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Does Transport Infrastructure Quality Really Affect Intra-regional Trade in Sub-Saharan Africa?

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Abstract

The quality of transport infrastructure is one of the determining factors in a nation's economic development, due to its knock-on effects on trade. However, Sub-Saharan Africa (SSA) is a region characterized by a lack of quality transport infrastructure. This situation could hamper trade, despite the establishment of the African Continental Free Trade Area. The objective of this research is to analyze the direct and indirect effects of transport infrastructure quality on intraregional trade in Sub-Saharan Africa. To achieve this objective, we used a dynamic spatial model with data from 20 countries covering the period from 2006 to 2019. Three main results emerge. First, improving the quality of transport infrastructure in countries has a positive effect on their intraregional trade. Secondly, improving the quality of transport infrastructure in one country promotes intra-regional trade in other SSA countries. Finally, this positive effect on trade is evident in both the short and long term, but is more pronounced in the short term. We therefore recommend the establishment of supranational institutions responsible for infrastructure investment.

Keywords: Quality of transport infrastructure, trade, spatial model, Sub-Saharan Africa.

1 Introduction

Intra-regional trade is one of the determining factors in the socio-economic development of the countries involved. For Fontagné (2002), it is: "the crossing of a border when moving goods or providing a service, which determines the international nature of trade." Intra-regional trade can be explained by an inadequate regulatory environment (Kouty, 2024), limited access to finance (Houngbedji, 2022; Mazorodze, 2024), armed conflicts and political instability (Boungou et al., 2025; Mamba et al., 2025), and infrastructures such as transport infrastructure (Babu & al., 2022; De, 2006). Indeed, transport, while playing a fundamental role in accelerating growth and socio-economic development, is also essential for measuring the connectivity of a region and more particularly within a country (Carter & al., 1984). It plays a central role in regional trade by facilitating the movement of goods, services, and factors of production (Munier, 1972; Button and Yuan, 2013).

The role of transport infrastructure in trade has attracted considerable interest among researchers, both from a theoretical and empirical perspective. Theoretically, transport cost theory emphasizes that transport costs influence the price of goods and services, terms of trade, and the competitiveness of firms (Hummels, 2007; Mundell,1957). Furthermore, Laussel and Riezman (2006) show that fixed transport costs lead to structural inefficiency in international trade, while establishing a bidirectional causality between costs and trade between two countries. A reduction in fixed costs for businesses and uncertainties increases trade in the sector, according to the new trade theory (Ciuriak & al., 2015). Similarly, the new theory of international trade, which incorporates economies of scale and product differentiation, states that investment in transport infrastructure promotes market access and connectivity as well as industrial attraction (Krugman, 1991, 2009).

While these studies have highlighted the direct effects of transport infrastructure on trade, others have focused on the knock-on effects of transport on trade and interdependence relationships. Durand (1998, 2001) conducted a spatial analysis showing that there is spatial interdependence in trade flows between regions within a country. An improvement or deterioration in a country's transport infrastructure affects its trade flows as well as those of its neighbors. Jessop & al. (2008) emphasize that socio-spatial relationships are polymorphic and should not be reduced to a single dimension. They criticize traditional approaches that do not take spatial relationships into account.

Empirically, study results diverge on its contribution to trade. Park (2020) shows that high- quality transport infrastructure is a source of comparative advantage for logistics-intensive industries. Similarly, Bahri and Dinar (2022) show that the quality of transport services is essential for business competitiveness. They, argues that the lack of quality infrastructure in a developing economy contributes to worsening trade deficits. Tandrayen-Ragoobur & al. (2023) show that the soft infrastructure index, a measure of physical infrastructure, and an efficient infrastructure index combining intangible and physical infrastructure components have a positive impact on trade in Africa. Furthermore, Sahoo & al. (2025) show that infrastructure development in Senegal has a positive effect on trade in Sub-Saharan Africa (SSA). Finally, Takpara & al. (2024) show that different qualities of transport infrastructure (roads, ports, and airports) contribute to intra-regional trade in Africa.

Our paper contributes to the economic literature on the effect of transport infrastructure on intra trade. It analyses the effects of transport infrastructure quality on African intra-trade for 20 Sub-Saharan African countries over the period 2006-2019. It put in light the direct and indirect effects of transport infrastructures quality on African intra-trade. It assumes that transport infrastructure quality has direct positive effects on intra-regional trade in the home country, but also increases the intra-regional trade in neighboring countries.

This paper contributes to the literature in two ways by assessing the effect of transport infrastructure quality on intra-regional trade in a sample of Sub-Saharan African countries. First, contrary to the existing literature (Takpara, 2024;

Tandrayen-Ragoobur et al., 2023) that has analysed the effect of transport infrastructure quality on intra-regional trade, our paper innovates by taking into account the spillover effects of transport infrastructure quality. It shows that an improvement in transport infrastructure quality in a given country can positively influence its intra-regional trade flows but also the intra-regional trade of its neighbors. It thus fills a major empirical gap, as most previous studies neglected these externalities, potentially leading to an underestimation of the effect of transport infrastructure quality. Second, from a methodological standpoint, this paper uses spatial econometrics, contrasting with traditional methods such as the Standard Gravity Model or the GMM and PPML estimators used by previous authors, such as Takpara (2024). Spatial econometrics allow for the modelling of spatial dependencies and quantify the indirect effects that transit across borders. Indeed, unlike gravity models that treat space as a simple barrier (distance), the spatial approach considers space as a transmission channel. By using Spatial Durbin Models (SDMs), our paper decomposes the total effect of transport infrastructure quality into direct and indirect effects, thus offering unprecedented analytical precision for African economic policymakers.

The rest of our work will be organized as follows. Section 2 presents the theoretical and empirical literature. Section 3 describes the methodological approach and the data used. Section 4 presents the empirical results while le last section concludes.

