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Infrastructure and intra-regional trade in Africa

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Abstract

This study examines the impact of infrastructural development on bilateral trade flows using a panel of 51 African countries from 2003 to 2015. An infrastructure-augmented gravity model was estimated with different indicators of infrastructural development. Three aggregate indicators were computed namely: (i) a soft infrastructure index, (ii) a hard infrastructure measure, and (iii) an effective infrastructure index combining both soft and hard infrastructure components. The soft and hard infrastructure indices were constructed using the principal component analysis. Disaggregated hard infrastructural development indices for transport, information and communication technologies (ICT), and electricity were also used to assess their differential effects on intra-African trade. By adopting the Pseudo Poisson Maximum Likelihood estimator with High Dimension Fixed Effects, the results confirm that both hard and soft infrastructures matter for trade in Africa. A disaggregation of the hard infrastructure index reveals that the electricity composite index has a greater impact on trade flows relative to transport and ICT infrastructures. Importantly, there is evidence that soft infrastructure matters most and complements hard infrastructure in the region. Targeted policies and resources should be channelled towards improving energy infrastructure and soft infrastructure in terms of streamlining trading rules and procedures to better propel and maximise the benefits of intra-African trade.

KEYWORDS
gravity model, infrastructure development, intra-African trade

1 | INTRODUCTION

Regional integration is considered by international trade theory and African policymakers to be beneficial to development (African Union, 2015, 2018; Balassa, 1965; Ingram, 1962). However, progress achieved so far both in terms of the integration of markets and integration of people in Africa are mixed (Kayizzi-Mugerwa et al., 2014; Tavares & Tang, 2011). Africa remains the least integrated continent in the world with a low level of intra-regional trade, as most of Africa's trade flows are with other continents (Edoho, 2011; Njinkeu et al., 2008). This contradicts fundamentally the predictions of gravity models of international trade where the intensity of trade between two countries is supposed to be inversely proportional to their distance and proportional to their economic mass (Anderson & Van Wincoop, 2004; Bergstrand, 1989; Di Stefano et al., 2021; Tinbergen, 1962).

The existing literature has explained the low levels of participation of African countries in regional and global trade via several factors, including economic policies (Rodrik, 1998), conflict and political tensions (Longo & Sekkat, 2004), corruption (Osegbue & Madubueze, 2017), to name a few; but one that stands out is infrastructure (Baita, 2020). Infrastructure plays an important role in market connectivity and trade promotion, while weak infrastructural development retards trade (Pereira & Pereira, 2020; Rehman et al., 2020). According to recent estimates by the African Development Bank (AfDB), the continent has an annual infrastructure deficit of $100 billion and its infrastructure financing needs will be as much as $170 billion annually by 2025 (AfDB, 2018). The poor infrastructure continues to reinforce the pattern where most African countries' trade outward rather than inside the continent. Therefore, regional integration is not a sufficient condition for increasing trade amongst countries as the quantity and quality of infrastructure also matter (Bougheas et al., 1999).

In trade literature, infrastructure is generally approximated by physical infrastructure and especially by transports infrastructure (roads, railways, ports, and airports) because transports play the main role in facilitating trade by providing a means to transport goods, where improvements can help reduce the transport cost of moving goods or services from one location to another, via efficient transport networks, and reduced transaction costs (Jouanjean et al., 2015). So, the existing empirical evidence supports the positive association between physical infrastructure development and regional trade (Donaubauer et al., 2018; Ochieng et al., 2020; Rahman et al., 2021; Raychaudhuri & De, 2016). However, since the beginning of the 2010s, a clear distinction has increasingly been made between “hard” and “soft” infrastructure in the infrastructure-trade nexus (Behar et al., 2011; Brenton et al., 2014; Hoekman & Nicita, 2011; Jouanjean et al., 2015; Ochieng et al., 2020; Portugal-Perez & Wilson, 2012).

“Hard infrastructure” or physical infrastructure includes transportation (roads, railways, ports, and airports), irrigation, energy, information and communication technologies (ICT), and water and sanitation. In contrast, “soft infrastructure” or institutional infrastructure, comprises the quality of domestic regulations, equitable and enforceable competition policy, and legal and judicial procedures amongst others. Trade-related soft infrastructures are customs efficiency and trade facilitation measures (Ismail & Mahyideen, 2015).

The literature in the African context on the infrastructure-trade nexus has rarely distinguished between infrastructure as “hard” and “soft” nor analysed the effects of the disaggregated forms of infrastructure (Ekeocha et al., 2021). To the best of our knowledge, the only studies that have either introduced a disaggregation of physical infrastructure or made a distinction between hard and soft infrastructure are those of Ochieng et al. (2020) and Chuku et al. (2022). However, although Ochieng et al. (2020) estimated an infrastructure augmented gravity equation model and disaggregated infrastructure into transport and ICT infrastructures, their study was limited to 11 East African countries, and they fail to differentiate between soft and hard infrastructure. A more recent study by Chuku et al. (2022) assessed the extent to which infrastructure development has been a catalyst for trade, innovation, and income improvements in Africa, and then used the results to determine the relative importance of different infrastructure sectors for accelerating Africa's integration process. However, they have not adopted a gravity equation model to explain bilateral trade and they have analysed trade facilitation indicators as a trade variable explained by physical infrastructure rather than an explanatory variable (trade input) that can influence trade volumes. Our study addresses all these limitations by modelling both hard infrastructure and soft infrastructure in explaining intra-African trade flows.

Apart from these two studies, the infrastructure-trade-related literature in Africa has mainly focused on various measures of the physical infrastructure to show that insufficient or sub-standard roads, ports, airports, energy systems, and ICTs stand out as major trade barriers and hamper intra-regional trade and to evaluate the impact of trade facilitation measures on trade flows (Akpan, 2014; Amurgo-Pacheco & Pierola, 2008; Bankole et al., 2015; Bouët et al., 2008; Carrère, 2013; Coulibaly & Fontagné, 2006; Iwanow & Kirkpatrick, 2007; Jouanjean et al., 2015; Limão & Venables, 2001; Longo & Sekkat, 2004; Mlambo, 2021; Portugal-Perez & Wilson, 2012).

