

Olowofeso, Olorunsola E. et al.

Research Report

The multidimensional effects of infrastructural development on intra-regional trade in the WAMZ

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THE MULTIDIMENSIONAL EFFECTS OF INFRASTRUCTURAL DEVELOPMENT ON INTRA-REGIONAL TRADE IN THE WAMZ

DECEMBER 2025



WEST AFRICAN
MONETARY INSTITUTE



INSTITUT MONETAIRE DE
L'AFRIQUE DE L'OUEST

**THE MULTIDIMENSIONAL EFFECTS OF INFRASTRUCTURAL
DEVELOPMENT ON INTRA-REGIONAL TRADE IN THE WAMZ***

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Table of Contents

1.0 Introduction	6
2.0 Stylise Facts on Intra-WAMZ Trade and Infrastructure Development in the WAMZ	9
2.1 Bilateral Trade, Distance and Infrastructure Development in the WAMZ	9
2.2 Trend of Trade Flows and Infrastructure Development in Individual WAMZ Countries	12
3.0 Literature Review	16
3.1 Theoretical Framework	16
3.2 Empirical Literature	17
4.0 Methodology	18
4.1 Model Specification	18
4.2 Estimation Technique	23
4.3 Data	24
5.0 Presentation and Discussion of Results	26
5.1 Descriptive Statistics	26
5.2 Empirical Analysis	28
6.0 Conclusion and Policy Recommendations	31

List of Figures

FIGURE 2. 1: INFRASTRUCTURE INDICES AND INTRA-WAMZ TRADE FLOWS OF THE GAMBIA	12
FIGURE 2. 2: INFRASTRUCTURE AND INTRA-WAMZ TRADE FLOWS IN GHANA	13
FIGURE 2. 3: INFRASTRUCTURE AND INTRA-WAMZ TRADE FLOWS OF GUINEA.....	14
FIGURE 2. 4: INFRASTRUCTURE AND INTRA-WAMZ TRADE FLOWS OF LIBERIA	14
FIGURE 2. 5: INFRASTRUCTURE AND INTRA-WAMZ TRADE FLOWS OF NIGERIA	15
FIGURE 2. 6: INFRASTRUCTURE AND INTRA-WAMZ TRADE FLOWS OF SIERRA LEONE	16

List of Tables

TABLE 2. 1:INFRASTRUCTURE DEVELOPMENT AND BILATERAL TRADE IN THE WAMZ	11
Table 5. 1: Descriptive Statistics	27
TABLE 5. 2: CORRELATION COEFFICIENTS.....	28
TABLE 5. 3: PPML REGRESSION RESULTS: DEPENDENT VARIABLE IS BILATERAL TRADE FLOW.....	29

The Multidimensional Effects of Infrastructural Developments on Intra-Regional Trade in the WAMZ

Abstract

This study examines the impact of infrastructure development on intra-WAMZ trade, with a comparative assessment of the effects of different infrastructure categories on trade flows among member states. A modified gravity model, employing the Poisson pseudo-maximum likelihood (PPML) estimation technique, is utilised to ensure reliable results and achieve the study's objectives. The study covers all six member states of the Zone over the period 2005 to 2023. Findings reveal that while overall infrastructure development exhibits a positive relationship with intra-WAMZ trade, the effect is statistically insignificant. Similar outcomes are observed for energy and information technology infrastructure. Conversely, water and sanitation infrastructure demonstrates a statistically significant positive impact on trade within the Zone, whereas transport infrastructure exerts a negative and significant effect. These outcomes underscore persistent infrastructure gaps and highlight the need to improve infrastructure quality across the region. The significant positive coefficient for water and sanitation infrastructure suggests opportunities to enhance trade flows, particularly through addressing sanitary and phytosanitary (SPS) constraints. Accordingly, the study recommends intensified regional collaboration to overcome structural and policy barriers and improve infrastructure quality. Such efforts should aim to promote economic diversification, strengthen trade complementarities, and foster regional value chains, thereby advancing deeper integration, enhancing trade flows, and supporting sustainable economic growth.

JEL Classification: C55, F14, F15, H54, O55

Key Words: Gravity model, Bilateral trade, Infrastructure Development, Intra-WAMZ Trade, Trade Complementarity.

1.0 Introduction

The West African Monetary Zone (WAMZ) continues to serve as a critical platform for advancing economic integration and enhancing trade among its member states. Despite its potential, intra-regional trade remains limited, largely due to structural challenges and infrastructural deficits. Recent studies underscore that poor transport connectivity, inadequate energy supply, and limited trade finance access are key constraints undermining trade facilitation across the zone (AfDB, 2024; UNECA, 2024). Although efforts to enhance regional trade integration have shown some progress with a marginal increase in trade integration indices, deep-rooted infrastructural gaps continue to raise transaction costs and inhibit competitiveness (WAMI, 2025). The predominance of primary commodity exports further limits value addition and diversification, weakening the region's economic resilience (IMF, 2024). Addressing these constraints through targeted investment in transport corridors, energy infrastructure, and trade finance mechanisms is essential to unlocking the full trade potential of the WAMZ and achieving meaningful economic convergence.

In recent years, regional institutions such as the African Union (AU) have intensified efforts to close Africa's significant infrastructure gap. One of the flagship initiatives in this regard is the Programme for Infrastructure Development in Africa (PIDA), which seeks to accelerate infrastructure development across the continent, focusing on key sectors such as transport, energy, and information and communication technology (ICT). The core objective of PIDA is to promote regional integration and economic transformation by enhancing cross-border connectivity and reducing trade-related transaction costs (AUDA-NEPAD, 2021).

Despite these efforts, the impact of continental infrastructure initiatives on trade within the West African Monetary Zone (WAMZ) remains empirically unclear. Historically, intra-WAMZ trade has remained low relative to its potential, a trend attributed to a combination of factors, including underdeveloped infrastructure, persistent trade barriers, weak institutional frameworks, and heterogeneity in macroeconomic policies among member states (UNECA, 2016; WTO, 2022). Although frameworks like the ECOWAS Trade Liberalisation Scheme (ETLS) were designed to promote free movement of goods and services, trade within the WAMZ continues to be heavily oriented towards non-WAMZ countries (UNECA, 2016; Akpan et al., 2020).

Infrastructure is widely regarded as a critical enabler of trade. Well-developed transport corridors, reliable power supply, and robust ICT networks can significantly reduce logistics costs, improve market

access, and boost competitiveness (AfDB, 2023; Calderón & Servén, 2014). Empirical studies confirm that improved infrastructure facilitates trade by lowering trade costs, increasing productivity, and stimulating private investment (Shepherd & Wilson, 2007; Freund & Rocha, 2020). However, within the WAMZ, infrastructure development has been uneven, with countries exhibiting varying levels of investment, maintenance, and efficiency, which may lead to asymmetric trade outcomes (UNCTAD, 2022).

Moreover, the type of infrastructure matters. For instance, while road and rail infrastructure is vital for the movement of goods, digital connectivity plays an increasingly central role in enabling services trade and cross-border e-commerce (Banga et al., 2021; OECD, 2023). Water and sanitation, although less directly linked to trade, influence overall productivity and investment climate, particularly for agro-industrial trade. Therefore, a granular assessment of different infrastructure types is crucial to understand their distinct effects on trade performance within the WAMZ.

This study empirically investigates the impact of infrastructure development on intra-WAMZ trade, with a strong policy-oriented motivation. Infrastructure is widely recognised as a key enabler of trade and regional integration. Variations in infrastructure quality, particularly in transport, energy, telecommunications, and water and sanitation, can significantly constrain trade efficiency and undermine efforts towards macroeconomic convergence in the WAMZ. By comparing the relative impacts of different infrastructure types on trade flows among member countries, the study highlights critical gaps and provides insights for targeted policy interventions. Linking these findings to domestic macroeconomic and trade policies underscores the importance of coordinated infrastructure investment in achieving regional development goals. Improved infrastructure could enhance competitiveness, reduce trade costs, and support the ECOWAS Monetary Cooperation Programme. This policy relevance aligns with the African Development Bank's (AfDB, 2023) emphasis on infrastructure as a cornerstone for regional transformation and the IMF's (2023) call for structural reforms to boost regional trade integration through improved infrastructure.

To achieve the stated objectives, this study adopts the Gravity Model of international trade, originally introduced by Tinbergen (1962), which has become a widely accepted empirical tool for examining bilateral trade flows. The model posits that trade between two countries is positively related to their economic mass, typically proxied by gross domestic product (GDP), and inversely related to the geographical distance between them. Its theoretical foundation was significantly strengthened by

Anderson and van Wincoop (2003), who incorporated multilateral resistance terms, making the model more consistent with economic theory. Since then, the model has been extended to account for a range of other trade determinants, such as shared language, colonial ties, common borders, and, more recently, infrastructure quality and trade facilitation (Head and Mayer, 2014; Francois and Manchin, 2013).

A key attraction of the Gravity Model lies in its empirical robustness and intuitive appeal. It allows for the integration of structural and policy-related variables, offering nuanced insights into the barriers and enablers of trade. This makes it particularly suitable for analysing regional integration initiatives, such as those in West Africa, where both structural constraints and policy harmonisation efforts coexist.