2 Literature review

2.1 Theoretical review

The role of transport infrastructure was neglected in classical international trade theory, which considers it to be neutral. These theories are based mainly on absolute advantages Smith (1776) and comparative advantages Ricardo (1817). Krugman (2009) argues that before 1990, international trade economists did not pay particular attention to the spatial location of production. However, transport infrastructure plays a key role in price setting, the mobility of goods and services, and above all the location of businesses.

The theory of transport costs, developed by Mundell (1957), measures them using a geometric model. It shows that transport costs alter domestic prices and terms of trade, and influence gains or losses linked to scarce or abundant factors, depending on the elasticity of production. Hummels (2007) identifies three major reasons for integrating transport costs into trade analysis. The first reason is to examine transport costs in relation to the value of the goods transported. The second reason is to examine transport costs in relation to other known barriers to trade, such as customs tariffs. Finally, the third reason is the extent to which transport costs alter relative prices. This theory is supported by Laussel & Riezman (2006), who describe the influence of fixed transport costs on trade while demonstrating a reverse causality effect. Very high fixed transport costs reduce the incentive to trade, as there is a decrease in potential gains. However, the decrease in trade volume leads to an increase in unit transport costs, as there is no amortization of fixed costs over large volumes.

Finally, according to the new trade theory incorporating economies of scale, product differentiation, imperfect competition, and transportation costs. According to this theory, transportation infrastructure plays a role in concentration and connectivity and facilitates market access (Krugman, 1991). It is also thanks to economies of scale and reduced transport costs that industries are attracted to certain regions and businesses are located there. An increase in transport costs therefore leads to a loss of efficiency and affects consumer welfare. This fixed cost plays a decisive role in the entry of firms into regional markets that are characterized by productivity heterogeneity, according to the new trade theory (Ciuriak & al., 2015). In addition to helping reduce fixed costs and the loss of goods, the quality of infrastructure plays a role in variable costs.

Beyond spillover effects, other researchers have examined spatial relationships and interactions in terms of trade within a region. Durand (1998, 2001) describes a methodological approach based on two main elements: the theoretical foundations of how the transport system works, and the method of analysis and modeling. He shows that there is an interrelationship between the transport system and the production and location system, which impacts the transformation of the spatial organization of activities on the geography of flows. An improvement in transport infrastructure therefore increases flows from region i to its neighbor j due to spatial interdependence.

In addition, the theory of socio-spatial relations developed by Jessop & al. (2008) proposes a dynamic spatial relationship between social relations.

2.2 Empirical review

Several authors have examined the empirical verification of the role of transport on trade. In a more comprehensive analysis, Tandrayen-Ragoobur & al. (2023) examine the effect of infrastructure development on trade flows in Africa. To measure infrastructure development, three aggregate indicators were calculated: a soft infrastructure index, a measure of physical infrastructure, and an efficient infrastructure index combining the components of intangible and physical infrastructure. The study uses a panel of 51 countries with data covering the period 2003 to 2015 and a gravity model with a fixed-effects pseudo-Poisson maximum likelihood estimator. The results show that a 1% increase in the soft infrastructure index (entry cost, entry time, and entry procedure) correlates with a 0.077% increase in trade in Africa.

Sénquiz-Díaz (2021) analyzes the effect of infrastructure and logistics quality on trade in 29 emerging countries, which must maintain the same classification level over the study period. After conducting preliminary tests, and due to heteroscedasticity, the author uses a robust fixed- effects model with standard error (HAC), as well as a dynamic model. The results differ depending on the estimation method used. In the fixed-effects model, only logistics quality has a significant effect on trade, with the other variables being insignificant. A one-unit improvement in the quality of roads, ports, and railways leads to an increase of 0.59%, 1.23%, and 0.057%, respectively, in exports as a percentage of GDP. On the other hand, a 1% improvement in logistics quality leads to a 0.77% decrease in exports as a percentage of GDP. For the dynamic model, a one-unit improvement in logistics and airport quality leads to a decrease of 0.84% and 1.02% respectively in exports as a percentage of GDP. These results can be explained by these countries' heavy dependence on sensitive, low-volume products. In a similar vein, Takpara & al. (2024) study the effect of transport infrastructure on trade in Africa, using a panel of 54 countries over the period 2003-2020. For robustness tests, different types of infrastructure quality were used, with a pseudo-Poisson maximum likelihood estimator. The results indicate that infrastructure development has a positive effect on intraregional trade in Africa. A one-unit increase in the transport infrastructure development index leads to a 1.2% increase in intra-African trade. The quality of roads, ports, and airports leads to increases of 5.13e-4%, 14.5%, and 28.4% in intra-African trade, respectively. In addition, Park (2020) studies the effect of transport infrastructure and logistics quality as a comparative advantage for logistics-intensive industries. The study measures export performance in terms of national value added rather than gross values. The results show that countries' ability to provide good transport infrastructure and high-quality logistics is a comparative advantage for logistics-intensive industries.

Similarly, Thia, and Ong Lopez (2023) analyze the effect of infrastructure quality on trade liberalization. They use data from 145 countries over the period 2006-2017. The authors use the gravity model, estimated using a fixed effects model. The results indicate that a one-point improvement in the infrastructure score relative to a trading partner leads to a 0.063 logarithmic point improvement in the bilateral trade balance. In fact, a one-point improvement in the PCA (Principal Component Analysis) score for infrastructure is associated with an improvement in the bilateral trade balance of

approximately $30 million with a threshold of 60% of exports.

Finally, Bahri & Dinar (2022) analyze the effect of transport infrastructure on national competitiveness. They use a multiple regression model and data covering 137 countries over the period 2017-2018. The results show that the overall quality of infrastructure enhances the competitiveness of economies, enabling them to maximize their comparative advantages. Indeed, transport services are a key factor in production, and the availability of high-quality services is essential for the competitiveness of businesses.