This paper thus contributes to the existing literature on the linkage between infrastructure and intra-African trade in several ways. First, two aggregate indices, namely the "hard infrastructure index" and "soft infrastructure index", are constructed. The hard infrastructure index is a combination of indicators reflecting transport, electricity, and ICT. The soft infrastructure index is obtained by combining proxies for cost, time, and procedures needed to import/export commodities. Second, the paper analyses the extent to which soft infrastructure amplifies the trade impact of hard infrastructure by enhancing bilateral trade amongst African countries. To that end, an "effective infrastructure development index" is computed by multiplying the hard infrastructure index and the soft infrastructure index. Lastly, the study controls for the multilateral resistance term in explaining intra-African trade using the Pseudo Poisson Maximum Likelihood (PPML) estimator with High Dimension Fixed Effects (HDFE), which allows for multiple sources of heterogeneity and supports multiple fixed effects (Correia et al., 2020).

The remainder of the paper is structured as follows: Section 2 provides an overview of the related literature and sets out the conceptual framework. Section 3 discusses the methodology and presents the data used. The results are discussed in Section 4 whilst Section 5 concludes with relevant policy recommendations.

2 | RELATED LITERATURE

Writings of Limão and Venables (2001), Coulibaly and Fontagné (2006), Buys et al. (2010) and Carrère (2013) show that the development of hard infrastructures has a positive effect on trade within the African continent. For instance, Amadji and Yeat (1995) indicate that the failure to develop and maintain an efficient transport network in the region negatively affects African export performance. Limão and Venables (2001) point out that poor infrastructure account for 40% of transport costs for merchandise exports from countries with a sea port, and 60% of transport costs for landlocked countries. The elasticity of trade flows in relation to the cost of transport is about −3. Further, deterioration of infrastructure from the median country level to the 75th percentile leads to an increase in transport costs equivalent to an additional 3466 km of maritime travel, or 419 km of land travel, and a reduction of 28% of the country's volume of trade. Similarly, Coulibaly and Fontagné (2006) estimate the elasticity of the trade performance of seven West African Economic and Monetary Union (WAEMU) countries to infrastructure endowments. It is shown that trade flows in this region would be 3.2 times higher if 100% of interstate roads were paved. Buys et al. (2010) confirm that the coordinated upgrading and maintaining of road networks in Sub-Saharan Africa would expand intra-African trade by 18% annually over 15 years. Further, Carrère (2013) finds that harmonisation of the infrastructure index amongst trade partners will result in a large increase in exports for both the WAEMU and the Central African Economic and Monetary Community (CEMAC).

Besides transport infrastructure, several studies have examined the impact of telecommunication infrastructures on the structure of African trade (Fink et al., 2002; Yeboah, 1993). Weak communication links between African countries make it expensive for importers and exporters to obtain relevant market information. International variations in telecommunication costs have a significant negative influence on bilateral trade flows. Accordingly, Longo and Sekkat (2004) estimate that a 1% increase in the stock of transport and telecommunications infrastructure in the exporting country boosts exports to other African countries by 3%. Further, Bankole et al. (2015) find that the telecommunication infrastructure (fixed telephony, mobile telephony, and internet use) has a positive impact on intra-African trade. In addition to its direct impact, Bouët et al. (2008) show that transport and communication infrastructure accounts for nearly half of the transport cost penalty borne by intra-sub-Saharan African trade.

Though the importance of physical infrastructure is recognised in Africa, defective regulatory and administrative practices impede the quality of infrastructure and hence hinder trade (Mbekeani, 2010). The evidence indicates the need to address soft infrastructure to maximise the benefits of investments in hard infrastructure, especially in logistics markets (Hoekman & Nicita, 2011). Behar et al. (2011) show that an improvement of one standard deviation in logistics quality will raise Botswana's exports by 27%. Brenton et al. (2014) further support this result by concluding that borders are “thicker” for countries affected by poor logistics across Central and Eastern Africa, hence impeding market integration and trade in the region. Iwanow and Kirkpatrick (2007) underline the specific role of customs procedures (trade facilitation) in improving intra-African trade.

Similarly, Freund and Rocha (2011) study the shipment of a standard 40-foot container from a large sample of African countries. They state that inland transit is the most significant component causing domestic delays (documentation, transit time, port handling, and customs clearance). A reduction in trade costs through trade facilitation will increase the volume of exports, and promote export diversification and economic transformation (Dennis & Shepherd, 2011). Mlambo (2021) also indicates that good port performance positively affects Africa's trade competitiveness. Resourceful and well-connected container ports with consistent shipping services are likely to reduce transport costs, connect supply chains, and increase Africa's trade.

Portugal-Perez and Wilson (2012) show that the marginal effect of infrastructure improvement on exports appears to be decreasing in per capita income, meaning that in least-developed countries infrastructure could be more trade enhancing. They also report that improving the quality of infrastructure in Malawi halfway to the level of that in Mauritius will lead to a rise in exports equivalent to a reduction in tariffs of 10% of its partner countries. A recent study by Ochieng et al. (2020) states that ICT and transport infrastructures and quality institutions positively impact the volumes of total bilateral exports between 11 countries within the East African region.

The literature provides support for both components of infrastructure in lowering the costs of trading to reach full integration of markets and economies (Hoekman & Nicita, 2011; Portugal-Perez & Wilson, 2012; Rehman et al., 2020). Though there is a general consensus on the positive contribution of infrastructure investments in fostering trade, existing evidence on the effects of both soft and hard infrastructures is scant.

