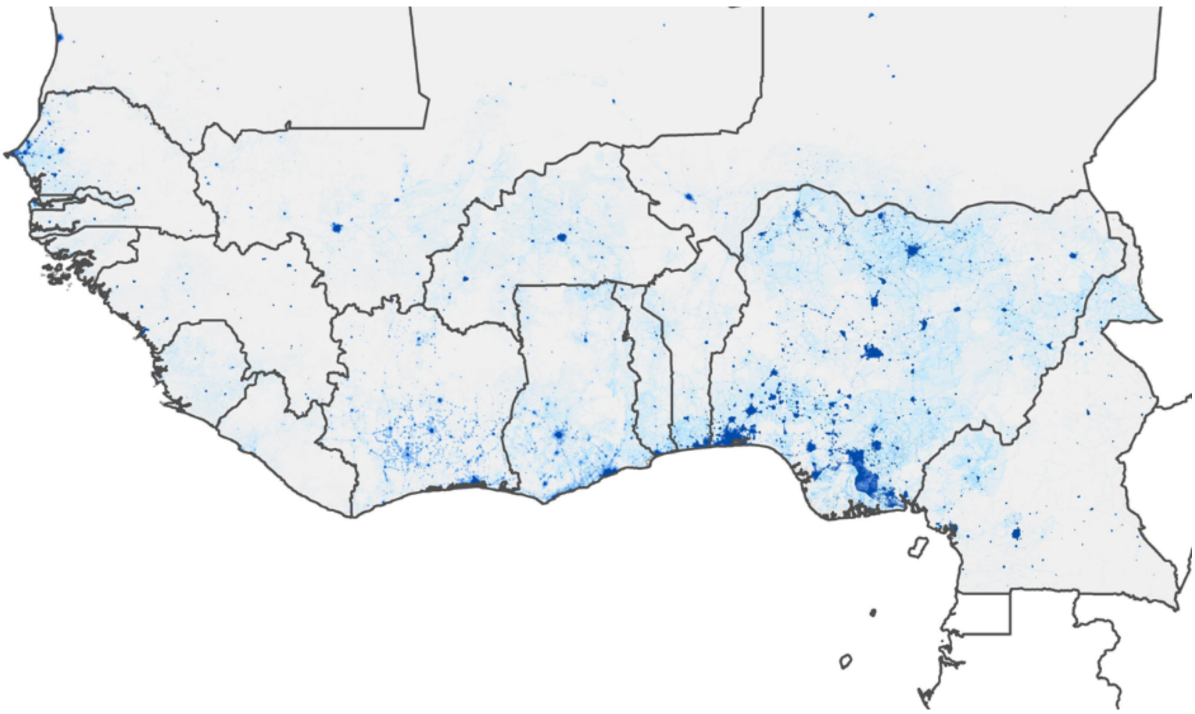
Source: GHSL, 2014. Population per administrative unit was calculated by taking the sum of GHSL data (2014 estimates).