This literature, which studies the role of transport infrastructure quality on trade, does not take into account the spillover effects of transport infrastructure quality in a region.

3 Methodology

This methodological approach involves presenting the analysis model, then presenting the various tests and specifications of the model, and finally presenting the selected variables.

3.1 Methodological Framework

To test our hypothesis that the quality of transport infrastructure positively affects regional trade in SSA, we draw on the model developed by (Wilson, 1970, 2010). This model provides a critical and forward-looking review of entropy-based spatial interaction models following their introduction in 1970. Known as the entropy model, it relies on entropy maximization to predict the most likely distribution of flows (goods, population, information, etc.) in a city or region under observable cost constraints. Its initial objective is to model transport flows within a city or region. It assumes a set of origins i, a set of destinations j, and a flow from i to j denoted by T_{ij}. In this model, the number of departures O_i is equal to the number of arrivals D_j, which is generally not the case in reality due to factors such as costs. Finally, it defines a disincentive matrix c_{ij}, which measures the cost of travel between i and j. This model is based on maximizing entropy under the constraints of supply, demand, and travel cost, unlike the gravity model, where flows depend directly on GDP and inversely on distance.

By contextualizing, this model makes it possible to estimate the most likely distribution of trade flows in the region, and the cost of trade can be determined by taking into account the quality of transport infrastructure.

The model equation can be written as follows:

$$T_{ij} = A_i B_j O_i D_j c_{ij}^{-\beta} \quad (1)$$

Where

- T_{ij} *= trade flows of goods and services from country i to country j,*
- O_i *= exportable volume of country i (which may be linked to GDP or trade openness),*
- D_j *= potential demand in country j,*
- c_{ij}*= transportation costs,*
- β *= a cost sensitivity parameter,*
- A_i*et* B_j *= are normalization factors to satisfy margin constraints.*

3.2 Conceptual framework and justification for the use of spatial econometrics

To analyze the effects of transport infrastructure quality on intraregional trade, it is necessary to take spatial effects into account, the absence of which can lead to an underestimation of their impact on trade. Indeed, transport infrastructure quality influences not only a country's trade, but also that of its neighbors. There are three main reasons for this interdependence:

First, the spillover effect occurs when an exporting country must cross several countries (territories) before reaching its final destination, making the infrastructure of other countries crucial. Zongo (2022), transport infrastructure is a prerequisite for foreign direct investment (FDI) and represents a strategic spatial attribute on which choices are made in a given geographical area. Second, there is a spatial dependence between observations, especially economic ones, in different countries. The volume of trade between countries is influenced by trade with their neighbors. Thirdly, transport infrastructure has a spatial dimension due to the existence of cross-border roads. Transport infrastructure is often interconnected between countries, particularly rail infrastructure, which frequently links capital cities.

3.3 The empirical model

To analyze the effect of transport infrastructure quality on intraregional trade in SSA, we use a dynamic model. This model allows us to take into account temporal dependence, i.e., the effect of past trade and spatial relationships over time. The empirical model is based on the work of Sénquiz-Díaz (2021), explicitly integrating the spatial dimension.

$$Flux_{ijt} = \alpha_{it} + \rho \sum_{j=1}^{N} W_j Flux_{t-1} + \theta qlt_{it} + \delta \sum_{j=1}^{N} W_j qlt_{it} + \beta X_{it} + \tau \sum_{j=1}^{N} W_j X_{it} + \varepsilon_{it} \quad (2)$$

$W_j Flux_{t-1}$ denotes the endogenous spatial interaction variable, shifted by one period, representing trade flows. qlt_{it} represents the quality of transport infrastructure. $W_j qlt_{it}$ and $W_j X_{it}$ denote the spatial interactions of the explanatory variables. ρ is the shifted spatial autoregressive coefficient. X_{it} is the vector of control variables in the model. The coefficients δ and τ refer respectively to the spatial interaction effects of transport infrastructure quality and the control variables. The matrix is composed of the following control variables:

Trade flows are the exchange of goods and services between nations, measured in terms of value or volume, and influenced by various factors such as trade policies, transport costs, and comparative advantages (Krugman and Obstfeld, 2009). This variable is used by Clark & al. (2004) and Kouassi (2024) to measure trade.

The quality of transport infrastructure. Two types of indicators will be used to measure this variable. These are: the logistics performance index, which measures the quality of trade and transport infrastructure, and the quality of infrastructure in a disaggregated manner, namely: the quality of road, port, airport, and rail infrastructure. These variables have already been used by (Sénquiz-Díaz, 2021; Takpara & al., 2024). According to the hypothesis of this research, a positive sign is expected.

Inflation is measured by the consumer price index as an annual percentage and used by (Zehri, 2022). We expect a negative sign for this variable.

Corruption control: this variable is used as an approximation to capture the effect of corruption and is used by (Babu & al., 2022; Kere and Zongo, 2023). A negative coefficient is expected for this variable.

Political stability is a composite index of political stability and the absence of violence/terrorism, measured by the probability of political instability and/or politically motivated violence, including terrorism. This variable has been used by (Beke, 2022; Mamba and Ballaki, 2020). This variable is assumed to have a negative effect.

Per capita income describes the level of variation in per capita income in national currency over a given period. It is considered to be close to the per capita growth rate. A positive coefficient is expected for this variable.

The exchange rate is the relative price between two currencies. The variable is already used by (Ben Salah, 2010). We use uncertain quotes against the US dollar. A positive effect of this variable on the dependent variable is expected.

3.4 Data and study sample

3.4.1 Description of variables

This study is based on a panel of twenty (20) SSA countries, covering the period from 2006 to 2019. The choice of countries and period is explained by the availability of data for the selected variables. Trade flow data comes from CEPII (Center for

Prospective Studies and International Information), the logistics performance index comes from the World Bank's World Development Indicators (WDI), and road and port quality data comes from the GlobalEconomy.com database. Control variables such as inflation, per capita income, corruption, political stability, trade openness, and exchange rates also come from the World Bank database.