Despite the model's global application, its use in African regional contexts remains relatively underexplored. Existing studies, such as Deen-Swaray et al. (2011), examined trade in the ECOWAS region but excluded Sierra Leone and Liberia, two key members of the WAMZ, due to data limitations. Similarly, Akpan (2014) assessed ECOWAS trade flows over the period 2008 to 2012, but the study included only 11 out of 15 ECOWAS countries, limiting the generalisability of its findings.

This study seeks to fill these gaps by providing a more comprehensive and up-to-date analysis of trade patterns among WAMZ countries within the broader ECOWAS framework. In particular, the inclusion of previously omitted countries and a longer time horizon will offer richer insights into intra-regional trade dynamics. Furthermore, the study aims to introduce new perspectives by incorporating variables that capture the multi-dimensional effect of infrastructure on intra-WAMZ trade.

This study contributes to the literature by empirically examining the impact of infrastructure development on intra-regional trade flows within the WAMZ, a subject that has received relatively little attention in recent empirical studies on the region. While prior studies such as Gani (2017) and Freund and Rocha (2011) have highlighted the importance of infrastructure in facilitating trade globally and across African regions, this paper builds on and extends these insights by focusing specifically on the WAMZ using a more recent and region-specific dataset. Unlike broader studies that often generalise across Africa, this paper tailors the analysis to the unique institutional, economic, and geographic features of the WAMZ, thereby enhancing the precision and policy relevance of its findings.

A key methodological strength of this paper lies in its extension of the Gravity Model of trade by explicitly incorporating infrastructure indicators such as Transport Composite Index, Energy Composite Index, Water and Sanitation, etc, into the model, capturing their direct and indirect effects on bilateral trade flows within the zone. This approach advances existing models by introducing context-specific

variables that better reflect the structural trade barriers facing WAMZ member states. In doing so, the paper offers robust empirical evidence that infrastructure bottlenecks significantly constrain intra-WAMZ trade, and that targeted investments in transport and energy networks can serve as powerful levers for regional integration.

This study's findings provide actionable policy recommendations by identifying which types of infrastructure investments yield the greatest trade-enhancing effects. These insights are particularly relevant given ongoing efforts by ECOWAS and other regional bodies to deepen economic integration and operationalise the African Continental Free Trade Area (AfCFTA). In this respect, the paper not only contributes to empirical literature but also serves as a timely tool for evidence-based policymaking. By shedding light on the infrastructure–trade nexus in a region where data-driven research is scarce, this study lays the groundwork for future scholarly inquiry and policy design tailored to the WAMZ context.

In addition to the Introduction, the remainder of the paper is structured as follows: Section II presents a review of the relevant literature; Section III outlines the methodology employed; Section IV focuses on the estimation and analysis of results; and Section V concludes the paper with key policy recommendations.

2.0 Stylise Facts on Intra-WAMZ Trade and Infrastructure Development in the WAMZ

2.1 Bilateral Trade, Distance and Infrastructure Development in the WAMZ

This section explores the relationship between bilateral trade, distance and infrastructure development across the WAMZ from 2005 to 2023 by analysing key trade and infrastructure indicators, which are bilateral export and import figures, distances between countries, and national averages of the different infrastructure indices. The indices include the Infrastructure Development Index (IDI), transport composite index (TCI), energy composite index (ECI), information and communication technology index (ICT), and water and sanitation services composite index (WCI).

Infrastructure plays a crucial role in shaping the trade dynamics of WAMZ member countries. Therefore, this analysis assesses how differences in infrastructure development have impacted trade flows and economic integration within the region. Moreover, the analysis considers the effect of geographical distance on trade, highlighting the challenges posed by the spatial distribution of member states.

The trade flows among WAMZ countries show considerable variation in bilateral exports and imports. Ghana and Nigeria emerge as the main trading partners within the region, supported by their larger

economies and better-developed infrastructure. For example, bilateral exports from Ghana to Nigeria amount to \$2,382.5 million, while imports reach \$6,001.7 million. Conversely, trade involving smaller economies such as Liberia or The Gambia displays lower volumes. For instance, The Gambia's bilateral exports to Liberia total \$0.5 million, whereas imports are recorded at \$3.4 million during the study period.

Distance also plays a vital role in shaping trade flows and facilitates trade by lowering transportation costs and logistical challenges. The geographical proximity between Nigeria and its WAMZ partners demonstrates a clear link between closeness and trade intensity. Among these, Ghana records the highest trade volumes with Nigeria, benefiting from both its proximity and shared economic interests. Shorter distances, such as between Guinea and Sierra Leone (186.4 km), enable higher trade volumes, with exports and imports summing up to \$802.2 million and \$222.6 million, respectively during the study period. Additionally, The Gambia's relationship with Guinea is influenced by its relatively closer proximity (555.4 km), allowing some cross-border trade, although this remains underdeveloped. In contrast, longer distances, such as between Nigeria and The Gambia (2,476.1 km), is associated with lower sum of bilateral exports of \$33.2 million and imports of \$33.3 million respectively during the study period. However, geography alone does not fully explain trade dynamics. Other factors—such as economic size, market potential, infrastructure quality, and regional integration—also play critical roles. For example, The Gambia, being a relatively small economy, limits its trade engagement with Nigeria. In contrast, Ghana's larger and more diversified economy, along with stronger infrastructure, enhances its trading relationship with Nigeria.

Table 2.1:

Table 2. 1:Infrastructure Development and Bilateral Trade in the WAMZ

Sum of the Bilateral Trade Between Countries-2005-2023				Country	Average Infrastructure Index 2005-2023				
Country Pair	Distance (KM)	Bilateral Export from Country _i to Country _j (Mn'\$)	Bilateral Import from Country _i to Country _j (Mn'\$)		IDI	TCI	ECI	ICT	WCI
Gambia-Ghana	1,883.7	1.43	12.63	Gambia	25.2	8.3	2.1	9.4	77.7
Gambia-Guinea	555.4	157.89	10.69	Gambia	25.2	8.3	2.1	9.4	77.7
Gambia-Liberia	1,027.3	0.49	3.36	Gambia	25.2	8.3	2.1	9.4	77.7
Gambia-Nigeria	2,476.1	0.37	26.97	Gambia	25.2	8.3	2.1	9.4	77.7
Gambia-Sierra Leone	684.7	3.02	37.42	Gambia	25.2	8.3	2.1	9.4	77.7
Ghana-Gambia	1,883.7	47.38	17.62	Ghana	22.3	10.5	6.8	10.5	72.7
Ghana-Guinea	555.4	171.49	140.06	Ghana	22.3	10.5	6.8	10.5	72.7
Ghana-Liberia	1,065.7	338.18	115.64	Ghana	22.3	10.5	6.8	10.5	72.7
Ghana-Nigeria	659.1	2,382.51	6,001.67	Ghana	22.3	10.5	6.8	10.5	72.7
Ghana-Sierra Leone	1,334.2	351.89	128.20	Ghana	22.3	10.5	6.8	10.5	72.7
Guinea-Gambia	1,883.7	12.05	8.08	Guinea	13.4	5.8	1.8	5.6	54.9
Guinea-Ghana	555.4	3,675.54	328.77	Guinea	13.4	5.8	1.8	5.6	54.9
Guinea-Liberia	392.2	75.24	249.59	Guinea	13.4	5.8	1.8	5.6	54.9
Guinea-Nigeria	2,005.3	131.55	82.31	Guinea	13.4	5.8	1.8	5.6	54.9
Guinea-Sierra Leone	186.4	802.24	222.61	Guinea	13.4	5.8	1.8	5.6	54.9
Liberia-Gambia	1,027.3	1.02	29.64	Liberia	11.4	3.1	0.2	4.6	54.9
Liberia-Ghana	1,065.7	153.42	201.62	Liberia	11.4	3.1	0.2	4.6	54.9
Liberia-Guinea	392.2	4.40	224.94	Liberia	11.4	3.1	0.2	4.6	54.9
Liberia-Nigeria	1,747.3	33.01	156.51	Liberia	11.4	3.1	0.2	4.6	54.9
Liberia-Sierra Leone	332.6	339.62	42.01	Liberia	11.4	3.1	0.2	4.6	54.9
Nigeria-Gambia	2,476.1	33.19	33.28	Nigeria	17.6	5.8	2.6	8.1	57.9
Nigeria-Ghana	659.1	15,972.91	1,643.10	Nigeria	17.6	5.8	2.6	8.1	57.9
Nigeria-Guinea	2,005.3	144.23	375.93	Nigeria	17.6	5.8	2.6	8.1	57.9
Nigeria-Liberia	1,747.3	2,071.41	48.17	Nigeria	17.6	5.8	2.6	8.1	57.9
Nigeria-Sierra Leone	1,995.2	72.67	81.56	Nigeria	17.6	5.8	2.6	8.1	57.9
Sierra Leone-Gambia	684.7	41.35	13.33	Sierra Lec	8.4	4.4	0.5	4.6	45.3
Sierra Leone-Ghana	1,334.2	102.88	242.80	Sierra Lec	8.4	4.4	0.5	4.6	45.3
Sierra Leone-Guinea	186.4	197.81	236.02	Sierra Lec	8.4	4.4	0.5	4.6	45.3
Sierra Leone-Liberia	332.6	45.08	20.75	Sierra Lec	8.4	4.4	0.5	4.6	45.3
Sierra leone-Nigeria	1,995.2	14.41	92.26	Sierra Lec	8.4	4.4	0.5	4.6	45.3

Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

The quality and accessibility of infrastructure vary widely among WAMZ countries, as reflected in the average IDI. Gambia consistently outperformed its peers with an average IDI of 25.2 in the sample period, underpinned by high scores in WSS at 77.7, followed by Ghana scoring 22.3 in the IDI. However, The Gambia is not the leading performer in intra-regional trade, suggesting that while infrastructure is a critical enabler, it is not the sole driver of trade performance in the WAMZ region. Other structural,

institutional, and policy-related factors also play a pivotal role. By contrast, Liberia and Sierra Leone lagged, with Liberia recording the lowest IDI of 11.4 and a TCI of 3.1, which adversely impacts its trade competitiveness. The water and sanitation services composite index (WCI) also highlights disparities, with The Gambia scoring a period average of 77.7 compared to Sierra Leone's 45.3. Such gaps underscore the challenges of facilitating seamless trade across the region.