Figure A6: Urban built-up



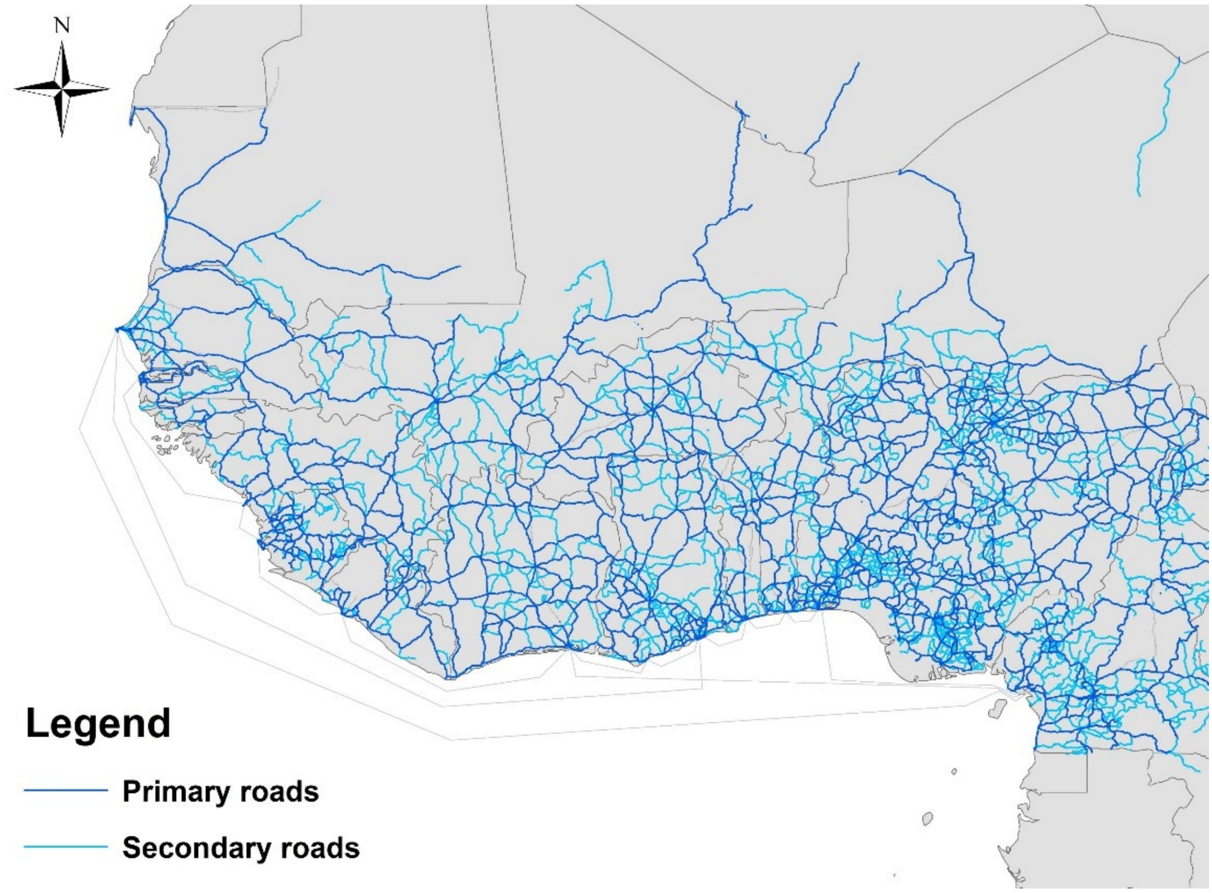
Source: GHSL, 2014.

Figure A7: Wages



Source: Ghosh, 2010. Wages were proxied through GDP per capita from a geographically disaggregated dataset based on a combination of Nighttime lights and Landscan data (in order to account for agricultural activity not reflected by NTL).

Figure A8: Transport networks



Source: 2019 Open Street Map data.

Table A2: Gains in real wages at the country level (Baseline)

Transport investments	None	None
Transit investment	Removal	Removal
Final Borders investment	None	Half border time
Benin	2.75	7.64
Burkina Faso	2.75	6.3
Cote d'Ivoire	1.3	3.2
Cameroon	0.85	2.79
Gambia	2.93	6.27
Ghana	2.12	4.86
Guinea	2.97	6.51
Guinea-Bissau	6.82	12.65
Liberia	4.58	10.24
Mali	2.61	6.14
Mauritania	0.12	3
Niger	3.09	8.35
Nigeria	0.35	0.97
Senegal	3.46	4.86
Sierra Leone	3.64	7.7
Togo	4.38	10

Table A3: Gains in real wages at the country level (Whole corridor Dakar Lagos)