Data on trade flows of manufactured goods were aggregated from a database designed for the gravity model to facilitate the integration of spatial relationships. In concrete terms, a country's trade flows for a given period are obtained by summing all its trade flows to other SSA countries for that same period. This method makes it possible to obtain the total amount of a country's trade flows to all SSA countries for a given year.

With regard to variables of interest, the World Bank's logistics performance index takes several dimensions into account (infrastructure, customs efficiency, quality of services). The indicator varies on a scale of 1 to 5. However, the quality of road and port infrastructure, as measured by the Global Economic Index, is based on the perceptions of business leaders and local economic actors. The value is measured on a scale of 1 to 7, so each respondent had to give their perception. A value of 1 indicates very poor transport infrastructure quality, while a value of 7 indicates high transport infrastructure quality. Good transport infrastructure quality in a country will tend to result in good logistics performance.

3.4.2 Descriptive statistics of the variables

The table below presents the descriptive statistics of the variables used in this research. Trade flows of manufactured goods are concentrated but show significant differences between countries. As for the different qualities of infrastructure, the averages are moderate and the standard deviations show that they vary from one country to another. Inflation is unstable. The gap between the minimum (-9.55) and the maximum (225.39) shows that some countries experience very high inflation. GDP per capita differs from one country to another, which explains the divergence in wealth. Corruption and political stability are generally negative, which explains poor governance in most countries. The region shows divergence in terms of governance. The exchange rate shows a wide dispersion (minimum value 0.92 and maximum value 9686.89).

***Table 1**: Descriptive statistics of variables*

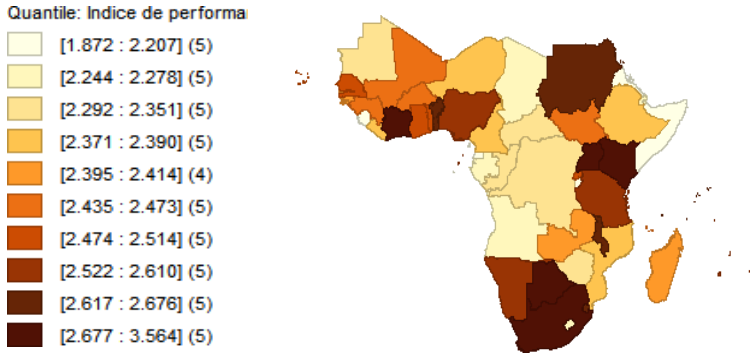
Variable	*Obs*	*Mean*	*Standard*	*Min*	*Max*
ln_Trade_flows	*280*	*12.47*	*2.04*	*6.32*	*16.21*
Logistics performance index	*280*	*2.33*	*0.37*	*1.68*	*3.79*
Road quality	*280*	*3.14*	*0.71*	*1.36*	*5.0*
Port quality	*280*	*3.46*	*0.80*	*1.37*	*5.23*
Inflation	*280*	*8.00*	*18.49*	*-9.56*	*225.40*
lnpib_h	*280*	*11.72*	*2.13*	*5.83*	*14.94*
Corruption	*280*	*-0.72*	*0.42*	*-1.53*	*0.38*
Political Stability	*280*	*-0.67*	*0.75*	*-2.21*	*0.66*
Commercial opening	*280*	*43.60*	*14.83*	*16.73*	*105.50*
Exchange rate	*280*	*961.32*	*2048.69*	*0.92*	*9686.89*

Source: author

3.4.3 Spatial distribution of the logistics performance index

Figure 1 illustrates the distribution of the logistics performance index in SSA, with countries colored according to their performance level. The lowest levels of logistics performance are observed in Somalia, Eritrea, Liberia, and Equatorial Guinea. Countries with average logistics indices include Burkina Faso, Mali, Guinea, and South Sudan. Finally, the best logistics performance is recorded in Côte d'Ivoire, South Africa, Botswana, Kenya, and Uganda. This shows a homogeneity of logistics performance in SSA.

***Figure 1**: Spatial distribution of the logistics performance index*



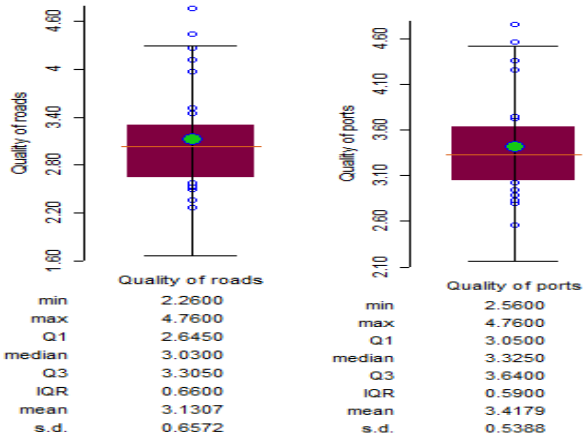
Source: Author based on World Bank WDI data

3.4.4 Descriptive statistics: quality of transport infrastructure

Analysis of Figure 2 shows that the distribution of data varies according to the type of transport infrastructure. Looking at road infrastructure, there are some outliers, mainly at the upper end of the scale. The minimum quality is 2.1 and the maximum is 5.24. The first quartile (Q1) is 2.63, indicating that 25% of countries have a road quality level below 2.63. The third quartile (Q3) is 3.43, which means that 25% of countries have a road quality level above this value. The mean, which is slightly higher than the median, shows that although the distribution is symmetrical.

With regard to the quality of port infrastructure, there are outliers at the upper level. The minimum value is 2.24 and the maximum is 5.21. It should also be noted that 25% of countries have a port quality level below 3.05 and a quality level above 3.64.