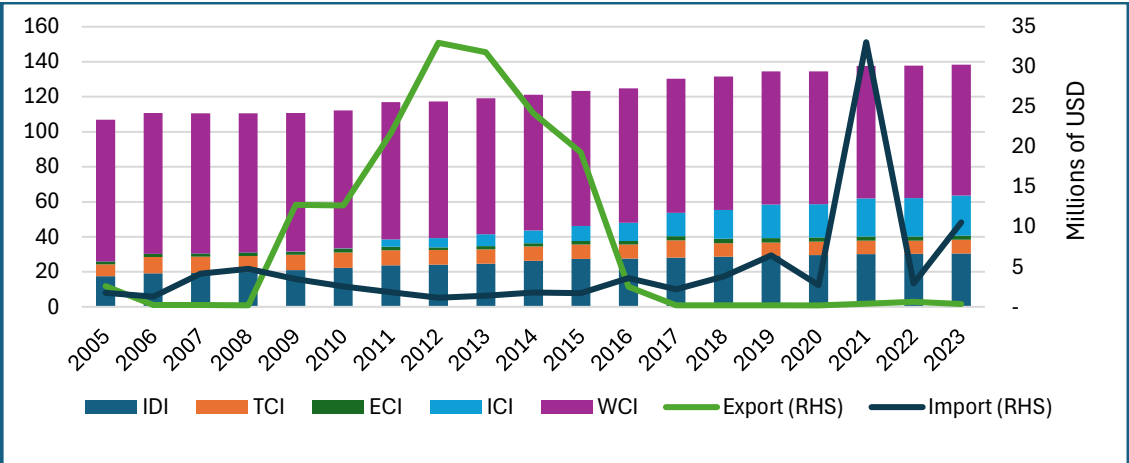
2.2 Trend of Trade Flows and Infrastructure Development in Individual WAMZ Countries

This analysis explores the trends in the Infrastructure Development Index (IDI) and its individual components alongside total exports and imports for the individual countries in the WAMZ.

The Gambia

The Gambia’s Infrastructure Development Index (IDI) has shown modest progress, mainly driven by improvements in WCI and ICI indices. The main driver of the ICI index was the increased mobile and internet connectivity supporting trade logistics. However, transport infrastructure remains underdeveloped, as shown by the TCI index, due to limited road and rail networks, which restrict the efficiency of trade flows. The energy index (ECI) is notably low, with rural areas experiencing significant challenges in electricity access, thereby limiting industrial growth and trade capacity. The WCI index has gradually declined over the study period. Trade flows in The Gambia are characterised by stable yet low intra-regional exports, primarily agricultural goods, while imports are mainly consumer goods. The lack of robust transport and electricity infrastructure considerably hampers the country’s ability to expand intra-regional trade within the WAMZ.

Figure 2. 1: Infrastructure Indices and Intra-WAMZ Trade Flows of the Gambia

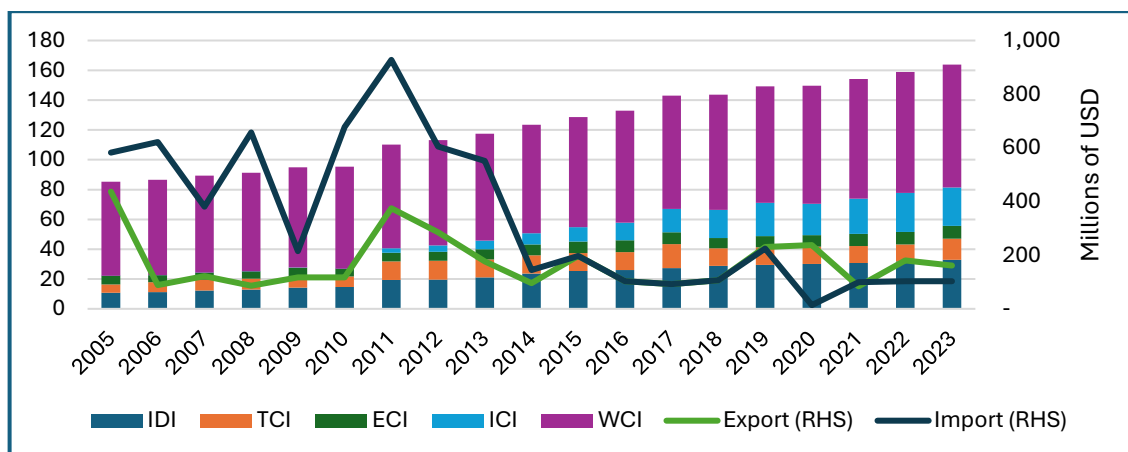


Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

Ghana

Ghana demonstrates a relatively strong IDI, supported by significant progress in the TCI index, which features improved road networks and port facilities, boosting trade efficiency. The Information and Communication Technology Composite Index has also advanced, with investments in broadband and mobile networks aiding trade logistics. The Electricity Composite Index shows progress, although power reliability issues persist, especially in rural areas, limiting industrial export potential. The Water and Sanitation Composite Index has improved in urban areas, yet rural access remains a challenge. Ghana's trade flows are robust, with exports of small, manufactured goods driving intra-regional trade within the WAMZ, complemented by imports of agricultural produce from the region. Infrastructure developments, particularly in transport and ICT, positively correlate with trade growth, although electricity constraints continue to hinder industrial expansion.

Figure 2. 2: Infrastructure and Intra-WAMZ Trade Flows in Ghana



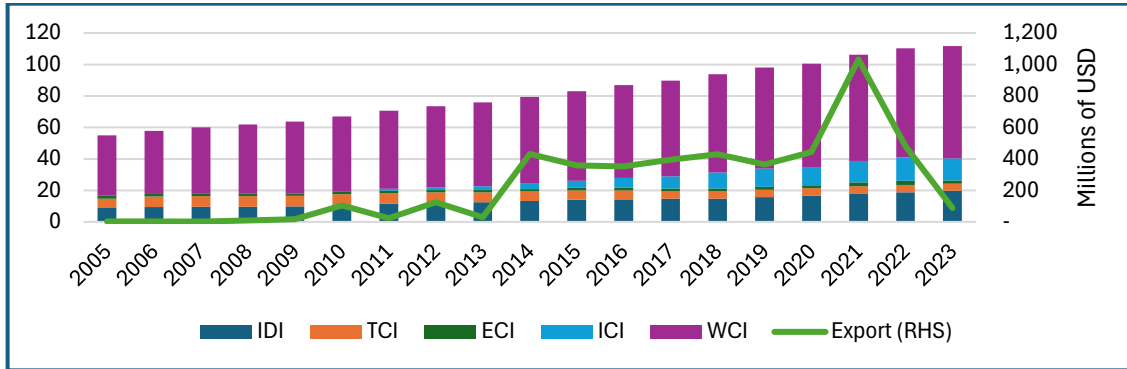
Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

Guinea

Guinea's IDI indicates moderate progress, with the TCI limited by poor road networks, despite some port developments that enhance trade. The ECI remains weak, with low electricity access, especially in rural areas, hindering industrial and trade activities. The ICI has grown, driven by private investments in mobile networks that support trade logistics. The WCI is still underdeveloped, affecting health and productivity. Guinea's trade flows are mainly composed of exports of bauxite and agricultural products, primarily to external markets, with intra-regional trade restricted by limited final products and

infrastructure gaps. Intra-WAMZ imports focus on food and agricultural produce, with trade flows increasing slowly due to logistical challenges caused by inadequate infrastructure.