3 | CONCEPTUAL FRAMEWORK

To capture the intertwined dimensions of infrastructural development, the conceptual framework builds on Jouanjean et al. (2015) (Figure 1). Hard infrastructures are measured in terms of functional

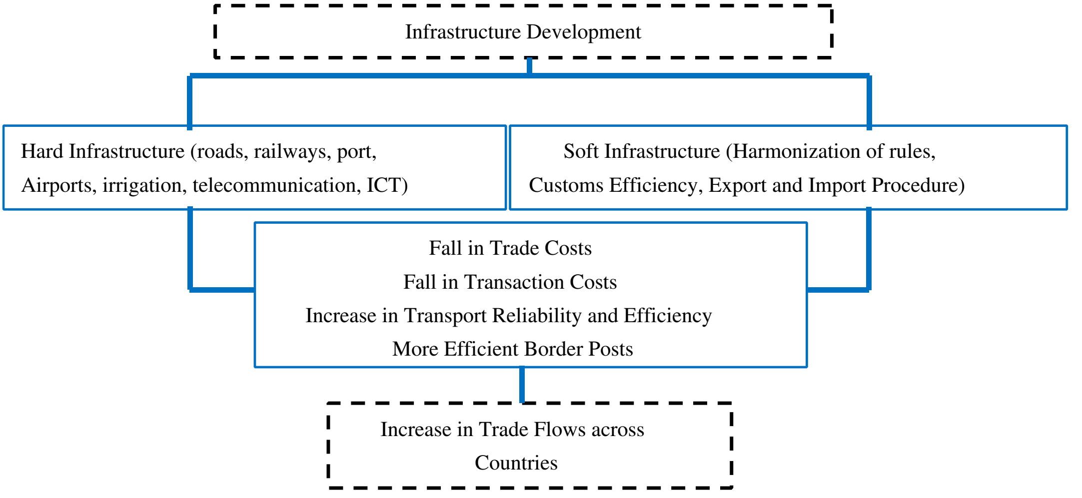

FIGURE 1 Impact of infrastructure on intra-African trade. *Source*: Adapted from Portugal-Perez and Wilson (2008) and Jouanjean et al. (2015)

roads, transport, and telecommunications systems, while soft infrastructures include customs efficiency and trade facilitation measures.

Improving soft infrastructure also involves the harmonisation of standards, elimination of non-tariff barriers, and the simplification of customs procedures. Lengthy cross-border trade procedures are major cost barriers to exports and at the same time slow delivery reduces market competitiveness. Border constraints to trade increase the cost of trading. In addition, investment in efficient, seamless, and cost-effective transport, energy, water, and ICT cross-boundary networks reduces transport costs. The framework thus stresses the importance of complementarities within various aspects of hard and soft infrastructures. The way hard and soft infrastructure components and policies are combined influences transaction costs and trade (Portugal-Perez & Wilson, 2012).

4 | INTRA-AFRICAN TRADE AND INFRASTRUCTURE DEVELOPMENT

Intra-African trade has generally been very low relative to extra-continental trade as there is a high dependence of African economies, on primary exports such as minerals and oil whereby the markets for these products lie outside the continent. Hence, this limits the amount of intra-African trade. In essence, in 2019, intra-African trade stood at 14.4% of total African exports. The export potential of Africa is undermined by a high dependence on primary commodities (mineral fuels and raw products) which represent about 70% of extra-African exports, while manufactured goods account for only 15% (UNCTAD, 2021). The significant dependence on primary commodities exports makes the region highly vulnerable to external shocks. From 2000 to 2019, Africa had the highest level of export dependence on the rest of the world and the lowest share of intra-regional exports. In terms of intra-African services exports, the figure stood at 8.1% of total services trade in 2019 (UNCTAD, 2021). Similar to exports, only 13% of African imports come from other African nations (African Trade Report, 2018). Amongst regional economic communities, it is also noted that intra-regional exports as a share of total exports remain low for the past decades. Across all African regional economic communities, intra-REC exports and imports are < 20% of total exports and imports, except for SADC (20.2% of total exports; UNCTAD, 2021).

TABLE 1 Average value of the Africa infrastructure development index (AIDI) across RECs from 2003 to 2018.

RECs	2003	2005	2010	2015	2018
EAC	10.3	10.6	12.6	16.0	16.5
ECCAS	10.7	11.2	12.4	16.8	17.8
ECOWAS	9.5	10.1	12.8	18.6	19.7
COMESA	17.9	18.6	23.0	30.7	32.1
SADC	19.4	20.3	24.6	31.7	33.0
AMU	25.8	27.0	35.5	54.7	57.4

Source: Authors' Computation from the African Development Bank Group (2019).

However, it has recently been argued that the orthodox narrative of low intra-African trade may be driven by three errors (Mold & Chowdhury, 2021). These are first, the failure to account for the scale of unrecorded trade or informal cross-border trade (Ellis & MacGaffey, 1996). Second, the fact that larger economies whose trade is less dependent on their regional neighbours, tend to drag down the African average of intraregional trade which thus gives a distorted picture of the importance of intra-African trade to the continent. The high dependence on minerals and oil exports to non-African countries of a minority of African nations further provides a misleading narrative around intra-African trade. Lastly, Mold and Chowdhury (2021) argue the need to compare similar countries due to the highly diverging levels of income and economic diversification of countries along with their varied engagement in the different types of economic integration. In particular, landlocked African economies tend to depend significantly more on intraregional trade with higher levels of intra-African trade compared to the continental average.

To assess the infrastructure development in Africa, the Africa Infrastructure Development Index (AIDI) (African Development Bank, 2018) is used. The AIDI is a weighted average of nine indicators covering four infrastructure dimensions: transport' electricity, ICT, and water and sanitation. Though the AIDI aims to evaluate the status and progress of infrastructure development across the continent, it puts more emphasis on the infrastructure stock rather than on infrastructure quality. Further, within the transport dimension, the AIDI focuses principally on the road network, while seaports and airports are also vital features that promote trade.

Infrastructure access and quality relate to economic growth and indirectly via export diversification and trade competitiveness. For countries to achieve their regional trade goals, they need to have adequate services at the national level. The level of access to water, sanitation, and energy as well as good logistics is important for achieving inclusive and sustainable development. Improved water, electricity, and sanitation services can lead to a large increase in productivity, reduce production costs and boost the competitiveness of enterprises. This will thereby unlock the trade potential of businesses across sectors. Better services including transport and ICT will also boost development and encourage trade.