***Figure 2**: Box plots of different types of transport infrastructure*



Source: Author based on data from GlobalEconomy

4 Results and discussion of the effect of transport infrastructure quality on intra- regional trade in manufactured goods in SSA

Before analyzing the effect of transport infrastructure quality on trade in SSA, we present the results of the various tests. The tests and estimation results are divided into two main parts, according to the variable taking into account the variable of interest. Model (1) presents the results and tests relating to the logistics performance index. Models (2) and (3) present the results for the quality of road and port infrastructure, respectively. These models are also used for robustness tests.

4.1 Results of spatial model specification tests

After performing the various tests, the results are presented in the following tables: spatial dependence tests and

autocorrelation tests of variables.

4.1.1 Results of the Hausman test

After estimating the Hausman test, presented in Table 3, the Chi2 is significant at the usual thresholds (1%, 5%, and 10%) in all models. We therefore do not reject the hypothesis H_0 . The fixed-effects model is more suitable for estimates than the random-effects model.

***Table 2**: Hausman test result*

Test	*Model (1)*	*Model (2)*	*Model (3)*
chi2(15)	*71.65*	*494.90*	*61.55*
Prob>=chi2	*0.000*	*0.000*	*0.000*
Decision	*Fixed effects model*	*Fixed effects model*	*Fixed effects model*

Source: Author

4.1.2 Spatial dependence test results

The Pesaran test was used to test for spatial dependence in our research. The results are shown in Table 3. The results show that the values are all significant at the 1% threshold. We can therefore reject the hypothesis H_0. There is therefore spatial dependence. A disruption in trade in one country in the region has repercussions on the other member countries.

***Table 3**: Pesaran test*

Test	***Model (1)***	***Model (2)***	***Model (3)***
CD test	*6.66*	*4.35*	*3.07*
p-value	*0.00*	*0.00*	*0.00*

Source: author

4.1.3 Spatial model specification

*Table 4 presents the results of the Moran, Geary, and Getis_Ords global indices after estimation: **Moran's I**: Moran's index, estimated for the logistics performance index, is 0.05. For the robustness tests on the quality of road and port infrastructure, the Moran indices are 0.17 and 0.078, respectively. These results indicate weak positive spatial autocorrelation, significant at the 1% threshold for the whole and for roads at 10%. This shows that the values tend to cluster slightly in space.*

With regard to the nature of spatial dependence, the Morran test shows that in the three models in this study, there is strong spatial dependence in the model errors. The residuals of our different models are therefore not independently distributed, but there is significant spatial correlation. These results confirm the findings of Pesaran's spatial dependence test.

***Table 4**: Presumption test and the nature of spatial autocorrelation*

	Model (1)		*Model (2)*		*Model (3)*	
	Coefficient	*P-value*	*Coefficient*	*P-value*	*Coefficient*	*P-value*
Moran's I	*0.06*	*0.00*	*0.08*	*0.07*	*0.07*	*0.00*
Geary's C	*1.01*	*0.73*	*1.79*	*0.51*	*1*	*0.96*
Getis-Ord's G	*–0.04*	*0.00*	*–0.11*	*0.08*	*–0.04*	*0.00*
Moran MI Error Test	*4.86*	*0.00*	*2.74*	*0.00*	*4.86*	*0.00*

Source: author

4.1.4 Spatial model specification test

To achieve our objective, we specify the model using the Langrage multiplier test developed by (Anselin, 1988; Anselin & al., 1996). After estimating the different types of spatial models, due to the presence of spatial autocorrelation in models (1, 2, 3), the results are presented in Table 5. According to the Akaike criterion, the most appropriate model is the one with the lowest AIC value. Table 7 shows that the SDM model has the lowest AIC value among the models.

Beyond the AIC criterion, econometric literature highlights several advantages of the SDM model. First, the SDM model is more flexible than the SAR and SEM models because it captures both direct and indirect effects and is robust to specification errors (LeSage & Pace, 2009). On the one hand, the SDM model, compared to the SAR model, allows for the integration of exogenous spatial interactions and captures endogenous dependence with the SDEM model (Golgher & Voss, 2016).

***Table 5**: The Langrange test*

Model	***AIC (1)***	***BIC (1)***	***AIC (2)***	***BIC (2)***	***AIC (3)***	***BIC (3)***
SAR	*612.54*	*645.25*	*610.05*	*642.76*	*611.18*	*643.90*
SDM	*610.73*	*668.89*	*607.70*	*665.86*	*605.04*	*663.19*
SEM	*615.04*	*647.76*	*612.27*	*644.98*	*613.38*	*646.09*
SAC	*612.54*	*645.25*	*610.05*	*642.76*	*611.18*	*643.90*
GSPRE	*730.82*	*774.43*	*724.62*	*768.23*	*731.35*	*774.97*

Source: author

After performing these various tests, which are necessary and mandatory for panel data estimates in spatial econometrics, we recommend the estimator from (Belotti & al., 2017). This estimator, in addition to being one of the new estimators in spatial econometrics, provides a rigorous and operational econometric framework for estimating spatial panel data models. Furthermore, it allows for the analysis of short- and long-term effects as well as direct and indirect effects. Next, for the fixed-effect SDM model, the model also allows for dynamic specification by applying the bias-corrected maximum likelihood approach described above. Finally, the estimator allows users to use spatial weighting matrices to calculate direct, indirect, and total marginal effects.

4.2 Results and discussion

After checking all preliminary tests and estimating the model using SDM, in which only the lagged dependent variable is included, the results are divided into three main parts: immediate direct effects, short-term effects (direct, indirect, total), and finally long-term effects (direct, indirect, total).