Transport investments	Dakar-Lagos	Dakar-Lagos	Dakar-Lagos	Dakar-Lagos
Transit investment	None	Removal along corridor only	Removal	Removal
Final Borders investment	None	None	None	Half border time
Benin	1.35	3.12	4.29	9.44
Burkina Faso	-0.09	0.1	2.65	6.16
Cote d'Ivoire	3.54	4.8	5.17	7.55
Cameroon	-0.03	0.29	0.98	3
Gambia	-0.03	4.32	4.7	9.26
Ghana	1.32	2.81	3.65	6.71
Guinea	1.92	4.68	6.2	10.48
Guinea-Bissau	4.72	12.7	14.31	21.95
Liberia	3.87	9.45	10.09	17.8
Mali	-0.1	0.23	2.63	6.19
Mauritania	-0.14	0.34	2.09	5.14
Niger	-0.08	0.47	3.1	8.37
Nigeria	0	0.32	0.43	1.13
Senegal	3.22	6.35	7.73	9.45
Sierra Leone	4.51	8.91	9.36	14.75
Togo	0.42	2.7	5.07	11.2

Table A4: Gains in real wages at the country level (Dakar-Abidjan)

Transport investments Transit Final Borders	Dakar-Abidjan None None	Dakar-Abidjan Removal None	Dakar-Abidjan Removal Half border time
Benin	-0.02	2.75	7.67
Burkina Faso	-0.06	2.68	6.2
Cote d'Ivoire	3.08	4.41	6.39
Cameroon	-0.01	0.85	2.81
Gambia	-0.03	4.14	8.4
Ghana	-0.01	2.15	4.94
Guinea	1.87	5.61	9.49
Guinea-Bissau	4.67	13.37	20.5
Liberia	3.73	8.99	15.84
Mali	-0.07	2.5	5.99
Mauritania	-0.1	1.92	4.9
Niger	-0.06	3.01	8.24
Nigeria	-0.01	0.36	0.98
Senegal	3.22	7.5	9.1
Sierra Leone	4.46	8.63	13.49
Togo	-0.02	4.4	10.06

Table A5: Gains in real wages at the country level (Abidjan-Lagos)

Transport investments Transit Final Borders	Abidjan-Lagos None None	Abidjan-Lagos Removal None	Abidjan-Lagos Removal Half border time
Benin	1.37	4.22	2.75
Burkina Faso	-0.03	2.73	2.68
Cote d'Ivoire	0.44	2.01	4.41
Cameroon	-0.01	0.95	0.85
Gambia	-0.01	3.06	4.14
Ghana	1.33	3.6	2.15
Guinea	0.03	3.38	5.61
Guinea-Bissau	0.01	7.32	13.37
Liberia	0.12	5.44	8.99
Mali	-0.03	2.67	2.5
Mauritania	-0.03	2.16	1.92
Niger	-0.02	3.14	3.01
Nigeria	0.01	0.41	0.36
Senegal	-0.01	3.53	7.5
Sierra Leone	0.03	4.15	8.63
Togo	0.43	4.99	4.4

Table A6: Change in spatial inequality at the country level (Baseline)

Transport investments Transit investment Final Borders investment	None Removal None	None Removal Half border time
Benin	0.99	0.98
Burkina Faso	0.99	0.97
Cote d'Ivoire	1.00	0.99
Cameroon	1.00	0.99
Gambia	0.98	0.96
Ghana	0.99	0.99
Guinea	1.00	0.99
Guinea-Bissau	1.03	1.06
Liberia	0.99	0.98
Mali	0.99	0.98
Mauritania	1.00	0.99
Niger	0.99	0.97
Nigeria	1.00	1.00
Senegal	0.98	0.98
Sierra Leone	0.99	0.99
Togo	0.97	0.96