Table 1 shows the AIDI for six Regional Economic Communities (RECs) within Africa, namely the Eastern African Community (EAC), the Economic Community of Central African States (ECCAS), the Economic Community of West African States (ECOWAS), the Southern African Development Community (SADC), the Common Market for Eastern and Southern Africa (COMESA) and the Arab Maghreb Union (AMU). For all six regional groups, the AIDI has improved from 2003 to 2018. AMU, SADC, and COMESA do relatively better where the index for the former has more than doubled. Countries within these groups view infrastructure development as a priority. Though the indices for EAC, ECCAS, and ECOWAS have improved over time, they remain low. An improvement in infrastructure via better physical regional connectivity and infrastructure integration may lower the cost of doing business and enhance competitiveness.

A country-wise comparison of the AIDI in 2018 shows that the top five countries with the highest value of the AIDI index are Seychelles, Egypt, Libya, South Africa, and Mauritius with a score ranging from 94.3 to 76.8. These countries are characterised principally by a robust investment performance across all sectors. Countries at the bottom are Somalia, South Sudan, Niger, Chad, and Congo. Dem. Rep. with AIDI value at the lowest being 3.4 for Somalia to 8.1 for Congo. Dem. Rep.

5 | MODEL SPECIFICATION, METHODOLOGY, AND DATA

5.1 | Model specification and methodology

The gravity equation has been widely used in the empirical trade literature since the pioneering work of Tinbergen (1962). Introducing the concept of multilateral resistance term (Anderson & Van Wincoop, 2003), the gravity model of bilateral trade between importing country i and exporting country j,[1] can be expressed as below:

$$M_{ij} = \frac{E_i}{P_i^{-\varphi}} \frac{Y_j}{\pi_j^{-\varphi}} \theta_{ij}^{-\varphi} \tag{1}$$

where Y_j represents the total output of the origin country, E_i the total expenditure in the destination country, θ_{ij} is a vector of variables that may affect trade costs between any pair of countries, such as distance, common languages, barriers to trade, infrastructure, and customs unions, amongst others. Further, φ is the elasticity of trade flows with respect to trade costs π_j and P_i is the inward and outward multilateral resistance indices (Anderson & Van Wincoop, 2003), which capture the general equilibrium effects in trade. It is the specification of θ_{ij} that allows the introduction of infrastructure in the gravity model. In the basic gravity model, θ_{ij} is approximated by the distance between trade partners. We follow Carrère (2006) by adopting the following formulation of θ_{ij}.

$$\theta_{ij} = \left(Dist_{ij}\right)^{\delta_1} (Area_i)^{\delta_2} \left(Area_j\right)^{\delta_3} \times \left[\exp \left(\begin{array}{c} \delta_4 hinfr_i + \delta_5 hinf\mathrm{r}_j + \delta_6 sinfr_i + \delta_7 sinfr_j \\ \delta_8 Cont + \delta_9 Lock + \delta_{10} Colony + \delta_{11} Lang \\ + \delta_{12} Curr + \delta_{13} REC \end{array} \right) \right] \tag{2}$$

where $hinfr_{i(j)}$ is the hard infrastructure index of the country $i(j)$; $sinfr_{i(j)}$ is the soft infrastructure of the country $i(j)$; $Area_{i(j)}$ is the area of country $i(j)$ in sq. kms; $Dist_{ij}$ is the distance between country i and country j; $Cont = 1$ if i and j share the same border, otherwise 0; $Colony = 1$ for common coloniser; $Lock = 1$ if country i or country j is landlocked, otherwise 0; $Lang = 1$ if country i and country j share the same language, otherwise 0; $Curr = 1$ if country i and country j belong to the CFA Zone, otherwise 0; $REC = 1$ if country i and country j belong to the same regional economic community, otherwise 0.

To introduce the multilateral resistance terms, country fixed effect dummy variables $\alpha_{i(j)}$ are used. To account for the origin of the import flows, five dummy variables are constructed for each of the

[1]The choice to use imports to measure bilateral trade is justified by the fact that generally, and especially in of developing countries which have a weak statistical apparatus, imports are measured with less errors than exports.

following regional trade agreements: ECOWAS, ECCAS, AMU, SADC, and EAC. After applying log to Equation (1), the following equation is estimated:

$$\begin{aligned}\log M_{ij,t} &= \beta_0 + \beta_1 \log Y_{i,t} + \beta_2 logY_{j,t} + \beta_3 logArea_{i,t} + \beta_4 logArea_{j,t} + \beta_5 hinfr_{i,t} \\ &+\beta_6 hinfr_{j,t} + \beta_7 sinfr_{i,t} + \beta_8 sinfr_{j,t} + \beta_9 Cont + \beta_{10} Lock \\ &+\beta_{11} Colony + \beta_{12} Curr + \beta_{13} REC + \beta_{14} Lang \\ &+\alpha_i + \alpha_j + \lambda_t + \varepsilon_{i,t}\end{aligned} \tag{3}$$

The main contribution of the paper to the existing literature is to evaluate the capacity of soft infrastructure in offsetting the weakness associated with lower development of hard infrastructure. The concept of *effective infrastructure* (eff_infr) is thus introduced by multiplying hard infrastructure by some components of soft infrastructure. The effective infrastructure index is constructed as follows:

$$eff\_infr_{i(j)} = hinfr_{i(j)} \times \frac{1}{entry\_cost_{i(j)} \times entry\_proc_{i(j)}} \tag{4}$$

This index is designed in such a way that a country with weak hard infrastructure can have a better effective infrastructure if its soft infrastructure, measured by entry time and entry procedures, is lower. Here, the entry cost is the cost to import/export (US$ per container) and entry time is the time to export/import (days). The second contribution of the study is to assess the impact of the disaggregated forms of hard infrastructure on intra-African trade. To identify the contributions of the various components of hard infrastructure to bilateral trade in Africa, the aggregate hard infrastructure index is replaced by different components, namely transport $\left(Trans_{i(j)}\right)$, electricity $\left(Elec_{i(j)}\right)$, and Information and communication technology $\left(ICT_{i(j)}\right)$.

