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Quality of Road Transport Infrastructure and Intra-African Agricultural Exports: A Long Run Two-Step System Generalized Method of Moments Analyses

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ABSTRACT

Sustainable growth requires developing economies to simultaneously attain economic and environmental sustainability. This study examines the effect of the quality of road transport infrastructure of the exporting and importing countries on intra-African agricultural exports from 2006 to 2018. To achieve this objective, the study employed the two-step system generalized method of moments, short-run and long-run estimators. The pooled mean group estimator was also used as a robustness check. The results revealed that the quality of road transport infrastructure of the exporting countries increases intra-African agricultural exports by an average of 1.24 to 1.25 percentage points in the short-run and 1.80 to 2.01 percentage points in the long-run. Furthermore, the role of Africa's regional trading blocs in determining intra-African agricultural exports was also analyzed. The results showed that the East

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African Community (EAC), the Economic Community of West African States (ECOWAS), and the Southern African Development Community (SADC) increase intra-African agricultural exports. However, the EAC is more integrated than the SADC, followed by the ECOWAS, in both the short and long-run. Thus, exporters' quality of road transport infrastructure and regional trading blocs promote intra-African agricultural exports. The study recommends strengthening the political and institutional will of national authorities to support green road construction and rehabilitation financing and investments, de-risk, and co-promote green road infrastructure projects to attract investments in road transport infrastructure.

Keywords: Road Transport Infrastructure; Intra-African Agricultural Exports; Two-Step System Generalized Method of Moments; Pooled Mean Group; Regional Trading Bloc

1. Introduction

The quest of countries to achieve economic growth has led to an unprecedented rise in greenhouse gas (GHG) emissions, which causes climate change. The far-reaching effects of climate change pose a concern to the world economy, and as such, nations have agreed to limit global warming to 1.5 °C^[1,2]. Thus, realizing sustainable economic growth hinges on understanding how developing economies simultaneously attain economic and environmental sustainability^[3,4].

Intra-regional trade, which involves the movement of goods between countries within a particular geographical location with proximity, is crucial for achieving economic development through increased market access, price reduction, and quality improvement, increasing income, and fostering innovation^[5,6]. The gains from intra-regional trade arguably inspired African countries to form the African Continental Free Trade Area (AfCFTA), which is the largest regional trading bloc in Africa. As such, with the African continent having 20.36% of the world's land area, a population of approximately 1.5 billion^[7] and abundant natural resources, the AfCFTA is expected to be the largest free trade area in the world since the World Trade Organization was formed, in terms of membership, with US\$2.5 trillion gross domestic product (GDP)^[8]. Hence, significantly plays a role in facilitating trade and shaping the world market.

Despite the potential of the African continent to significantly contribute to world trade, Africa's contribution to global trade was 14%, which is far lower than the contribution of Europe (65%) in 2022^[9]. Additionally, in 2023, Africa's net trade stood at US\$1.3 trillion,

which is comparatively the lowest among developing regions, such as South Asia (US\$11.8 trillion)^[10]. Furthermore, the intra-African to global African trade share plummeted by 6% in 2022 after attaining a record high of 21% between 2015 and 2016^[11]. Moreover, Africa's agricultural exports increased by 12%, while imports rose by 15.4% in 2023, resulting in an agricultural trade deficit^[12]. Conversely, intra-African trade experienced a 3.2% increase in 2023 over the previous year, and such an increase is projected to further rise to 35% following the full implementation of the AfCFTA^[13,14]. Despite the rise in intra-African trade, its share of total intra-African agricultural trade remains relatively small, and only a few product groups account for the majority of Africa's agricultural exports. The most exported products (fish, edible vegetables, and roots, cocoa, coffee, tea, spices, and edible fruits and nuts) account for 53% of total agricultural exports. Specifically, the proportion of intra-African agricultural exports (IAAEs) to agricultural exports in Africa was 19.8% in 2019–2021, which is quite comparable to the value of 20.4% in 2003–2005, almost a decade earlier^[15]. Given the continent's poor performance, it is most unlikely that Africa will meet its three-fold intra-African agricultural trade target by 2025^[16]. This low level of trade within the African continent can be attributed to an infrastructural gap^[17].