Figure 2. 3: Infrastructure and Intra-WAMZ Trade Flows of Guinea

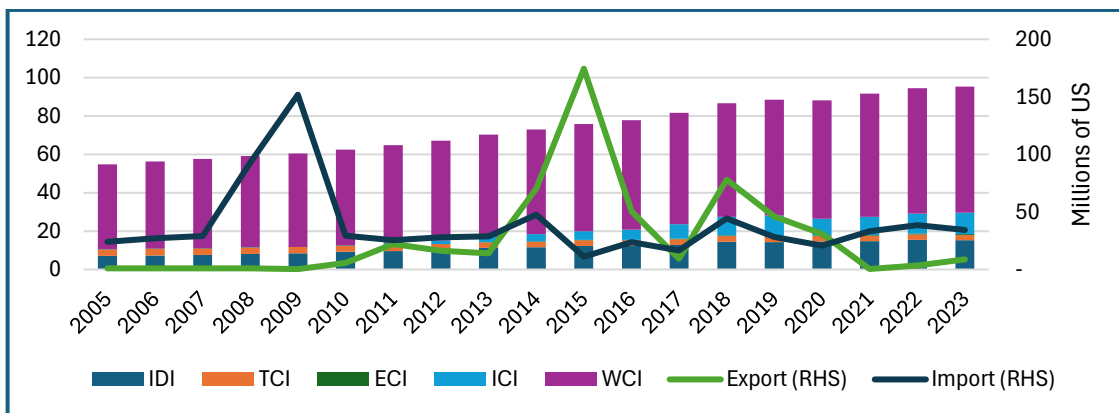


Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

Liberia

Liberia’s IDI ranks among the lowest in the WAMZ, while the TCI is severely limited by poor road conditions and port inefficiencies, which hinder trade efficiency. The Energy infrastructure (ECI) is critically underdeveloped, with rural electricity access below 10%, thereby suppressing industrial growth and trade potential. The ICI index shows some progress through mobile penetration, but broadband access remains limited. The WCI index has experienced minimal improvement, with ongoing sanitation challenges hampering economic productivity. Liberia’s trade flows are weak, with exports such as rubber and iron ore primarily directed to extra-regional markets and imports dominated by food and fuel. Infrastructure deficits markedly constrain Liberia’s intra-regional trade potential within the WAMZ.

Figure 2. 4: Infrastructure and Intra-WAMZ Trade Flows of Liberia

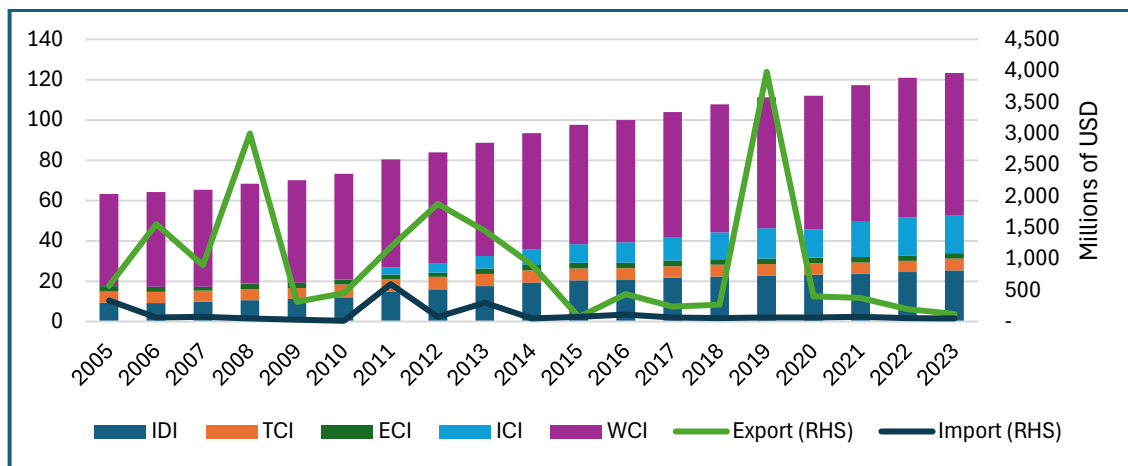


Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

Nigeria

Nigeria exhibits a moderate IDI, with notable investments in transport infrastructure, such as the Lagos-Ibadan railway, which boosts trade logistics. The ECI index faces challenges due to an unreliable power supply, although urban areas have better access compared to rural regions. The ICI index performs strongly, with projects like the Main One Cable System enhancing connectivity and trade efficiency. The Water and Sanitation Index shows uneven progress, with urban areas better served than rural ones. Nigeria dominates WAMZ trade flows, with substantial exports of petroleum and agricultural products and imports of machinery and consumer goods. Infrastructure improvements, especially in transport and ICT, drive intra-regional trade growth, although electricity remains a significant bottleneck.

Figure 2. 5: Infrastructure and Intra-WAMZ Trade Flows of Nigeria

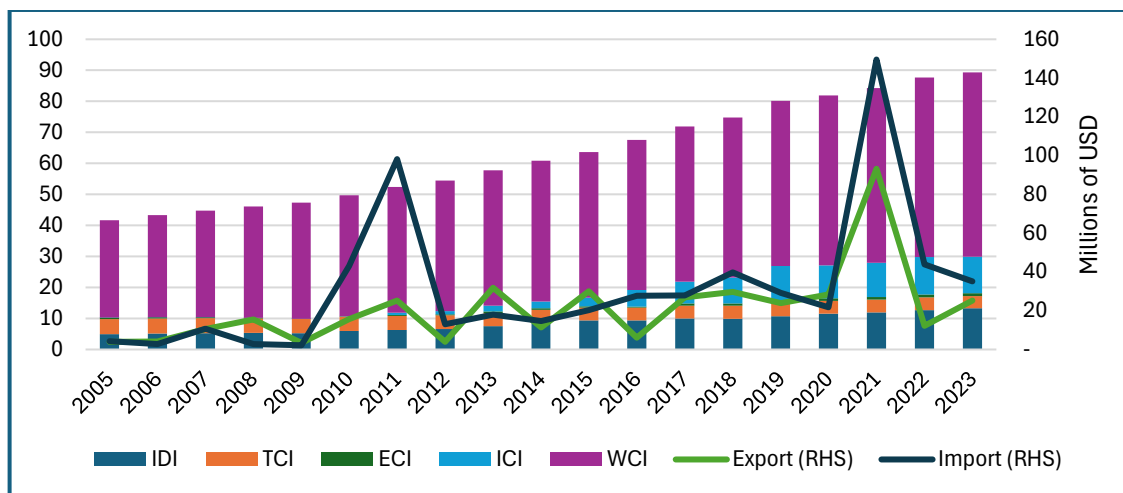


Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

Sierra Leone

Sierra Leone's IDI is low, with the Transport Infrastructure Index hampered by poor road networks and limited port capacity, restricting trade efficiency. The ECI index is critically weak, with rural electricity access below 2%, severely limiting economic activity and trade potential. The ICI index shows modest growth through mobile networks, aiding trade coordination. The WCI index remains underdeveloped, impacting health and productivity. Sierra Leone's trade flows are characterised by exports of diamonds and agricultural products, mainly to extra-regional markets, with intra-regional trade minimal due to infrastructure constraints and the underdeveloped local industries. Imports include food and fuel, with trade flows growing slowly as infrastructure sees marginal improvements.

Figure 2. 6: Infrastructure and Intra-WAMZ Trade Flows of Sierra Leone



Data Source: AfDB Infrastructure Index Database and WAMI/ECOWAS Database

In summary, it is noteworthy that infrastructure development in the WAMZ countries significantly influences intra-regional trade. In recent years, Nigeria and Ghana lead in IDI and trade flows, driven by stronger investments in transport and ICT infrastructure, although gaps in electricity, water, and sanitation remain. The Gambia, Guinea, Liberia, and Sierra Leone face severe infrastructure deficits, particularly in transport and electricity, which limit their trade potential. Improvements in ICT consistently support trade logistics across all countries, while water, sanitation, and electricity infrastructure constraints hinder broader economic growth. Targeted infrastructure investments, especially in transport and electricity, are essential to boosting intra-regional trade in the WAMZ.

3.0 Literature Review

3.1 Theoretical Framework

The theoretical nexus between infrastructure and trade flows is grounded in the Gravity Model of Trade and supported by insights from Neoclassical Trade Theory. The Gravity Model, first introduced by Tinbergen (1962) and later refined by Anderson and van Wincoop (2003), posits that trade flows between countries are positively influenced by their economic size and inversely related to geographical distance and trade frictions. This framework has been instrumental in analysing the role of infrastructure, both hard (e.g., transport, energy, ICT) and soft (e.g., customs procedures, trade regulations) in reducing trade costs and enhancing connectivity. Infrastructure development effectively shrinks the "economic distance" between trading partners, thereby increasing the intensity and volume of trade. Anderson and

van Wincoop's (2003) inclusion of multilateral resistance terms further emphasises how better infrastructure can ease not just bilateral trade but also improve access to broader regional markets.

Complementing this is Neoclassical Trade Theory, which underscores trade complementarity based on comparative advantage and factor endowments. According to this theory, trade flourishes when countries export goods they produce efficiently in exchange for those they cannot produce competitively. Infrastructure enhances this mechanism by reducing transaction and coordination costs, enabling countries with complementary trade profiles to engage more effectively. Moreover, soft infrastructure such as customs efficiency and regulatory transparency amplifies the gains from hard infrastructure investments, as argued by Hoekman and Nicita (2011). Together, these theories illuminate how improved infrastructure facilitates trade integration by both lowering costs and enabling countries to exploit comparative advantages within sub-regional blocs like WAMZ.