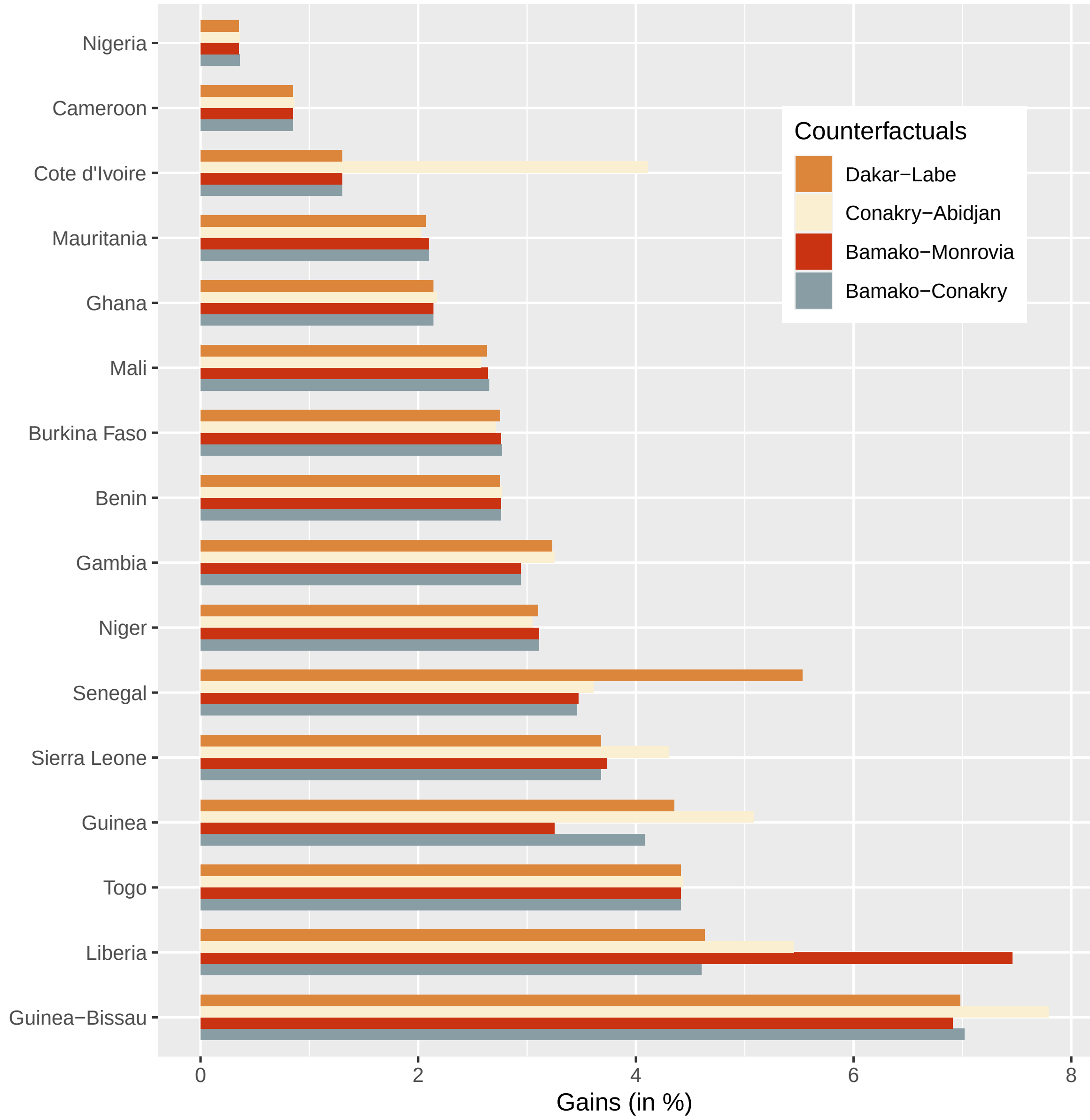
Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Table A7: Change in spatial inequality at the country level (Whole corridor Dakar Lagos)