Lastly, one of the most recognised problems when estimating gravity models is the presence of nonnegative trade flows. To deal with the zero trade flows, the PPML estimator, using a log-linear function instead of log–log one approach is adopted (Silva & Tenreyro, 2006). For robustness check, the Heckman Sample Selection Estimator is also applied (Helpman et al., 2008). Since the work of Anderson and Van Wincoop (2003), a multilateral resistance term has been included in the estimation of gravity models. The multilateral resistance term captures the changes in trade cost on one bilateral route that can affect trade flows on all other routes because of relative price effects. So, exports from country *i* to country *j* depend on trade costs across all possible export markets, and imports into country *i* from country *j* depend on trade costs across all possible suppliers. To deal with these multilateral resistance terms, we use the PPML estimator with HDFE which in turn allows for multiple sources of heterogeneity and multiple fixed effects (Abowd et al., 1999; Correia et al., 2020).

5.2 | Data

Data from different sources are collected to estimate the gravity model. For intra-African trade (bilateral imports) the UN Comtrade data provided by the United Nations Conference on Trade and Development database (UNCTADSTAT) is used (UN Comtrade Data, 2019). Data on distance, the use of the same official language, the same coloniser, areas of countries, landlockness, and contiguity, are from the Centre d'Études Prospectives et d'Informations Internationales (CEPII) database (CEPII, 2019). To avoid a correlation between trade-related soft infrastructure (cost of import/export, time to import/export, and procedures to import/export) and hard infrastructure, we use institutional infrastructure as proxies for trade-related infrastructure. The soft infrastructure variables are (i) entry-cost (cost of business start-up procedures) measured in percentage of GNI per capita; (ii) entry-time (time required to start a business) computed in days; and (iii) entry-procedures (start-up procedures to register a business) denoted in number. These data are also from the CEPII database. Data on GDP and population are from the World Development Indicators database (World Bank, 2020). Data on hard infrastructure are from the AIDI database of the African Development Bank (African Development Bank, 2019). Due to the limited time span of the AIDI data, which is produced since 2003, and due to the high number of missing values on bilateral trade beyond 2015, all variables are collected for the period 2003–2015 for 51 African countries.

6 | FINDINGS

6.1 | Gravity model – Estimation results with aggregate indicators of hard and soft infrastructure

Equation (3) is next estimated using different techniques (columns 1–4 in Table 2). Column (1) applies the OLS while the simple PPML method is shown in column (2) and the PPML-HDFE is in column (3). To ensure the robustness of the results, the country area is replaced by population density in column (4) under the estimation technique of PPML-HDFE.

In all four models, the coefficients of hard infrastructure and soft infrastructure of the exporting country (*j*) are all positive and statistically significant, meaning that African countries import more from countries with high levels of hard and soft infrastructure development. This result confirms that an important prerequisite for countries to remain competitive and export within the continent is the quantity and quality of their infrastructure. Better transport infrastructure reduces transport costs and increased the value of exports (Celbis et al., 2014; Francois & Manchin, 2013). Similarly, the shortage of energy is a huge impediment to international trade, hence investment in the energy sector is crucial for securing a high trade balance (Estache & Garsous, 2012; Ochieng et al., 2020; Rehman et al., 2020). The other component in the hard infrastructure index is ICT whereby ICT infrastructure is likely to enhance efficiency and increase exports and overall trade. Similar results have been observed by Portugal-Perez and Wilson (2012) where both ICT and physical infrastructures as well as border and transport efficiency and sound business and regulatory environment improve the export performance of developing countries. Rahman et al. (2021) also support the positive role of hard infrastructure as well as quality infrastructure on merchandise trade flows between China and 21 Asian economies.

Our results further support that of Ochieng et al. (2020), where both hard infrastructure and the quality of institutions influence positively the volume of bilateral exports in East Africa. In terms of magnitude, the coefficient of soft infrastructure is higher than that of hard infrastructure for the exporting country in the PPML-HDFE regression, whereby a 1% improvement in the soft infrastructure index (entry cost, entry time, and entry procedures) is correlated with a 0.077% rise in trade while a 1% rise in hard infrastructure index is correlated with a 0.054% increase in trade. This is evidence of complementarity between hard and soft infrastructure in enhancing bilateral trade between African countries. Our results contradict Portugal-Perez and Wilson (2012) where hard infrastructures had a higher impact on the export performance of developing countries compared to soft infrastructures measured by border and transport efficiency and business and regulatory environment. In contrast, the level of infrastructure development (hard or soft) of the importing country is not statistically significant.

The results show that African countries import less from ECCAS and ECOWAS with a negative coefficient. This result can be attributed to the weak infrastructural development observed in this community relative to other regions (Table 2). The negative coefficient of ECCAS can also

TABLE 2 Results from gravity model with aggregate hard and soft infrastructure indices.