3.2 Empirical Literature

Empirical literature underscores the critical role of infrastructure, both hard and soft, in facilitating trade, particularly within regional blocs such as ECOWAS and the broader African context. The Samuelson iceberg cost model conceptualises trade costs as the proportion of goods lost during transit, emphasising how infrastructure upgrades mitigate these losses and improve trade efficiency. This conceptual foundation is extended in the New Economic Geography (NEG) framework, where Krugman (1991) and later Fujita, Krugman, and Venables (1999) highlight how reduced transportation costs due to improved infrastructure promote agglomeration economies and strengthen linkages between producers and consumers, thereby integrating peripheral regions into regional markets. Sandler and Tschirhart (1980) argue that infrastructure often displays public goods characteristics, advocating regional cooperation to maximize spillover effects, a view echoed by Devarajan et al. (2011), who highlight the importance of joint infrastructure initiatives in overcoming fragmented national strategies.

Several empirical studies have focused on the pivotal role infrastructure plays in promoting international trade. The level of infrastructure quality as well as quantity has the propensity to enhance or impede international trade (Celbis et al. 2014). Some of the empirical evidence aligning with these theoretical assertions include Akpan (2014), who adopted an augmented gravity model, finds that upgrading ECOWAS roads to South African standards could boost intra-regional trade by nearly 5%. More recently, Takpara et al. (2024), using GMM and PPML estimators, confirm that airport, seaport, and

road infrastructure positively influence intra-African trade, although rail infrastructure shows a limited impact, and road quality remains a weak link. Wahab (2024) further reveals that ICT infrastructure significantly influences trade flows, particularly imports, underscoring the importance of digital connectivity.

The importance of ITC and energy infrastructure to trade cannot be overemphasised. Mbekeani (2010) highlights the importance of ICT and energy for trade, but crucially adds that their impact is dependent on complementary investments and policy frameworks. Calderón and Servén (2010) provide strong empirical support for a positive impact of infrastructure development on economic outcomes, specifically highlighting its role in enhancing trade and overall economic performance within developing countries. Crucially, their work extends beyond traditional trade-related infrastructure (like transport and energy) to include the significant contribution of water and sanitation infrastructure. Their emphasis on the comprehensive benefits of various infrastructure types, including water and sanitation, offers a theoretical and empirical basis for expecting a positive relationship between such investments and trade. Easterly and Levine (1997) provide a critical caveat, arguing that infrastructure development's positive impact on trade is contingent upon efficient usage and good governance. It implies that simply building infrastructure might not be enough; its effectiveness hinges on how well it is managed and integrated within a supportive policy and institutional environment. Finally, the quality of transport infrastructure matters for it to have a positive impact on trade. Amjadi and Yeats (1995) linked poor transport infrastructure and high logistics costs to reduced trade competitiveness in Sub-Saharan Africa, which aligns with the general expectation that better transport should boost trade.

4.0 Methodology

4.1 Model Specification

We employ the gravity model to investigate the effect of infrastructural development on intra-WAMZ trade, consistent with its extensive use in the literature to analyse bilateral trade flows between or among countries. The gravity model, adopted from Newton's law of gravity, posits that trade volume between two countries is directly proportional to the relative sizes of the exporting and importing countries and inversely proportional to the distances between the two countries. Though the gravity model originally emerged as an empirical tool to analyse trade flows, its theoretical underpinnings were later enhanced by the imperfect competition theory and the intra-industry trade theory by Helpman (1987) and Bergstrand (1989). Dell'Araccia (1998) reinforced the suitability of the model to analyse trade flows

under conditions of imperfect competition.

The basic form of the gravity model is specified in equation (1):

$$Tr_{ijt} = \beta_0 \frac{GDP_{it}^{\beta_1} * GDP_{jt}^{\beta_2}}{Dist_{ij}^{\beta_3}} \quad (1)$$

Where the subscripts i and j are the origin (exporter) and destination (importer) countries, respectively; Tr_{ijt} is the value of total merchandise trade flows from the origin country (exporter) to the destination country (importer) at year t . GDP_{it} and GDP_{jt} are the real GDP of the origin country and the destination country at year t , respectively. $Dist_{ij}$ is the geographical distance between the origin country and the destination country; β_0 is a constant; and β_1 , β_2 , and β_3 are parameters. In the multiplicative form, the gravity model is given as:

The trade literature predicts that bilateral trade between trading countries would increase with increases in the real GDP of both countries and decrease with geographical distance between them.

We transform equation (1) by taking the natural logarithm of both sides of the equation, which yields the basic gravity model linear specification below:

$$\ln (Tr_{ijt}) = \beta_0 + \beta_1 \ln (GDP_{it}) + \beta_2 \ln (GDP_{jt}) + \beta_3 \ln (D_{ij}) + \varepsilon_{ijt} \quad (2)$$

Since D_{ij} is a proxy for transportation costs, the coefficient on D_{ij} is expected to be negative since proximity reduces transportation and information costs (Bayoumi & Eichengreen, 1997).

To achieve the objectives of the paper, the model is augmented to capture the effect of infrastructure development and other variables that influence intra-WAMZ trade, consistent with the empirical literature on the gravity model (e.g. Helpman, 1987; Matyas, 1997; Anderson & van Wincoop, 2003; Carrere, 2006; Trotignon, 2010 Akpan, 2014; and Ali & Berahab, 2018). The other control variables included in the model are bilateral real exchange rates (RER), relative factor endowments (RFE), similarity in real GDP (SIM) between countries, and remoteness (R). In addition, the country-pair fixed effects (γ_{ij}) and time-fixed effects (δ_t) are also included in the model. Thus, the augmented version of the linear gravity model is specified in equation (3):

$$\ln (Tr_{ijt}) = \beta_0 + \beta_1 \ln (INFR_{ijt}) + \beta_2 \ln(GDPT_{ijt}) + \beta_3 \ln(RER_{ijt}) + \beta_4 \ln(RFE_{ijt}) + \beta_5 CMP_{ijt} + \beta_6 RLFAC_{ijt} + \beta_7 SIM_{ijt} + \beta_8 \ln(REM_{ijt}) + \gamma_{ij} + \delta_t + u_{ijt} \quad (3)$$

Where γ_{ij} represents the unobserved, time-invariant characteristics specific to country pairs. These factors, which remain constant over time, are not directly measured but are accounted for in the model to control for their potential impact on the results (Westerlund & Wilhelmsson, 2011).

The time-fixed effects (δ_t) represent factors that change over time and affect all country pairs equally, such as global economic trends or shifts in business cycles. These effects in the model control for time-specific influences consistent across all pairs (Egger, 2000; Egger & Pfaffermayr, 2003). Whilst u_{ijt} is the error term.

The main variable of interest in this paper is $INFR_{ij}$, which is infrastructure development and is proxied by the African Development Bank's (AfDB) infrastructure index. The AfDB Infrastructure Index is a composite measure developed by the AfDB to assess and compare the state of infrastructure development across African countries. The index aims to provide a comprehensive overview of the availability, quality, and efficiency of infrastructure in key sectors such as transportation, energy, water, sanitation, and ICT. The index helps policymakers identify infrastructure gaps, prioritise investments, and track progress over time. Data for the index is collected for each indicator across all African countries. The indicators are normalised to ensure comparability by converting them into standardised scores (e.g., z-scores). This removes the influence of units and makes all indicators dimensionless. Each indicator is assigned a weight reflecting its relative importance. Weighted indicators are aggregated to create sectoral scores (e.g., transport, energy). And sectoral scores are then combined to compute the overall infrastructure index for each country. The Index is structured into individual sectoral indices and a composite index; therefore, we explore the different sectoral indices and the composite index to see which sector affects trade more and how.

RER_{ijt} , represents the bilateral real exchange rate between country i and country j at year t . In line with empirical literature, RER_{ijt} was included in the model to capture how competitiveness has evolved, especially when the data spans over a long period (Carrere, 2006; Trotignon, 2010). An increase in RER_{ijt} implies a real depreciation of the origin (exporter) country's currency against that of the destination (importer) country and is expected to boost export flows (Kien and Hashimoto, 2005; Trotignon, 2010). Therefore, β_3 is expected to be positively related to bilateral trade flows.

Another control variable used is the trade complementarity index, represented as CMP_{ijt} . This index evaluates the degree to which the trade structures of two countries align, specifically whether the exports of country i to the world correspond with the imports of country j from the world (Chandran, 2010; Ali & Berahab, 2018). Based on the work of Chandran (2010) and Qayyum and Nigar (2020), the trade intensity index and export intensity index are used as proxies for trade complementarity between trading countries.