Transport investments Transit investment Final Borders investment	Dakar-Lagos None None	Dakar-Lagos Removal along corridor only None	Dakar-Lagos Removal None	Dakar-Lagos Removal Half border time
Benin	1.01	1.00	1.00	0.99
Burkina Faso	1.00	1.00	0.99	0.98
Cote d'Ivoire	1.02	1.01	1.01	1.00
Cameroon	1.00	1.00	1.00	0.99
Gambia	1.00	0.98	0.97	0.96
Ghana	1.00	1.00	1.00	0.99
Guinea	1.00	1.01	1.00	1.00
Guinea-Bissau	0.98	1.07	1.04	1.07
Liberia	1.01	0.99	0.99	0.98
Mali	1.00	1.00	0.99	0.98
Mauritania	1.00	1.00	0.99	0.99
Niger	1.00	1.00	0.99	0.97
Nigeria	1.00	1.00	1.00	1.00
Senegal	1.01	1.00	0.99	0.98
Sierra Leone	0.99	0.98	0.98	0.98
Togo	1.01	1.01	0.98	0.97

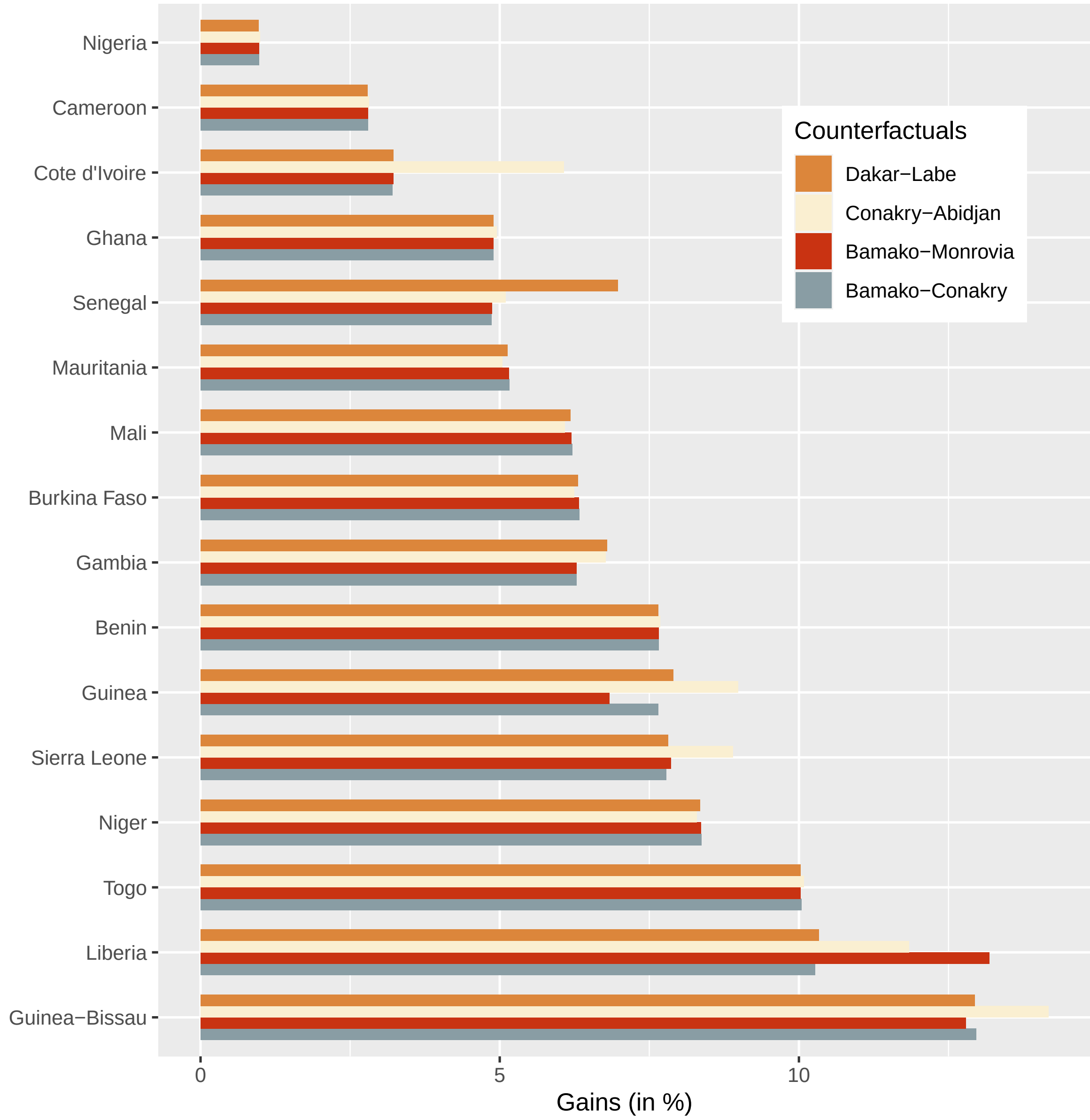
Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Figure A9: Gains in real wages from road corridor and transit infrastructure investments