Dependent variable: Log (imports + 1)	(1) OLS-HDFE	(2) PPML	(3) PPML-HDFE	(4) PPML-HDFE
Log (distance)	−1.765***	−0.388***	−0.452***	−0.451***
	(0.117)	(0.0308)	(0.0300)	(0.0300)
Log (GDP), reporter	0.366***	0.182***	0.0556**	0.0679**
	(0.0894)	(0.0101)	(0.0204)	(0.0210)
Log (GDP), partner	1.183***	0.241***	0.267***	0.273***
	(0.0498)	(0.0110)	(0.0119)	(0.00842)
Log (Area), reporter	0.0214	0.0400***	0.0417*	_
	(0.0721)	(0.01000)	(0.0202)	_
Log (Area), partner	−0.0708	0.0213*	0.00804	_
	(0.0363)	(0.00977)	(0.00994)	_
Hard infrastructure, reporter	−0.0898	0.0328**	−0.0459	−0.0497
	(0.141)	(0.0126)	(0.0346)	(0.0347)
Hard infrastructure, partner	0.298***	0.0594***	0.0543***	0.0518***
	(0.0586)	(0.0130)	(0.0126)	(0.0113)
Soft infrastructure, reporter	−0.0229	0.00444	−0.00263	−0.000522
	(0.0253)	(0.00823)	(0.00613)	(0.00616)
Soft infrastructure, partner	0.309***	0.0278**	0.0770***	0.0779***
	(0.0371)	(0.00853)	(0.00959)	(0.00957)
Common coloniser	0.927***	0.233***	0.230***	0.229***
	(0.154)	(0.0383)	(0.0394)	(0.0393)
Common currency	1.154***	0.149**	0.243***	0.240***
	(0.245)	(0.0524)	(0.0630)	(0.0632)
Landlockness	−1.153***	−0.205***	−0.283***	−0.281***
	(0.117)	(0.0289)	(0.0350)	(0.0342)
Contiguity	1.654***	0.0564	0.0181	0.0161
	(0.262)	(0.0534)	(0.0513)	(0.0514)
Common language	0.489***	0.165***	0.119***	0.120***
	(0.135)	(0.0347)	(0.0355)	(0.0354)
ECCAS	−1.770***	−0.406***	−0.444***	−0.451***
	(0.148)	(0.0453)	(0.0457)	(0.0455)
AMU	−0.224	0.0456	−0.0374	−0.0332
	(0.210)	(0.0415)	(0.0419)	(0.0418)
ECOWAS	−0.128	0.0180	−0.0462	−0.0394
	(0.118)	(0.0338)	(0.0336)	(0.0343)
SADC	0.00594	0.0643*	0.0695**	0.0670*
	(0.100)	(0.0274)	(0.0269)	(0.0269)
EAC	0.386**	0.0910*	0.0863*	0.100*
	(0.134)	(0.0387)	(0.0367)	(0.0400)

TABLE 2 (Continued)

Dependent variable: Log (imports + 1)	(1) OLS-HDFE	(2) PPML	(3) PPML-HDFE	(4) PPML-HDFE
Same REC	0.402**	0.213***	0.118**	0.122***
	(0.152)	(0.0318)	(0.0366)	(0.0369)
Log (population density), reporter	_	_	_	−0.181
	_	_	_	(0.128)
Log (population density), partner	_	_	_	−0.0136
	_	_	_	(0.0118)
Constant	5.040***	0.0772	1.629***	2.294***
	(1.338)	(0.269)	(0.339)	(0.361)
Time fixed effects	Yes	No	Yes	Yes
Reporter fixed effects	Yes	No	Yes	Yes
Partner fixed effects	No	No	No	No
Number of observations	27,398	27,398	27,398	27,398

Note: Standard errors are in parentheses. Model (1) uses OLS; model (2) uses simple PPML; model (3) PPM with HDFE; and model (4) the country area is replaced by population density.

$*p < .05$, $**p < .01$, $***p < .001$.

be explained by the fact that countries of this community are less integrated into the continent. The signs and the level of significance of the other variables are as predicted in the theoretical and empirical literature of gravity models. African countries import more from countries with high GDP.[2]

An increase in GDP of the importing country implies a higher marginal propensity to imports and hence higher import levels and similarly a rise in the GDP of the exporting country suggests a greater capacity to produce domestically and thus more exports. The presence of a common language reduces communication costs and subsequently increases trade. Having the same currency reduces transaction costs and having the same border facilitates trade. Being within the same REC implies a reduction in trade costs and greater availability of goods and services. They trade less with countries that are far away, landlocked countries, and with big areas countries. The longer distance is associated with higher trade costs thus hindering trade. Similarly, landlocked countries and those with large areas face high transport costs and delays and trade less; show the importance of access to sea routes and sea transport in determining a nation's trade (Munim & Schramm, 2018; Rahman et al., 2021).

[2]The choice of the five RECs introduced into the gravity model is justified as follows. ECOWAS, COMESA, ECCAS, EAC are the RECs that are recognised by the African Union in the Treaty establishing the African Economic Community (AEC) which was established in 1991 in Abuja. The African Union recognises eight RECs, namely: (i) Arab Maghreb Union (UMA); (ii) Common Market of Eastern and Southern Africa (COMESA); (iii) Community of Sahel-Saharan States (CEN-SAD); (iv) East African Community (EAC); (v) Economic Community of Central African States (ECCAS); (vi) Economic Community of West African States (ECOWAS); (vii) Intergovernmental Authority on Development (IGAD); and (viii) Southern African Development Community (SADC). Even there is no specific trade agreement between AMU countries, it is clear that they are a specificity in the region, and bilateral trade flows among them are the highest in Africa. Further, the AMU countries have committed to accelerate the setting up of a free-trade area within member countries of the organisation to consolidate trade. The other RECs, such as CEMAC, UEMOA or SACU has not been taken into account because their member countries are at least included in one of the five RECs considered. In addition, CEMAC and UEMOA is indirectly accounted by the adding of a dummy variable that captures the use of a common currency.

6.2 | Gravity model with the effective infrastructure index

To evaluate the potential complementarity link between hard and soft infrastructure, the effective infrastructure development index is computed and the results are as per Table 3.

The findings indicate a much higher value of the coefficients of the effective infrastructure index. For the exporting country, the coefficient of infrastructure is now greater than 1 and statistically significant across all models. The PPML-HDFE results show that a 1% increase in the effective infrastructure index leads to a 3.30% rise in trade for the exporting country while that for the importing country though being positive, is statistically insignificant. With respect to the importing country, the coefficient of the effective infrastructure index is statistically significant only in the PPML regression, where a 1% rise in the combination of both hard and soft infrastructures contributes to a 2.55% increase in trade.