4.2.1 Immediate effects

Table 6 analyzes the immediate direct effects of the explanatory variables on the explained variable of the country without taking spatial relationships into account. This part should not be interpreted in isolation, as the estimates represent the combination of the direct and indirect influences of the independent variables on the dependent variable. However, the lagged dependent variable, which takes spatial relationships into account, will be interpreted because it no longer appears in the short- and long-term effects. In model (1), a one-unit increase in intraregional trade in period t-1 leads to an average decrease in trade of 6.62% in other countries at the 1% threshold. In the other models, namely 2 and 3, a one-unit increase in intraregional trade in period t-1 leads to an average decrease of 3.195% (significant at 1%) and 2.977% (significant at 10%) respectively in a given country in the region. This can be explained by the similarity of export products in SSA, which leads to negative competition in the region.

In addition, the rho coefficient is significant in all models, which means that there is a positive spatial dependence of the error terms. In other words, there are shared unobserved factors that influence trade flows. These spatial autocorrelations are positive and significant at the 1%, 5%, and 10% thresholds for models 1, 2, and 3, respectively. This means that trade dynamics in one country tend to influence those of its neighbors, which justifies the inadequacy of OLS.

***Table 6**: Immediate effects, and spatial relationship*

VARIABLES	***Model_1***	***Model_2***	***Model_3***
lnL, Trade Flows	*-6.62*	*-3.20****	*-1.10*
	(0.59)	*(0.56)*	*(0.58)*
Wx	*41.96****	*25.22*	*8.38*
	(2.53)	*(1.99)*	*(1.13)*
rho	*1.41****	*0.63*	*0.49*
	(0.26)	*(0.26)*	*(0.26)*
sigma2_e	*2.19****	*2.32****	*2.32*
	(0.17)	*(0.18)*	*(0.18)*

Source: author

4.2.2 Analysis of the effect of the logistics performance index

The following tables present the results of the direct, indirect, and total effects obtained from the various models estimated in our study. More specifically, the direct effects measure the impact of an improvement in the quality of a country's transport infrastructure on its intraregional trade. In other words, this effect reflects the extent to which improving the quality of a country's transport infrastructure stimulates its trade with other member countries in the region.

Indirect effects measure the impact of an improvement in the quality of transport infrastructure in neighboring countries on the intra-regional trade of the country under study. Finally, total effects correspond to the sum of direct and indirect effects. These effects measure the overall impact of an improvement in the quality of transport infrastructure in the region (country under study and neighboring countries) on intra-regional trade.

In Table 7, the results of model (1) show that, in the short term, a one-unit improvement in a country's logistics performance index has no significant effect, either in terms of direct or indirect effects. However, when considering the improvement in the logistics performance index of the country and its neighbors simultaneously, there is an average increase of 19.02% in intraregional trade, which is significant at the 1% level.

In the long term, the results show that an improvement in the logistics performance index has a positive and significant effect on intra-regional trade in SSA, in terms of direct, indirect, and total. More specifically, a one-unit improvement in a country's logistics performance index leads to an average increase of 3.467% in its intra-regional trade at the 1% threshold. The indirect effect, linked to the improvement in the logistics performance of other countries in the region, leads to an average increase of 1.55% in the intra-regional trade of the country in question, which is significant at the 1% threshold. Overall, a one-unit improvement in the logistics performance index in the region leads to an average increase of 5.20% in the intra- regional trade of the country in question at the 1% threshold.

***Table 7**: Analysis of the aggregate variable of interest in the short term*

	Model 1					
VARIABLES	***SR_Direct***	***SR_Indirect***	***SR_Total***	***LR_Direct***	***LR_Indirect***	***LR_Total***
logistics performance unit	*-0.83*	*19.86*	*19.03****	*3.47****	*1.55****	*5.02****
	(-73.60)	*(-73.60)*	*(-2.38)*	*(-0.34)*	*(-0.26)*	*(-0.31)*
Inflation	*0.00*	*-0.00*	*0.00*	*0.00*	*-0.00*	*0.00*
	(-0.02)	*(-0.02)*	*(-0.00)*	*(-0.00)*	*(-0.00)*	*(-0.00)*
Ln_GDP per capita	*0.12*	*-0.08*	*0.04**	*0.08**	*-0.07**	*0.01**
	(-0.49)	*(-0.48)*	*(-0.02)*	*(-0.05)*	*(-0.04)*	*(-0.01)*
Corruption	*2.04*	*-1.29*	*0.75****	*1.57****	*-1.37****	*0.20****
	(-7.18)	*(-7.18)*	*(-0.16)*	*(-0.32)*	*(-0.29)*	*(-0.04)*
Political Stability	*-0.34*	*0.22*	*-0.13**	*-0.26**	*0.23**	*-0.03**
	(-1.24)	*(-1.23)*	*(-0.07)*	*(-0.14)*	*(-0.13)*	*(-0.02)*
Trade openness	*0.02*	*-0.02*	*0.01***	*0.02***	*-0.01***	*0.00***
	(-0.08)	*(-0.08)*	*(-0.00)*	*(-0.01)*	*(-0.01)*	*(-0.00)*
Exchange Rate	*0.00*	*0.00*	*0.00****	*0.00****	*-0.00****	*0.00****
	(-0.00)	*(-0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*

Source: author

4.2.3 Robustness test

To analyze the robustness of our results, we disaggregated the main variable. Thus, the logistics performance index, used in model (1) as an overall indicator of transport infrastructure quality, was subdivided into two components: road infrastructure quality (model 2) and port infrastructure quality (model 3). The performance index is a composite index consisting mainly of six main components, including infrastructure quality (roads, ports, airports, and communication technology).