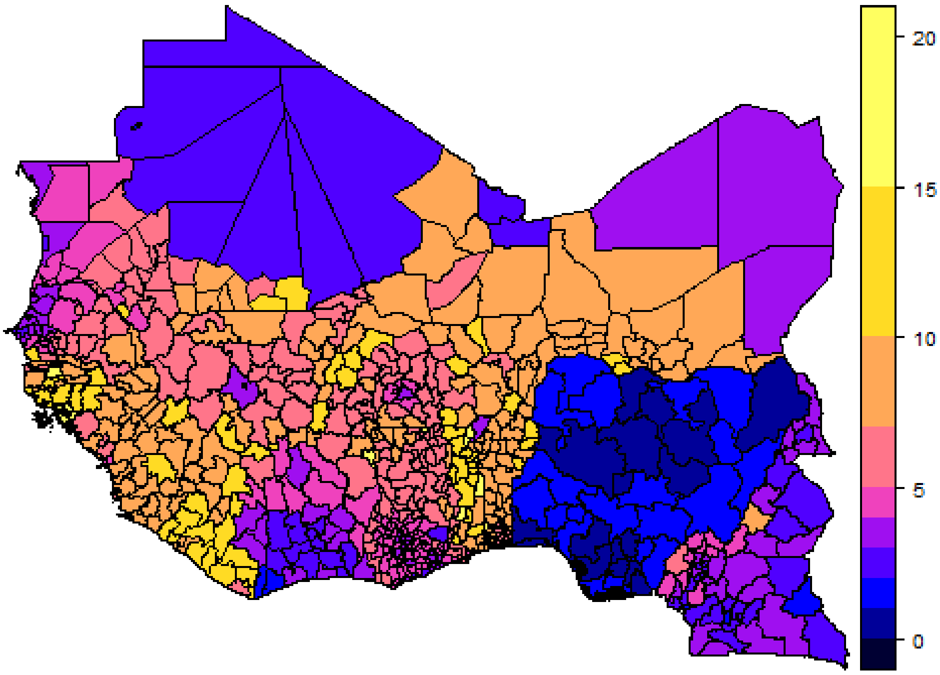
Source: Authors' calculations.

Figure A10: Gains in real wages from road corridor, transit and border infrastructure investments



Source: Authors' calculations.

Figure A11: Spatial Gains in real wages from road (Bamako-Conakry) and border investments (in %)



Source: Authors' calculations.

Table A8: Gains in real wages at the country level (Bamako-Conakry)

Transport investments Transit Final Borders	Bamako Conakry None None	Bamako Conakry Removal None	Bamako Conakry Removal Half border time
Benin	0.59	2.76	7.66
Burkina Faso	0.09	2.77	6.33
Cote d'Ivoire	0.14	1.3	3.21
Cameroon	0.04	0.85	2.8
Gambia	0.04	2.94	6.28
Ghana	0.32	2.14	4.89
Guinea	1.24	4.08	7.65
Guinea-Bissau	0.18	7.02	12.96
Liberia	0.28	4.6	10.27
Mali	0.01	2.65	6.21
Mauritania	0	2.1	5.16
Niger	0.01	3.11	8.37
Nigeria	0.08	0.36	0.98
Senegal	-0.01	3.46	4.86
Sierra Leone	0.2	3.68	7.78
Togo	0.45	4.41	10.04