Transport infrastructure—including roads, rail, airports, and ports^[18]—is essential for moving goods and supporting economic activities. In Africa, high trade costs are particularly burdensome for landlocked countries, which face 50% higher costs than coastal countries. Since road transport accounts for 80% of African trade, the quality of road transport infrastructure (QRTI) is of

particular importance^[19,20].

Road transport infrastructure, including road quality stock, is crucial for increasing trade volume and economic growth^[21], as it enables the movement of goods from surplus to shortage countries^[22]. Consequently, with globalization and most intra-African trade conducted by road, the QRTI can provide countries with a competitive edge^[23]. Conversely, poor road transportation may help explain the low levels of intra-African agricultural trade, as road remains the dominant mode of transport in Africa^[24]. Therefore, investing in road infrastructure is essential, especially in regional and landlocked markets. Recent data reveal significant gaps in road density and quality, which further constrain IAAE's potential.

In this regard, the African Development Bank in-

vested US\$13.5 billion to construct over 18,000 km of roads linking 25 transport corridors, to facilitate intra-African trade^[25]. Moreover, Sub-Saharan African countries financed 90% of their domestic road transport infrastructure projects between 2015 and 2018 to bridge the infrastructure gap by 2030^[26]. Thus, with such investments in domestic and regional road transport infrastructure in Africa, intra-African agricultural trade is expected to have increased. However, from **Figure 1**, the trend line is positively sloped but inelastic because it is relatively flat. This signifies that a greater improvement in the QRTI will result in a less-than-proportional increase in IAAEs for countries below the trend line, which are in the majority. This is puzzling and begs the question: Why are IAAEs less responsive to the improvement in QRTI for countries below the trend line?



Figure 1. Quality of road transport infrastructure puzzle.

Note: The quality of road transport infrastructure is measured by the global competitiveness index on road quality, which ranges from 1 to 7, with 7 being the highest quality. Data on QRTI is sourced from the World Economic Forum database. The intra-African agricultural exports are measured by a country's total exports of food and agricultural goods to other countries within the African continent. Data on IAAEs is solicited from the FAOSTAT database.

Source: Author's construction based on FAOSTAT and WEF data.

The nexus between trade and the quality of road infrastructure has been a topical issue for researchers, but research in this area has been limited. To start with, Netirith and Ji^[27] used total road length as a proxy for QRTI and Data Envelopment Analysis as an estimation technique. They observed that QRTI explains trade flows in most member states of the Regional Comprehensive

Economic Partnership, but is inefficient in a few. Using a different proxy for QRTI, the density of paved roads in the greater Mekong sub-region, Fujimura^[28] estimated his model using the random effects technique. He suggested that domestic road infrastructure has a beneficial influence on intra-regional trade, whereas foreign road infrastructure has a negative influence on intra-regional

trade. In Spain, the generalized method of moments (GMM) estimator was used by Arbués and Baños^[29]. They demonstrated that QRTI has an impact on freight. Complementing the work of Arbués and Baños^[29], Jang and Lopez^[30] argued that differences in QRTI explain the variation in the competitiveness of countries. They employed the fixed effect estimation technique and revealed that the trade deficits recorded by developing countries are a result of a lack of QRTI.

Substituting the bilateral trading time for QRTI, and employing instrumental variables and difference in difference approaches, Baniya et al.^[31] demonstrated that trade volumes between nations that participated in China's Belt and Road Initiative increased by as much as 4.1% as a result of the reduction in bilateral trade time. Similarly, Fontagné et al.^[24] used exporters' transport times to mean QRTI and employed the general equilibrium modeling estimation approach. They showed that the reduction in road transportation time and other modes of transport will result in a 11.5% increase in exports.