In general, the trade intensity index indicates the level of closeness in trade relations between two partners. It measures how much country j 's share in country i 's total exports compares to country j 's share in world trade (Drysdale, 1969). A higher index value reflects greater trade complementarity between the trading countries (Qayyum & Nigar, 2020). Consistent with existing empirical studies, the trade intensity index TII_{ijt} is calculated as follows:

$$TII_{ijt} = \frac{(X_{ijt}/X_{it})}{X_{wjt}/X_{wt}}$$

Where X_{ijt} is exports of country i to country j at year t ; X_{it} represents the total exports of country i at year t ; X_{wjt} denotes the world's exports to country j at year t and X_{wt} represent total world exports at year t .

The Export Intensity Index (EII_{ijt}) is computed as follows:

$$EII_{ijt} = \frac{(X_{ijt}/X_{it})}{M_{jt}/(M_{wt} - M_{it})}$$

Where M_{jt} represent the total imports of country j at year t ; M_{wt} denote total world imports at year t ; and M_{it} is total imports of country i at year t . According to recent literature, there is a positive relationship between the trade complementarity index and bilateral trade flows between trading countries (Ali & Berahab, 2018). We follow the works of Kojima (1964) and Drysdale (1969) to construct these indices because they are widely used in the literature.

Similarly, $GDPT_{ijt} = (GDP_{it} + GDP_{jt})$ represents the combined economic size of the two countries, with larger overall economic size expected to result in higher bilateral trade flows (Egger, 2000). Likewise, the similarity in real GDP levels between the two countries (SIM_{ijt}) is also expected to have a positive

relationship with bilateral trade flows, as it reflects the relative economic size of the trading partners (Egger, 2000; Wang, Wei, and Liu, 2010). This variable is calculated using the following formula:

$$SIM_{ijt} = \ln \left[1 - \left(\frac{GDP_{it}}{GDP_{it} + GDP_{jt}} \right)^2 - \left(\frac{GDP_{jt}}{GDP_{it} + GDP_{jt}} \right)^2 \right]$$

The similarity index SIM_{ijt} ranges from 0, indicating complete divergence in economic size between two countries, to 0.5, signifying equal economic size. According to the literature, a higher value of this index suggests greater similarity in the economic sizes of trading partners, which is associated with a larger share of intra-industry trade (Helpman, 1987; Egger, 2000; Wang, Wei, and Liu, 2010).

The variable $RLFAC_{ijt} = \left| \ln \left(\frac{K_{jt}}{N_{jt}} \right) - \ln \left(\frac{K_{it}}{N_{it}} \right) \right|$ represents the difference in relative factor endowments between the two countries, where K_{it} and K_{jt} are the capital stocks of countries i and j in year t , while N_{jt} and N_{it} are their respective labour forces. Economic theory suggests that greater disparities in factor endowments between countries lead to higher volumes of inter-industry trade and, consequently, increased overall trade, while reducing the share of intra-industry trade (Egger, 2000; Wang et al., 2010). Therefor $RLFAC_{ijt}$ is expected to have a positive relationship with bilateral trade flows.

In cases where data on capital-labour ratios is unavailable, many empirical studies (e.g., Trotignon, 2010) use per capita income as a proxy for these ratios. Accordingly, the $RLFAC_{ijt}$ variable can also be computed as follows:

$$RLFAC_{ijt} = \ln \left| \frac{GDP_{it}}{POP_{it}} - \frac{GDP_{jt}}{POP_{jt}} \right|$$

Here, GDP_{it} and GDP_{jt} represent the real GDP of country i and j in year t , respectively, while POP_{it} and POP_{jt} denote the populations of the two trading countries.

Some researchers argue that the gravity model should include a variable that account for multilateral trade resistance (REM_{ijt}) which reflects the relative distance to other trading partners in addition to the geographical distance between the two countries (e.g. Trotignon, 2010, Anderson & van Wincoop, 2003). This variable measures the relative attractiveness of trade origin and destination pairs and is included in

the model to address omitted variable bias. Accordingly, REM_{ijt} is calculated based on the relative distances of country i to all its bilateral trading partners:

$$REM_{ijt} = \sum_j \left(D_{ij} * \frac{GDP_{jt}}{GDPW_{it}} \right)$$

Where $GDPW_{it}$ represents the total global GDP in year t . According to the literature, REM_{ijt} variable is expected to have a positive relationship with bilateral trade flows. This suggests that trade is more likely to occur between countries that are geographically distant from the world's major economic centres compared to those that are closer (Trotignon, 2010).

4.2 Estimation Technique

A criticism against the use of the Ordinary Least Squares (OLS) estimator to estimate the gravity model, such as equation (3), is that log-transforming the dependent variable can result in biased and inconsistent parameter estimates when there is heterogeneity in trade levels (Silva & Tenreyro, 2006; Shepherd, 2012; Krisztin & Fisher, 2015; Baltagi, Egger & Erhardt, 2017; Mnasri & Nechi, 2021). This occurs because of heteroscedasticity in the disturbances u_{ijt} . The multiplicative gravity equation can create a correlation between the error terms and the explanatory variables, leading to estimation problems.

Another econometric issue involves how zero trade flows are handled in the estimation process. In practice, applying a log transformation excludes observations where trade values are zero, which results in the loss of valuable information and can introduce sample selection bias. To address these challenges, an effective solution is to estimate the multiplicative gravity model directly without log-transforming the dependent variable.

Silva and Tenreyro (2006) introduced the PPML estimator as a reliable approach for producing consistent parameter estimates in gravity models of trade. Unlike OLS, PPML works with the trade flow variable in its original levels rather than its logarithm, allowing for the inclusion of zero trade values and mitigating the effects of heteroscedasticity. Additionally, Silva and Tenreyro (2011) demonstrated that PPML performs well even in cases of overdispersion in the trade flow variable or when there are numerous zero trade values.

Another advantage of the PPML approach is its ability to incorporate fixed effects, as highlighted by Shepherd (2012). Including fixed effects enables the model to control for unobserved factors specific to country pairs and time periods, thereby accounting for time-varying and pair-specific heterogeneity.

Given the above, this study adopts the PPML estimator to empirically analyse the effect of infrastructure development on intra-WAMZ trade. Consistent with the empirical literature (Silva & Tenreyro, 2006; Westerlund & Wilhelmsson, 2011; Krisztin & Fisher, 2015; Tandrayen-Ragoobur et al., 2023), the multiplicative gravity model is directly estimated as an exponential regression function, with the fixed-effects conditional mean. Thus, equation (3) is re-specified in the exponential form as follows:

$$\mu_{ijt} = E[Tr_{ijt}/z_k] = \exp(\gamma_{ij} + \delta_t + \beta_0 + \beta_1 \ln(INFR_{ijt}) + \beta_2 \ln(GDPT_{ijt}) + \beta_3 \ln(RER_{ijt}) + \beta_4 CMP_{ijt} + \beta_5 RLFAC_{ijt} + \beta_6 SIM_{ijt} + \beta_7 \ln(REM_{ijt})) \quad (4)$$

Equation (4) represents the conditional expectation of Tr_{ijt} given the explanatory variables, where z_k denotes the vector of these covariates. Also, the short form of equation (4) can be written as follows:

$$\mu_k = E[\lambda_k/z_k] = \exp(z_k \beta) \quad k = 1, \dots, N \quad (5)$$

λ_k represents the k th element of the N -by-1 vector of trade flows between country pairs; and μ_k , the conditional mean, depends on the explanatory variables z_k and is associated with β , the parameter vector.

When the PPML estimator is used, specifying the model as in equation (4) simplifies the interpretation of the gravity model parameters. Thus, the coefficients of the explanatory variables in their logarithmic form can be directly interpreted as elasticities, while the coefficients of the explanatory variables in levels can be interpreted as semi-elasticities of trade with respect to these covariates (Shepherd, 2012; Tandrayen-Ragoobur et al., 2023).

4.3 Data

This study used panel data from all six WAMZ member countries. Due to limited trade data availability in the region, we utilised data spanning the period 2005 to 2023. The dependent variable, bilateral trade flows between countries (Tr_{ijt}), was sourced from the WAMI trade database and the ECOWAS Commission. These data were collected from individual country authorities during the semi-annual multilateral surveillance missions.

We measure the bilateral trade flows between countries as the annual nominal USD value of bilateral merchandise exports from the country of origin (country i) to the destination country (country j) at time t . However, we used bilateral total trade flows as an alternative measure of trade flows between countries to evaluate the robustness of the results.

Data on the main variable of interest, infrastructure development, was sourced from the AfDB AIDI database. The AIDI provides a single score representing a country's overall infrastructure development across all key sectors, enabling cross-country comparisons and tracking progress over time. The composite index is calculated by weighting and aggregating the scores from the individual sectoral indices, ensuring that each sector's contribution reflects its importance to infrastructure development. The Index is structured into individual sectoral indices and a composite index. The individual indices include: the Transport Infrastructure Index (TCI), which evaluates the state of roads, railways, ports, and airports and the indicators include road density, the percentage of paved roads, port throughput, and air traffic volume; the Energy Infrastructure Index (ECI), which assesses electricity generation, access to electricity, and energy efficiency; Water and Sanitation Infrastructure Index (WCI) which measures access to clean water and sanitation services; ICT Infrastructure Index (TCI) which examines the availability and quality of information and communication technology services and the indicators include mobile phone penetration, internet users per capita, and broadband access; and the Infrastructure Development Index (IDI), which is the composite index that aggregates the individual indices to provide an overall measure of infrastructure development for each country.