Table A9: Gains in real wages at the country level (Bamako-Monrovia)

Transport investments Transit Final Borders	Bamako Monrovia None None	Bamako Monrovia Removal None	Bamako Monrovia Removal Half border time
Benin	0.59	2.75	7.65
Burkina Faso	0.08	2.76	6.32
Cote d'Ivoire	0.14	1.3	3.22
Cameroon	0.04	0.85	2.8
Gambia	0	2.94	6.28
Ghana	0.3	2.13	4.87
Guinea	0.36	3.25	6.83
Guinea-Bissau	0.13	6.91	12.79
Liberia	3.19	7.46	13.18
Mali	0	2.64	6.2
Mauritania	-0.01	2.1	5.15
Niger	0	3.11	8.36
Nigeria	0.08	0.35	0.98
Senegal	0	3.47	4.87
Sierra Leone	0.13	3.73	7.86
Togo	0.42	4.39	10.01

Table A10: Gains in real wages at the country level (Conakry-Abidjan)

Transport investments	Conakry Abidjan	Conakry Abidjan	Conakry Abidjan
Transit	None	Removal	Removal
Final Borders	None	None	Half border time
Benin	0.59	2.76	7.67
Burkina Faso	0.05	2.71	6.24
Cote d'Ivoire	2.96	4.11	6.07
Cameroon	0.04	0.86	2.81
Gambia	0.24	3.26	6.77
Ghana	0.32	2.15	4.93
Guinea	2.11	5.08	8.98
Guinea-Bissau	0.58	7.79	14.17
Liberia	0.64	5.45	11.84
Mali	-0.03	2.58	6.09
Mauritania	-0.05	2.02	5.04
Niger	-0.04	3.05	8.29
Nigeria	0.08	0.36	0.98
Senegal	0.02	3.61	5.1
Sierra Leone	0.44	4.3	8.9
Togo	0.45	4.41	10.05

Table A11: Gains in real wages at the country level (Dakar-Labe)

Transport investments	Dakar Labe	Dakar Labe	Dakar Labe
Transit	None	Removal	Removal
Final Borders	None	None	Half border time
Benin	0.58	2.75	7.65
Burkina Faso	0.08	2.75	6.31
Cote d'Ivoire	0.14	1.3	3.22
Cameroon	0.03	0.85	2.79
Gambia	0.08	3.23	6.79
Ghana	0.3	2.12	4.87
Guinea	1.52	4.35	7.9
Guinea-Bissau	0.17	6.98	12.94
Liberia	0.28	4.63	10.33
Mali	-0.01	2.63	6.18
Mauritania	-0.03	2.08	5.14
Niger	-0.01	3.09	8.35
Nigeria	0.08	0.35	0.97
Senegal	1.78	5.53	6.97
Sierra Leone	0.15	3.68	7.81
Togo	0.42	4.38	10

Table A12: Change in spatial inequality at the country level (Bamako-Conakry)

Transport investments Transit Final Borders	Bamako Conakry None None	Bamako Conakry Removal None	Bamako Conakry Removal Half border time
Benin	1.00	0.99	0.98
Burkina Faso	1.00	0.99	0.97
Côte d'Ivoire	1.00	1.00	0.99
Cameroon	1.00	1.00	0.99
Gambia	1.00	0.98	0.96
Ghana	1.00	0.99	0.99
Guinea	1.00	0.99	0.99
Guinea-Bissau	1.01	1.03	1.06
Liberia	1.00	0.99	0.98
Mali	1.00	0.99	0.98
Mauritania	1.00	0.99	0.99
Niger	1.00	0.99	0.97
Nigeria	1.00	1.00	1.00
Senegal	1.00	0.98	0.98
Sierra Leone	1.00	0.99	0.99
Togo	1.00	0.97	0.96

Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Table A13: Change in spatial inequality at the country level (Bamako-Monrovia)