In a metadata analysis, Celbis et al.^[32] streamlined the proxies of road quality index to a single indicator, QRTI, and employed the instrumental variable technique for estimation. They revealed that the effect of the QRTI on exports is greater for exporting countries than importing countries.

From studies reviewed, it can be noted that researchers have employed varying measures of the QRTI and estimation techniques; hence, their results on the effect of QRTI on trade differ across infrastructure locations. Thus, this study, as a novelty, examines the short and long-run effects of the quality of road transport infrastructure on intra-African agricultural exports. To achieve this, the study collected data from 2006 to 2018 and analyzed the data using the novel two-step system generalized method of moments (two-step SGMM), which also captures the long-run dynamics.

The study is novel in four ways. First, it focuses on exports within the African continent, with a specific interest in the agricultural sector. Since agricultural production is concentrated in rural areas characterized by low income and a food-insecure population, the study output will be beneficial to policymakers and policy-

making in their quest to achieve food security, increase intra-African agricultural trade, and improve farmers' livelihoods. Second, the study employs a novel two-step SGMM technique, which accounts for both short and long-run dynamics and controls for serial correlation, heterogeneity, and endogeneity. In addition, the study employed the pooled mean group estimator as a robustness check. This makes the study findings robust and reliable; as such, the results can be relied on for sound policy decisions. Third, this study examines the long-run implications of the QRTI on IAAEs, which explains the benefits of maintaining the QRTI on a sustainable basis that previous studies did not capture. Fourth, a major challenge with bilateral trade flow data within the gravity framework, especially when applied in the context of Africa, is how to account for zero trade values. There are various econometric techniques, such as the Poisson Pseudo Maximum Likelihood, that account for zero trade flows. However, this study used multilateral rather than bilateral export flows to account for zero export values. Thus, providing a preventive approach to overcome zero trade values. Obtaining a reliable dataset provides reliable estimates that support effective policy decision-making.

This study may be pertinent to African countries with constrained budgets that are poised to increase agricultural trade, achieve economic growth, and reduce food insecurity on a sustainable basis, so that they will be prudent in using their limited resources, informed by evidence on whether IAAEs are driven by the QRTI or otherwise. In addition, it showed the importance of improving exporters' quality road transport infrastructure and the additional benefits of maintaining the quality of existing roads. Furthermore, with the implementation of the AfCFTA at the take-off stage, this study is crucial for the design, implementation, and or adjustment of a road transportation policy that will enhance agricultural exports within the African region, based on whether the road quality of exporters or Africa or both explains Africa's intra-regional agricultural trade flows. It may also serve as a baseline study for future research on the nexus between road transport infrastructure and agricultural exports in the African continent. Finally, it provides a pathway through which growth could be

achieved without degrading the environment.

2. Materials and Methods

2.1. Theoretical Frameworks for Modeling Trade Flows

Several economic theories model trade flows. However, a few of them can be reviewed. To start with, Viner^[33] propounded a basic static conceptual model that incorporates the core ideas of trade flows. The Viner model was then extended by relaxing some assumptions of the basic conceptual model. However, the model is limited because it only considers one market. The downside of this model leads us to the general equilibrium model posited by Lipsey and Lancaster^[34], which accounts for various markets. The general equilibrium model addresses both the static and dynamic effects in trade flows. Hence, the model is pertinent in predicting trade flows. However, the model lacks a specific formulation and the ability to account for different traded goods and trade policies^[35].

Perhaps the most commonly employed approaches to examine the impact of trade policy are the computable general equilibrium (CGE) and the gravity model. The CGE model provides an analytical framework for policy assessment that can estimate the size of the effects revealed by theories and predict the expected overall welfare effects. The weakness of this model, among others, is that it is mostly applicable for ex-ante studies^[36]. Thus, we employ the gravity model in this research because of its ability to measure trade flow effect (ex-post) and the ease of accessing real-world data^[37].