Because the trade impact of effective infrastructure is higher than the one of hard infrastructure, it means that soft infrastructure amplifies the trade effect of hard infrastructure. In terms of policy, the benefits, in terms of trade, of building physical infrastructure can be lower if the country does not improve its regulations and trade-related facilities. There is thus evidence of clear complementarity in the interaction between hard infrastructure and soft infrastructure in boosting the trade potential within the African region. All the other variables are in accordance with the gravity model (Anderson, 2011; Baniya et al., 2020).

6.3 | Regression with disaggregated hard infrastructure

It is important to determine the components of hard infrastructure that contribute most to bilateral trade in Africa. The hard infrastructure of the exporting country has been decomposed into its three principal components: Transport, electricity, and ICT (see Table 4). The results reveal that all the components of the hard infrastructure are important for bilateral trade in Africa. This result is in line with the study of Chuku et al. (2022) which included water and sanitation infrastructure. However, in terms of the level of significance, the results are different. Our results show that amongst hard infrastructure components, electricity is the most important determinant of bilateral trade between African countries, followed by transport and ICT. According to the PPM with HDFE estimation, a 1% increase in the electricity infrastructure index increases African imports of the country by 0.095%. In contrast, a 1% increase in the transport infrastructure index and a 1% rise in the ICT infrastructure boost trade by only 0.039% and 0.032%, respectively.

This result contradicts previous studies like Bouët et al. (2008) and Ochieng et al. (2020). Bouët et al. (2008) showed that poor transport and communication infrastructures are the most important constraint for trade in Africa, while Ochieng et al. (2020) argued that ICT infrastructure has a greater impact on trade flows across East Africa compared to transport infrastructure. Our results contradict Chuku et al. (2022) who found that the ICT composite infrastructure has the strongest impact, followed by transport. This difference in the relative importance of the various infrastructure indicators can be explained by the fact that Chuku et al. (2022) have not accounted for important bilateral trade variables like language, distance, the use of a common currency, the contiguity, and landlockness within a gravity estimation model.

One possible explanation for the relative low impact of ICT on trade flows comes from the possibility of trade diversion. Indeed, the development of ICT infrastructure in a country increases the capacity of firms to connect with other partners around the world, and this can reduce the impact of ICT on intra-African trade. The relative importance of the high impact of electricity on intra-African

TABLE 3 Results of the regression with the effective infrastructure index.

Dependent variable: Log (imports + 1)	(1) OLS	(2) PPML	(3) PPML-HDFE	(4) PPML-HDFE
Log (distance)	−1.700***	−0.381***	−0.438***	−0.439***
	(0.117)	(0.0300)	(0.0297)	(0.0297)
Log (GDP), reporter	0.367***	0.183***	0.0457*	0.0515*
	(0.0889)	(0.00971)	(0.0203)	(0.0204)
Log (GDP), partner	1.231***	0.246***	0.272***	0.269***
	(0.0506)	(0.0111)	(0.0123)	(0.00871)
Log (Area), reporter	0.495***	0.0389***	0.136***	_
	(0.0783)	(0.00963)	(0.0203)	_
Log (Area), partner	−0.158***	0.0110	−0.00289	_
	(0.0327)	(0.00954)	(0.00966)	_
Effective infrastructure, reporter	3.130	2.549***	0.280	0.113
	(2.296)	(0.736)	(0.503)	(0.554)
Effective infrastructure, partner	11.58***	2.592***	3.302***	3.612***
	(2.667)	(0.600)	(0.569)	(0.538)
Common coloniser	0.852***	0.216***	0.212***	0.209***
	(0.158)	(0.0382)	(0.0395)	(0.0394)
Common currency	1.108***	0.154**	0.253***	0.248***
	(0.244)	(0.0514)	(0.0611)	(0.0613)
Landlockness	−0.989***	−0.194***	−0.247***	−0.253***
	(0.116)	(0.0288)	(0.0341)	(0.0334)
Contiguity	1.688***	0.0625	0.0276	0.0218
	(0.266)	(0.0528)	(0.0516)	(0.0516)
Common language	0.548***	0.168***	0.131***	0.136***
	(0.140)	(0.0351)	(0.0361)	(0.0360)
ECCAS	−1.811***	−0.426***	−0.449***	−0.453***
	(0.150)	(0.0452)	(0.0461)	(0.0461)
AMU	0.106	0.0957*	0.0342	0.0372
	(0.213)	(0.0398)	(0.0408)	(0.0411)
ECOWAS	0.0124	0.0205	−0.0145	−0.00703
	(0.116)	(0.0328)	(0.0328)	(0.0336)
SADC	−0.0381	0.0517	0.0481	0.0471
	(0.102)	(0.0274)	(0.0269)	(0.0272)
EAC	0.333*	0.0760*	0.0648	0.0781*
	(0.136)	(0.0386)	(0.0364)	(0.0396)
Same REC	0.506***	0.221***	0.137***	0.140***
	(0.153)	(0.0321)	(0.0364)	(0.0366)

(Continues)

TABLE 3 (Continued)

Dependent variable: Log (imports + 1)	(1) OLS	(2) PPML	(3) PPML-HDFE	(4) PPML-HDFE
Log (population density), reporter	_	_	_	−0.100
	_	_	_	(0.138)
Log (population density), partner	_	_	_	−0.00956
	_	_	_	(0.0122)
Constant	4.286***	−0.000471	1.685***	2.020***
	(1.285)	(0.264)	(0.314)	(0.359)
Time fixed effects	Yes	No	Yes	Yes
Reporter fixed effects	Yes	No	Yes	Yes
Partner fixed effects	No	No	No	No
Observations	27,398	27,398	27,398	27,398

Note: Standard errors in parentheses. Model (1): OLS; model (2): PPML; model (3): PPML with HDFE; and model (4) country area is replaced by population density.

*$p < .05$, **$p < .01$, ***$p < .001$.

trade seems more realistic as the energy deficit appears as one of the major constraints to industrialisation in Africa. Given that in many African countries, raw materials and basic commodities are mainly exported out of Africa without undergoing any processing, industrial products play a crucial role in the intra-African trade. It is thus expected that increasing electricity production in a country increases its capacity to develop its transformation sector, and hence, its ability to export to other African countries.