Consistent with the empirical literature, we compute the bilateral nominal exchange rate between the origin country and the destination country as the annual average of the nominal value of country j 's currency per US dollar divided by the annual average of the nominal value of country i 's currency per US dollar (Matyas et al., 2004; Kien & Hishimoto, 2005; Trotignon, 2010). Therefore, the bilateral real exchange rate ($REER_{ijt}$) between countries i and j at time t was computed using this formula:

$$REER_{ijt} = \frac{NER_{jt/\$}}{NER_{it/\$}} * \frac{CPI_{it}}{CPI_{jt}}$$

Where CPI_{it} and CPI_{jt} are the consumer price indices of countries i and j , respectively. This variable captures movements in the nominal exchange rates between the origin and destination countries and their relative prices. The nominal exchange rates and consumer price index data were sourced from the World Bank's World Development Index (WDI) database.

We used two indicators as a proxy for trade complementarity, namely the Trade Intensity Index (TII_{ijt}) and Trade (Export) Integration Index (EII_{ijt}) as defined in section 4.1 (Model Specification section). The data on total exports, total imports, bilateral exports, and bilateral imports were sourced from the WAMI in-house database and the ECOWAS Commission. The trade complementarity variable is used to evaluate the effect of trade complementarity on bilateral trade flows.

Data on real GDP and real GDP per capita for exporting and importing countries, including world imports and exports, were sourced from World Bank's WDI database. The bilateral distance (D_{ij}) between country pairs is the geographical distance between the major cities of the country pairs and is weighted by the share of the population of each city to the total population of each country.

5.0 Presentation and Discussion of Results

This section presents the analysis of the relationships between key variables of interest, including the infrastructure development index, transport composite index, energy composite index, ICT index, water and sanitation index, bilateral real exchange rate, trade complementarity, and bilateral trade flows among WAMZ countries. It further examines the estimation results to empirically assess the impact of overall infrastructure development, its components, the bilateral real exchange rate, and the existing trade complementarity on bilateral trade flows within WAMZ member states.

5.1 Descriptive Statistics

Table 2 presents the descriptive statistics for the variables used in the study, offering a snapshot of their central tendencies, dispersion, and ranges across the 570 observations. The Infrastructure Development Index (IDI) and its components show varying average levels and spreads. The Water & Sanitation Composite Index has the highest mean (4.08) and lowest standard deviation (0.23), suggesting relatively consistent levels across observations. In contrast, the ITC Composite Index has a negative mean (-0.23) and the largest standard deviation (3.63), indicating significant variability and potentially some negative values in its construction. Bilateral Trade averages \$ 48 million but exhibits a very high standard deviation (\$ 235 million) and a wide range (from \$ 0 to \$3,970 million), highlighting the substantial heterogeneity in trade volumes among WAMZ country pairs. Similarly, Bilateral RER, Trade Intensity Index, and Export Integration Index also have large standard deviations relative to their means, pointing to considerable variation in exchange rates and trade integration levels. Economic Size averages 167 billion with a standard deviation of 207 billion, reflecting the diverse economic scales within the WAMZ.

Remoteness and Relative Factor Endowment show moderate variability, while the Similarity Index has a negative mean (-2.16) and a standard deviation of 1.36, indicating that, on average, economies are somewhat dissimilar, with a range from -5.21 to -0.71.

Table 5. 1: Descriptive Statistics

Variable	Obs.	Mean	Std. dev.	Min	Max
Infrastructure Development Index	570	2.683	0.488	1.590	3.483
Transport Composite Index	570	1.753	0.415	1.055	2.779
Energy Composite Index	570	0.229	1.324	-3.400	2.165
ITC Composite Index	570	-0.231	3.633	-9.413	3.362
Water & Sanitation Composite Index	570	4.078	0.233	3.447	4.408
Bilateral Trade (in millions)	570	48.000	235.000	0.000	3970.000
Bilateral RER	570	165.176	650.410	0.000	5806.208
Trade Intensity Index	570	101.058	609.306	0.000	11866.810
Export Integration Index	570	98.465	594.424	0.000	11582.650
Economic Size (in billions)	570	167.000	207.000	2.880	621.000
Remoteness	570	9.549	5.334	0.707	17.675
Relative factor endowment	570	1.040	0.688	0.006	2.448
Similarity index	570	-2.155	1.360	-5.206	-0.712

This table presents the descriptive statistics for all variables utilised in the regression analysis, encompassing a total of 570 observations for each variable. Where "Obs" refers to the number of observations, "Mean" is the average value, "Std. dev." denotes the standard deviation, "Min" represents the minimum value, and "Max" indicates the maximum value. All monetary figures, such as Bilateral Trade and Economic Size, are expressed in millions or billions as specified in their respective rows.

Table 3 displays the correlations between key variables of interest among WAMZ countries for the period 2005–2023. Except for water and sanitation infrastructure, the results indicate a positive relationship between infrastructure development (including its components) and bilateral trade among WAMZ countries. However, contrary to the expected positive association between the bilateral real exchange rate and trade flows, the correlation coefficient suggests a potential negative relationship. It is important to emphasise that correlation coefficients alone do not provide definitive evidence of significant relationships between variables. Therefore, a valuable extension of this analysis involves empirically exploring these relationships using the proposed PPML estimation technique, as previously outlined.

Table 5. 2: Correlation Coefficients

		1	2	3	4	5	6	7	8
1	Bilateral Trade	1.00							
2	Infrastructure Development Index	0.03	1.00						
3	Transport Composite Index	0.01	0.62*	1.00					
4	Energy Composite Index	0.11*	0.68*	0.82*	1.00				
5	ITC Composite Index	0.03	0.68*	0.12*	0.28*	1.00			
6	Water & Sanitation Composite Index	-0.01	0.93*	0.55*	0.60*	0.59*	1.00		
7	Bilateral RER	-0.17*	0.03	0.18*	0.04	0.00	0.11*	1.00	
8	Trade Integration Index	0.02	-0.01	-0.10*	-0.11*	0.04	0.00	-0.01	1.00

This table presents the correlation matrix, illustrating the pairwise linear relationships between the key variables included in the analysis. A total of 570 observations were used for all pairwise correlation calculations. An asterisk next to a correlation coefficient signifies that the correlation is statistically significant at the 5% level.

5.2 Empirical Analysis

Using the Poisson Pseudo-Maximum-Likelihood (PPML) estimation technique, we estimated the augmented gravity model as specified in equation (4). The estimation incorporated different components of the infrastructure development index as the main variable of interest, alongside the bilateral exchange rate and the standard gravity model control variables. The estimation results are presented in Table 4. Column (1) shows the estimation results when the aggregate infrastructure development index is used as the proxy for infrastructure development. Columns 2,3,4, and 5 represent Transport Composite Index, Energy Composite Index, ITC composite Index, and Water & Sanitation Composite Index, respectively, as proxies for infrastructure development. This approach allows us to analyse the relationship between different components of the infrastructure development index and bilateral trade flows in the WAMZ.

Table 5. 3: PPML Regression Results: Dependent Variable is Bilateral Trade Flow

VARIABLES	MODEL 1	MODEL 2	MODEL 3	MODEL 4	MODEL 5
Infrastructure Development Index	0.8372 (3.8699)				
Transport Composite Index		-1.6456** (0.6477)			
Energy Composite Index			0.4595 (0.5177)		
ITC Composite Index				0.6441 (0.5927)	
Water & Sanitation Composite Index					6.5951** (2.8831)
Bilateral RER	0.2441 (0.2678)	0.0070 (0.2857)	0.2641 (0.2595)	0.2683 (0.2465)	0.0108 (0.2387)
Trade Intensity Index	0.0003* (0.0002)	0.0003* (0.0002)	0.0003 (0.0002)	0.0003 (0.0002)	0.0003* (0.0002)
Economic Size	13.4488*** (2.9571)	12.9372*** (2.7692)	12.9209*** (2.9758)	11.4887*** (3.2666)	12.2007*** (2.7025)
Relative factor endowment	0.6332 (0.5111)	0.7024 (0.4734)	0.6458 (0.5158)	0.6801 (0.4601)	0.6299 (0.4638)
Similarity Index	4.0180** (1.6426)	4.0792** (1.6362)	4.2151*** (1.4757)	4.0816*** (1.5689)	3.6852** (1.5719)
remoteness	1.2602*** (0.4557)	1.2833*** (0.4759)	1.2050*** (0.4349)	1.0716*** (0.3651)	1.2291*** (0.4413)
Observations	570	570	570	570	570
Number of country pairs	30	30	30	30	30
Country-fixed effects	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes

*This table presents the results of five different PPML regression models, with bilateral trade as the dependent variable in all specifications. Each model uses one component of the infrastructure index as the variable of interest. Robust standard errors are provided in parentheses below the coefficient estimates. Statistical significance is denoted by asterisks: *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. All models incorporate both country-fixed effects and year-fixed effects to control for unobserved heterogeneity across countries and over time, respectively. The number of observations for each model is 570, encompassing 30 country pairs.*

The PPML estimates reveal some interesting results regarding the relationships between the various infrastructure development indices and bilateral trade flows within the Zone. The results in column (1) show that infrastructure development has a positive coefficient, suggesting a potentially positive relationship with intra-WAMZ trade. However, the result is not statistically significant, implying that we cannot conclude that infrastructure development has a substantial impact on intra-WAMZ trade when the aggregate composite index is used as a proxy. This might be due to the high variability of intra-WAMZ trade leading to a weak relationship with aggregate infrastructure development. Nonetheless, the results also show that trade intensity, economic size, similarity, and remoteness indices all have positive and significant effects on trade within the Zone.