4.2.3.1 Short-term analysis

Table 8 presents the results for these disaggregated variables (models 2 and 3). Model (2), which examines the effect of road quality, shows that good road infrastructure improves intra- regional trade in SSA. In fact, a one-unit improvement in road quality in a country leads to an average increase of 0.886% in its intra- regional trade, which is significant at the 5% threshold. The indirect effect reveals that an improvement in the quality of road infrastructure in neighboring countries leads to an average increase of 16.294% in the intra-regional trade of the country in question, which is significant at the 1% threshold. The total effect, resulting from a one-unit improvement in the quality of road infrastructure in the region, leads to an average increase of 17.179% in the intra-regional trade of the country in question at the 1% threshold. In model (3), a one-unit improvement in the quality of a country's ports leads to an average increase of 0.885% in its intraregional trade, which is significant at the 1% level. The indirect effect indicates that a one-unit improvement in port quality in neighboring countries leads to an average increase of 5.803% in the intra-regional trade of the country in question, which is significant at the 1% threshold. A simultaneous one-unit improvement in port quality leads to a 6.687% increase in the intra-regional trade of the country in question, which is significant at the 1% threshold.

***Table 8**: Analysis of the disaggregated variable of interest in the short term*

	Model 2			Model 3		
Variables	***SR_Direct***	***SR_Indirect***	***SR_Total***	***SR_Direct***	***SR_Indirect***	***SR_Total***
Transport Quality	*0.89***	*16.29****	*17.18****	*0.89****	*5.80****	*6.69****
	(-0.43)	*(-3.07)*	*(-3.42)*	*(-0.19)*	*(-1.48)*	*(-1.60)*
Inflation	*0.01*	*-0.00*	*0.00*	*0.01*	*-0.00*	*0.01*
	(-0.01)	*(-0.00)*	*(-0.00)*	*(-0.01)*	*(-0.00)*	*(-0.00)*
lnGDP_capita	*0.32****	*-0.12***	*0.20****	*0.30****	*-0.09**	*0.21****
	(-0.06)	*(-0.05)*	*(-0.05)*	*(-0.05)*	*(-0.05)*	*(-0.06)*
Corruption	*3.43****	*-1.31****	*2.11****	*3.97****	*-1.24***	*2.73****
	(-0.36)	*(-0.48)*	*(-0.43)*	*(-0.36)*	*(-0.63)*	*(-0.60)*
Political Stability	*-0.20*	*0.08*	*-0.12*	*-0.62*	*0.19*	*-0.42****
	(-0.17)	*(-0.07)*	*(-0.11)*	*(-0.17)*	*(-0.11)*	*(-0.14)*
Trade openness	*0.03****	*-0.01***	*0.02****	*0.03****	*-0.01**	*0.02****
	(-0.01)	*(-0.01)*	*(-0.01)*	*(-0.01)*	*(-0.01)*	*(-0.01)*
Exchange rate	*0.00****	*-0.00****	*0.00****	*0.00****	*-0.00**	*0.00*
	(0.00)	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*	*(0.00)*

Source: author

4.2.3.2 Analysis of the long-term effect

In model (2), the results indicate that a one-unit improvement in road quality in a country leads to an average increase of 1.726% in its intraregional trade in the long term, significant at the 1% level. Furthermore, a one-unit improvement in road quality in neighboring countries leads to an average increase of 3.912% in the intra-regional trade of the country in question in the long term at the 1% threshold. In total, intra- -regional trade increases by 5.637% in the long term in the country in question following a one-unit improvement in the quality of its roads and those of neighboring countries in the region at the 1% threshold.

Next, in model (3), the results show that a one-unit improvement in port infrastructure quality has no direct or indirect effect on intra-regional trade. However, the simultaneous effect following a one-unit increase in port quality at the regional level leads to an average increase of 3.746% in the intra-regional trade of the country in question at the 1% threshold.

***Table 10**: Analysis of the disaggregated variable of interest in the long term*

	Model (2)			Model (3)		
Variables	***LR_Direct***	***LR_Indirect***	***LR_Total***	***LR_Direct***	***LR_Indirect***	***LR_Total***
Transport Quality	*1.73****	*3.91****	*5.64****	*-24.48*	*28.22*	*3.75****
	(0.22)	*(0.40)*	*(0.53)*	*(516.18)*	*(516.14)*	*(0.61)*
Inflation	*0.01*	*-0.01*	*0.00*	*0.04*	*-0.03*	*0.00*
	(0.01)	*(0.00)*	*(0.00)*	*(0.52)*	*(0.52)*	*(0.00)*
lnGDP_capita	*0.31****	*-0.25****	*0.06****	*2.49*	*-2.38*	*0.12****
	(0.06)	*(0.05)*	*(0.01)*	*(44.47)*	*(44.47)*	*(0.02)*
Corruption	*3.36****	*-2.67****	*0.69****	*35.18*	*-33.65*	*1.53****
	(0.36)	*(0.30)*	*(0.08)*	*(642.58)*	*(642.59)*	*(0.21)*
Political Stability	*-0.19*	*0.15*	*-0.04*	*-5.58*	*5.34*	*-0.24****
	(0.17)	*(0.13)*	*(0.03)*	*(101.75)*	*(101.75)*	*(0.07)*
Trade opening	*0.03****	*-0.03****	*0.01****	*0.26*	*-0.25*	*0.01****
	(0.01)	*(0.01)*	*(0.00)*	*(4.57)*	*(4.57)*	*(0.00)*
Exchange rate	*0.00****	*-0.00****	*0.00****	*0.00*	*-0.00*	*0.00****
	(0.00)	*(0.00)*	*(0.00)*	*(0.05)*	*(0.05)*	*(0.00*

Source: author

4.3 Discussion

The quality of transport infrastructure is one of the determining factors of trade, particularly in developing countries. Several previous studies have examined this issue without taking spatial relationships into account in their analysis. Indeed, the development of transport infrastructure stimulates trade in a country, but also in its neighbors due to spillover effects.