7 | CONCLUSION AND POLICY IMPLICATIONS

This paper shows the importance of the complementarity between hard and soft infrastructures in promoting bilateral trade across a sample of 51 African countries. The empirical results reveal that the hard infrastructure (transport, electricity, and ICT) of the exporting country has a positive and significant impact on bilateral trade in Africa. These are common and basic measures of the level of economic development that are likely to impact positively on trade. A disaggregation of the different components of hard infrastructure reveals that the energy infrastructure plays a more significant role in boosting intra-African trade compared to transport and ICT infrastructures. Our results call for a “big push” in all components of infrastructure, with a greater focus on investment in electricity, transport, and ICT infrastructure to prevent the marginalisation of the continent on the global market.

There is evidence that improving soft infrastructure is as important as physical infrastructural development. The findings reveal that soft infrastructure seems to matter more than hard infrastructure for Africa, hence policies designed to reduce transaction costs through the removal of intangible barriers of exchange both within and between countries can help in unlocking the trade potential of the continent. However, the full integration of markets and economies can only be reached by considering both components of infrastructure and this is confirmed by the positive and statistically effective infrastructure index. This implies that countries with poor infrastructure and limited investment potential can mitigate their physical infrastructure gaps by significantly improving their soft infrastructure, particularly such aspects pertaining to trade facilitation by simplifying, modernising, and harmonising

TABLE 4 Results of the regression with disaggregated hard infrastructure indices.

Dependant variable: Log (imports + 1)	(1)	(2)	(3)	(4)
Log (distance)	−1.806***	−0.407***	−0.462***	−0.469***
	(0.115)	(0.0311)	(0.0302)	(0.0300)
Log (GDP), reporter	0.318***	0.212***	0.0475*	0.0634**
	(0.0920)	(0.0112)	(0.0210)	(0.0212)
Log (GDP), partner	0.899***	0.204***	0.192***	0.0925***
	(0.0515)	(0.0127)	(0.0134)	(0.0191)
Log (area), reporter	0.0522	0.0198*	0.0455*	–
	(0.0707)	(0.0101)	(0.0198)	–
Log (area), partner	0.114**	0.0397***	0.0492***	–
	(0.0387)	(0.0109)	(0.0112)	–
Log (transport), partner	0.328***	0.0537***	0.0394**	0.0372**
	(0.0665)	(0.0146)	(0.0150)	(0.0141)
Log (electricity), partner	0.337***	0.126***	0.0949***	0.120***
	(0.0398)	(0.0109)	(0.0117)	(0.0124)
Log (ICT), partner	0.0875	−0.0430***	0.0319*	0.0818***
	(0.0570)	(0.00376)	(0.0156)	(0.0151)
Hard infrastructure, reporter	−0.0979	0.0205	−0.0501	−0.0552
	(0.146)	(0.0124)	(0.0350)	(0.0349)
Soft infrastructure, reporter	−0.0297	0.0366***	−0.00486	−0.00334
	(0.0256)	(0.00865)	(0.00616)	(0.00610)
Soft infrastructure, reporter	0.229***	0.0536***	0.0582***	0.0420***
	(0.0351)	(0.00931)	(0.00921)	(0.00892)
Common coloniser	0.801***	0.225***	0.205***	0.203***
	(0.145)	(0.0384)	(0.0386)	(0.0397)
Common currency	1.260***	0.179**	0.250***	0.285***
	(0.249)	(0.0584)	(0.0668)	(0.0653)
Landlockness	−0.882***	−0.145***	−0.191***	−0.166***
	(0.125)	(0.0299)	(0.0381)	(0.0360)
Both countries are conitgus	1.605***	0.0334	−0.00575	0.0101
	(0.253)	(0.0554)	(0.0516)	(0.0516)
Common language	0.625***	0.152***	0.135***	0.130***
	(0.127)	(0.0337)	(0.0344)	(0.0347)
ECCAS	−1.218***	−0.262***	−0.288***	−0.153**
	(0.152)	(0.0467)	(0.0476)	(0.0478)
UMA	0.133	0.144***	0.0605	0.0222
	(0.187)	(0.0365)	(0.0397)	(0.0397)
ECOWAS	0.511***	0.219***	0.168***	0.158***
	(0.130)	(0.0384)	(0.0387)	(0.0383)

(Continues)

TABLE 4 (Continued)

Dependant variable: Log (imports + 1)	(1)	(2)	(3)	(4)
SADC	0.147	0.103***	0.101***	0.142***
	(0.0991)	(0.0274)	(0.0269)	(0.0280)
EAC	1.085***	0.322***	0.295***	0.202***
	(0.141)	(0.0434)	(0.0424)	(0.0413)
REC	0.451**	0.207***	0.133***	0.0976**
	(0.149)	(0.0314)	(0.0361)	(0.0361)
Log (population), reporter	–	–	–	−0.242
	–	–	–	(0.132)
Log (population), partner	–	–	–	0.158***
	–	–	–	(0.0195)
Constant term	4.616***	−0.127	1.858***	2.668***
	(1.388)	(0.265)	(0.344)	(0.526)
Observations	26,893	26,893	26,893	26,893
Time fixed effects	YES	NO	YES	YES
Reporter fixed effects	YES	NO	YES	YES
Partner fixed effects	NO	NO	NO	NO

Note: Standard errors in parentheses. Model (1): OLS; model (2): PPML; model (3): PPML with HDFE; and model (4) country area is replaced by population.

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

their trading rules and procedures. Thus, complementary policies and initiatives become fundamental to address the challenge of poor infrastructure and cumbersome border policies for intra-country and intra-region trade to flourish.

With the implementation of the African Union's Continental Free Trade Area, it is estimated that intra-African trade will almost double by early next decade but the poor state of infrastructure is the bane for Africans doing business within the continent. Hence, the need to harmonise development and economic policies, regulation, market structure, and governance. Any regional initiative will also necessitate huge investments in cross-border infrastructure.

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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