In column (2), the coefficient of transport infrastructure index is negative and statistically significant at the 5% level of significance, indicating that the level of transport infrastructure discourages trade flows across the Zone. The negative relationship between transport infrastructure and intra-regional trade might seem counterintuitive, as better infrastructure is typically expected to enhance trade. However, several factors can explain this anomaly. This negative relationship highlights systemic issues, including the inadequate level of quality transport infrastructure as well as the inconsistent and burdensome customs procedures across border points that reduce the efficiency of transport systems and increase trade costs. Amjadi and Yeats (1995) noted that poor transport infrastructure and high logistics costs reduce trade competitiveness in Sub-Saharan Africa, while Easterly and Levine (1997) argued that infrastructure development must be coupled with efficient usage and governance to positively impact trade.

In columns (3) and (4), the coefficients for the energy composite index and ICT, respectively, show a positive but statistically insignificant effect on bilateral trade flows. This indicates a potential role for energy and ICT in facilitating trade but lacks strong supporting evidence. While these factors are positively correlated with trade, their lack of statistical significance may reflect challenges in their utilisation or limited development. Mbekeani (2010) emphasised the role of ICT and energy in supporting trade but noted that their impact depends on complementary investments and policy frameworks. In column five (5), water and sanitation infrastructure have a significant positive effect on bilateral trade. A 1% increase in the index is associated with a 6.60% increase in trade flows. This result underscores the importance of basic infrastructure in supporting trade activities within the WAMZ. The significant positive impact of water and sanitation infrastructure aligns with the idea that basic infrastructure supports health, productivity, and trade. Calderón and Servén (2010) found that infrastructure improvements, including water and sanitation, enhance trade and economic performance in developing countries. This result points to opportunities for accelerated improvement in trade flows if issues regarding Sanitary and Phytosanitary (SPS) measures are addressed.

Overall, the relationships between key explanatory variables and intra-WAMZ trade largely align with theoretical expectations. For example, the coefficients of trade (export) intensity variables are positive and statistically significant, indicating that trade is more robust among countries with complementary trade structures. This underscores the importance of developing such structures to enhance bilateral trade within the WAMZ. Additionally, the coefficients for bilateral real exchange rates exhibit the expected

positive signs and are statistically significant. This implies that a real depreciation of the exporting country's currency relative to the importing country's currency boosts bilateral trade flows within the WAMZ.

Furthermore, positive relationships are observed between economic size, relative factor endowments, similarity index, remoteness, and bilateral trade flows, with trade exhibiting high elasticity with respect to these variables. This highlights their critical role in fostering trade among WAMZ countries. The findings suggest significant opportunities for WAMZ countries to enhance bilateral trade and capitalise on protocols like the ECOWAS Trade Liberalisation Scheme (ETLS) and the African Continental Free Trade Area (AfCFTA) initiative.

In sum, the results suggest that while economic size, similarity, and remoteness are consistent drivers of intra-WAMZ trade, the impact of infrastructure varies by type. Water and sanitation infrastructure stands out as the most significant contributor to trade, while transport infrastructure may need further investigation to understand its negative impact. This highlights the importance of targeted infrastructure investments for enhancing regional trade.

6.0 Conclusion and Policy Recommendations

This study investigates the impact of infrastructure on intra-WAMZ trade, comparing effects across different types of infrastructure on trade flows among the WAMZ member states. The study also evaluates the role of the real exchange rate and other complementary trade structures in enhancing intra-WAMZ trade. The modified gravity model, based on the Poisson pseudo-maximum likelihood (PPML) estimation technique, is utilised to obtain reliable results and achieve the objectives of the study. The study incorporates all six (6) member states in the Zone and covers the period from 2005 to 2023. At the aggregate level, the estimation results show that there is a positive relationship between infrastructure development and intra-WAMZ trade. However, the statistically insignificant result implies that we cannot conclude that infrastructure development has a substantial impact on trade within the Zone. Regarding different facets of infrastructure development, results also reveal a positive effect on intra-WAMZ trade for energy, water and sanitation, and ICT infrastructure index, but not for transport infrastructure. The negative and significant coefficient for the transport infrastructure index could highlight the existing infrastructure gap and inferior infrastructure quality across the region. The significant positive coefficient for the water and sanitation index points to opportunities for increased

improvement in trade flows if Sanitary and Phytosanitary (SPS) measures are addressed. Based on the study's interesting findings, several policy recommendations are advised:

Infrastructure Development: A multifaceted approach that combines increased investment, better governance, advanced technologies, and inclusive planning can significantly improve infrastructure quality and effectiveness. Member states should collaborate and engage with the private sector, regional organisations and development finance institutions, such as the World Bank, the African Development Bank, to help fund these investments despite external financial constraints. WAMZ countries should identify and prioritise trade-enhancing infrastructure, including cross-border infrastructure, particularly in critical sectors such as transport, energy, water & sanitation, and ICT, that guarantee affordable trade services for all groups and ensure quality standards measures for infrastructure construction and maintenance. These measures, if effectively implemented, could enhance connectivity, accelerate trade flows, boost economic growth, and improve the quality of life.

Creating a thorough regional infrastructure plan is essential for tackling the connectivity issues faced by WAMZ. Priority should be assigned to transport corridors and energy systems, as these are the foundation of economic integration. Investments in transport infrastructure, including the building and upgrading of roads, railways, and ports, will enable the smooth movement of goods and people across member states.

Strengthening Regulatory Frameworks: WAMZ countries are encouraged to coordinate and empower standard authorities and other regulatory bodies with the resources required to effectively manage food safety and plant/animal health issues and promote compliance with international standards. Surveillance and early warning systems should be developed to monitor and assess the risk of outbreaks in plants and animals, detect and promptly respond to sanitary and phytosanitary (SPS) related threats, and create platforms for sharing information on SPS risks, outbreaks, and mitigation strategies among WAMZ countries. Improving SPS measures in the WAMZ will require a coordinated approach involving investment in infrastructure, capacity building, regulatory harmonisation, and stakeholder collaboration. These measures will not only enhance food safety and agricultural productivity but also facilitate regional trade and integration into global markets.

Address trade bottlenecks through regional integration: Efforts should be directed towards harmonising customs regulations as well as enforcing regional regulatory frameworks. Moreover, non-tariff barriers such as burdensome customs procedures and inconsistent regulations must be eliminated to ease trade for businesses within the Zone. Ensuring consistent implementation of the ECOWAS Trade

Liberalisation Scheme (ETLS) and expanding its scope to include more goods and services would also promote tariff-free trade and boost intra-WAMZ trade flows.

Economic Diversification: Member states must encourage value addition in agriculture and manufacturing to create complementary trade structures. Investment in light manufacturing and agro-processing to produce goods that meet regional demand has the potential to boost trade within the Zone. Member states are encouraged to support small and medium-sized enterprises (SMEs) to diversify production within WAMZ economies. Focusing on value addition in key sectors such as crude oil refining, cocoa processing, and aluminium manufacturing from bauxite would go a long way in reducing dependence on external markets and accelerating trade flows across the region.

Development of Zonal value chains: WAMZ member countries should prioritise collaboration to develop regional value chains that add value to primary commodities and decrease reliance on external markets. This approach would also support efforts to diversify regional economies and reduce dependence on a narrow range of export commodities. For instance, rather than exporting raw materials individually, countries could establish cross-border value chains where raw materials from one nation are processed into finished goods in another. Such initiatives would expand the range of products available for intra-WAMZ trade, enable countries to derive greater benefits from their natural resources, and mitigate the impact of external economic shocks.

Progressing Monetary Union: Efforts must be intensified to fast-track the adoption of the eco, eliminating exchange rate risks and reducing trade transaction costs. A stable foreign exchange framework and a more robust financial system would reduce trade costs and facilitate intra-WAMZ trade. Achieving this goal requires strengthening regional institutions like the West African Monetary Institute (WAMI) by enhancing their capacity to address external shocks. This involves implementing early warning systems for economic disruptions, coordinating policy responses, and advancing strategies to build resilience across the region.

WAMZ has immense potential for intra-regional trade, driven by opportunities in diversification, infrastructure development, policy harmonisation, and regional value chain creation. By addressing structural and policy barriers, member states can unlock these opportunities to foster economic growth, reduce external dependence, and promote deeper regional integration. Strategic investments and collaborative policies will be key to realising the trade potential of the WAMZ region.

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