The results show that different types of transport infrastructure quality have a positive effect on intraregional trade in SSA. However, the magnitude of this effect is more pronounced in the short term than in the long term. The logistics performance index measures a country's ability to facilitate trade with a more efficient supply chain. In the short term, only the total effect is significant, while in the long term, all effects are significant. These results suggest that an isolated improvement in a country's logistics performance has no effect on its intraregional trade or on other countries, unless it is part of a coordinated regional dynamic in the short term. In the long term, intensive investment produces positive effects, even if it is carried out in isolation, particularly in a con l context marked by inefficient customs clearance procedures and poor-quality transport infrastructure.

Furthermore, improving road quality contributes positively to intraregional trade in both the short and long term. These results can be explained by the fact that roads are the main mode of transport for goods and services in the region, due to the high number of landlocked countries in SSA. In addition, they are not only the main axis for cross-border trade, but also the main means of connection to seaports and airports.

Finally, improving port infrastructure has a significant short-term impact, both for the countries concerned and for their neighbors. In the long term, this impact remains significant only at the global level, i.e., through total effects. These results can be explained by the context of SSA, where ports are a strategic point for trade, but their impact cannot be sustainable if they are improved in isolation. Indeed, ports are mainly used for extra-regional trade (to other regions of the world), due to exports focused on raw materials. Furthermore, the long-term results can be explained by the lack of complementarity with land infrastructure and also competition from corridors in SSA.

Road transport infrastructure is therefore the main means of transport for intra-regional trade in SSA due to its short- and long-term efficiency. Its improvement, even in isolation, influences trade in the countries concerned as well as in neighboring countries.

In order to better situate the contribution of this research, it should be compared with previous theoretical and empirical work.

On a theoretical level, this research confirms the theoretical foundations put forward in the conceptual theoretical framework (Hummels, 2007; Laussel & Riezman, 2006; Mundell, 1957). These theories stipulate that reducing transport costs stimulates trade between two countries or within a region. However, this research highlights the spillover effects associated with improving the quality of transport infrastructure in a country. It corroborates the spatial relationship theory (Durand, 1998, 2001; Jessop & al., 2008).

On a theoretical and empirical level, our results show similarities, but also differences. They corroborate the results obtained by (Park, 2020; Thia & Ong Lopez, 2023). Their work shows that improvements in the logistics performance index have a positive effect on intraregional trade. However, they diverge from the results of Sénquiz-Díaz (2021), who finds that the logistics performance index has a negative effect on trade.

Considering the disaggregated variables, the quality of road and port transport infrastructure, the results of this research corroborate those of. However, these studies did not take into account the spillover effects associated with improving the

quality of transport infrastructure in a country.

These results highlight the need for supranational policies, supported by international institutions, to promote investment in transport infrastructure. National policies aimed at maintaining and modernizing existing infrastructure should also be encouraged. Our results thus confirm our hypothesis that the quality of transport infrastructure has positive effects on intra-regional trade in manufactured goods in SSA. We can therefore conclude that the quality of transport infrastructure has a positive effect on intra-regional trade in manufactured goods in SSA, taking spillover effects into account.

5 Conclusion

Transport infrastructure is a lever for economic development and trade facilitation, particularly in a context marked by a lack of high-quality transport infrastructure. The SSA region faces many challenges, with trade that is more outward-oriented and based mainly on raw materials and manufactured goods that are not very diversified. However, previous studies have focused on the role of transport infrastructure quality on trade in the region without taking spillover effects into account. This can lead to an underestimation of its contribution to trade and neglect regional cooperation in public policy.

The objective of this research was to analyze the direct and indirect effects of transport infrastructure quality on intraregional trade in SSA. To do this, we used a dynamic spatial model applied to a panel of 20 SSA countries over the period 2006 to 2019. The data used comes from several sources, including the World Bank, Global-economic, and CEPII. To estimate the model, we used spatial econometrics and analyzed the direct, indirect, and total short-term and long-term effects.

The results show that the quality of transport infrastructure has positive effects on int al trade in manufactured goods in SSA. Indeed, an improvement in the quality of transport infrastructure has a direct effect (on the country) as well as an indirect effect (on the region) through spillover effects. However, the effect is more pronounced in the short term than in the long term, and varies according to the type of infrastructure considered. Furthermore, in both the short and long term, the quality of road infrastructure has a greater impact than ports. This is because road transport is the most widely used form of transport for trade, due to the high number of landlocked countries, while ports are mainly used for exports of raw materials to other regions of the world.

In light of the empirical findings highlighted in our paper, two economic policy recommendations can be drawn. Firstly, spatial externalities must be internalised through supranational planning and financing. Indeed, results indicate that a country's infrastructure benefits its neighbours' trade (positive spillover effect). However, if a state finances a road solely from its national budget, it tends to under-invest as it does not capture the benefits generated in its neighbours' economies. It is imperative to transfer the planning and financing of transport infrastructure to regional integration bodies (such as ECOWAS, UEMOA or the AfCFTA on a larger scale) and to rely on multilateral financial institutions (such as AfDB, BOAD, Afreximbank). This justifies the creation of regional funds dedicated to transnational 'development corridors' to pool costs commensurate with regional benefits. Second, it is important to anticipate long-term stagnation of infrastructure through maintenance and the reduction of non-tariff barriers. Indeed, results indicate that the positive effect of road infrastructure quality erodes over the long term. This is a classic phenomenon in our economies, generally reflecting two realities: the rapid physical deterioration of infrastructure due to a lack of maintenance, and the persistence of institutional bottlenecks. This finding indicates that the construction of physical infrastructure is not enough. On the one hand, public decision-makers must set aside autonomous Road Maintenance Funds (RMF) from the project design stage to prevent the depreciation of physical capital. On the other hand, 'hard' infrastructure must be complemented by 'soft' infrastructure: customs harmonisation, co-located checkpoints and the digitisation of customs procedures. A high-quality motorway will

lose its long-term impact on trade if lorries remain stuck for several days at borders due to administrative red tape.

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