Transport investments Transit Final Borders	Bamako Monrovia None None	Bamako Monrovia Removal None	Bamako Monrovia Removal Half border time
Benin	1.00	0.99	0.98
Burkina Faso	1.00	0.99	0.97
Cote d'Ivoire	1.00	1.00	0.99
Cameroon	1.00	1.00	0.99
Gambia	1.00	0.98	0.96
Ghana	1.00	0.99	0.99
Guinea	1.00	0.99	0.99
Guinea-Bissau	1.00	1.03	1.06
Liberia	1.01	1.00	0.99
Mali	1.00	0.99	0.98
Mauritania	1.00	0.99	0.99
Niger	1.00	0.99	0.97
Nigeria	1.00	1.00	1.00
Senegal	1.00	0.98	0.98
Sierra Leone	1.00	0.99	0.99
Togo	1.00	0.97	0.96

Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Table A14: Change in spatial inequality at the country level (Conakry-Abidjan)

Transport investments	Conakry Abidjan	Conakry Abidjan	Conakry Abidjan
Transit	None	Removal	Removal
Final Borders	None	None	Half border time
Benin	1.00	0.99	0.98
Burkina Faso	1.00	0.99	0.97
Côte d'Ivoire	1.01	1.01	1.00
Cameroon	1.00	1.00	0.99
Gambia	1.00	0.98	0.96
Ghana	1.00	0.99	0.99
Guinea	0.99	0.99	0.99
Guinea-Bissau	1.01	1.04	1.07
Liberia	1.00	0.98	0.97
Mali	1.00	0.99	0.98
Mauritania	1.00	0.99	0.99
Niger	1.00	0.99	0.97
Nigeria	1.00	1.00	1.00
Senegal	1.00	0.98	0.98
Sierra Leone	1.00	0.99	0.99
Togo	1.00	0.97	0.96

Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Table A15: Change in spatial inequality at the country level (Dakar-Labe)

Transport investments	Dakar Labe	Dakar Labe	Dakar Labe
Transit	None	Removal	Removal
Final Borders	None	None	Half border time
Benin	1.00	0.99	0.98
Burkina Faso	1.00	0.99	0.97
Côte d'Ivoire	1.00	1.00	0.99
Cameroon	1.00	1.00	0.99
Gambia	1.00	0.98	0.96
Ghana	1.00	0.99	0.99
Guinea	1.00	0.99	0.99
Guinea-Bissau	1.00	1.03	1.05
Liberia	1.00	0.99	0.98
Mali	1.00	0.99	0.98
Mauritania	1.00	0.99	0.99
Niger	1.00	0.99	0.97
Nigeria	1.00	1.00	1.00
Senegal	1.00	0.98	0.98
Sierra Leone	1.00	0.99	0.99
Togo	1.00	0.97	0.96

Note: The table shows the ratio of standard deviations after the investment over standard deviations in the baseline case.

Table A16: Net gains from investing along the different corridors including maintenance costs (in %)

Dakar-Abidjan (~3000 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	3.85	0.46	3.33	0.40
High bound	3.85	0.46	2.47	0.29

Abidjan-Lagos (~1000 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.13	0.10	0.11	0.08
High bound	0.13	0.10	0.06	0.05

Bamako Conakry (~980 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.47	0.12	-0.11	0.10
High bound	0.47	0.12	-1.07	0.07

Bamako Monrovia (~1150 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	0.77	0.14	0.15	0.11
High bound	0.77	0.14	-0.85	0.07

Conakry Abidjan (~2210 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Scenario 1	1.75	0.23	1.12	0.18
Scenario 2	1.75	0.23	0.10	0.11

Dakar-Labe (~1140 kms)				
Costs	Total real income gains		Net total gains	
	Countries along the corridor	All countries	Countries along the corridor	All countries
Low bound	1.78	0.19	1.30	0.17
High bound	1.78	0.19	0.96	0.15

Note: Authors' calculations. Annual maintenance costs are assumed to be equal to 3% of the initial capital cost.