The origin of the gravity model, which measures the economic size of two countries and the distance between them, is traced to Tinbergen^[38], Pöyhönen^[39], and Linnemann^[40]. It got its name because its formulation is analogous to that of Newton's law of motion. Despite the usefulness of the gravity model in earlier studies, it was viewed as suspect because it lacked a theoretical foundation. However, a clear micro-foundation of the gravity model was first provided by Anderson^[41].

Several authors, such as Helpman et al.^[42], augmented the gravity model in their studies. However, perhaps the most notable of these is the inclusion of the mul-

tilateral resistance, the major contribution of Anderson and van Wincoop^[43]. The gravity model has been further developed to include port power and road transport time^[24,44]. Thus, following the line of thinking of these authors, we also augment the gravity model to incorporate the QRTI.

The gravity model, despite its popularity, has some limitations. First, the model suffers from omission bias or measurement error due to its assumption of bilateral trade flows depending only on the economic sizes of the trading parties and the distance between them. For instance, the distance term represents several trade cost measurements. So, assuming it for physical distance alone oversimplified the model, as other factors, such as transport infrastructure, may also represent distance. Furthermore, the data used in the gravity model estimation can be unreliable, which renders the estimated results inaccurate. For example, the inclusion of zero trade in a data set^[37]. Third, the static nature of the gravity model. This makes its application in dynamic model estimation impractical. Despite the downside of the gravity model it still upholds its popularity because of the establishment of credible data repositories like the Centre for Prospective Studies and International Information (CEPII), the FAOSTAT, and the World Bank Development Indicator databases, theoretical adjustment of the gravity model in dynamic form^[29] and the application of robust estimation techniques that account for zero trade values, multicollinearity and bias caused by omitted variable, which are prevalent in the gravity model.

2.2. Specification of the Gravity Model

The gravity model credited to previous researchers^[38-40] can be specified in its basic form as:

$$T_{ij} = \frac{(C_i)^{\omega_1} (C_j)^{\omega_2}}{D_{ij}^{\omega_3}}, \text{ for } i \neq j \quad (1)$$

where T denotes IAAE of country i to all countries j across Africa, C denotes a country's affluence, and D_{ij} is the distance between country i and j .

A common practice in recent trade literature is the shift from the traditional static specification of the gravity model to the dynamic gravity model because it is believed that past trade values are correlated with the

present trade values^[29]. Specifying Equation (1) as a mathematical model in dynamic double-log form yields:

$$\ln T_{ijt} = \omega_0 + \omega_1 \ln T_{ijt-1} + \omega_2 \ln C_{it} + \omega_3 \ln C_{jt} + \omega_4 \ln D_{ijt} + \mu_{ijt} \quad (2)$$

where t is the time, μ is the error term, ω_i 's are the parameters to be estimated, $\ln$ is the natural logarithm, and T_{ijt-1} is the lag of IAAE.

2.2.1. Modelling the Quality of Road Transport Infrastructure

Bilateral trade, which is the total amount of exchange of goods and services that occurs between an importing and an exporting country, can be measured from the country of origin or the destination country. Assuming the QRTI is measured as bilateral trade flow, it can be measured principally in four ways^[32]. The result would be a two-by-two trade matrix in the form:

$$T_{ij} = \begin{bmatrix} Q_{ii} & Q_{ij} \\ Q_{ji} & Q_{jj} \end{bmatrix}$$

where i represents the exporter and j the importer, the matrix can be interpreted as:

- Exports of the country i as a result of QRTI i
- Exports of the country i as a result of QRTI j
- Exports of the country j as a result of QRTI i
- Exports of the country j as a result of QRTI j

We take the trace (Tr) of the matrix T_{ij}

$$Tr(T_{ij}) = Q_{ii} + Q_{jj} \quad (3)$$

Thus, if we are to model the effect of QRTI on IAAEs, it will yield two effect sizes only. Hence, Equation (3) can be written in dynamic regression form as follows:

$$\ln T_{ijt} = \omega_0 + \omega_1 \ln T_{ijt-1} + \omega_5 \ln Q_{it} + \omega_6 \ln Q_{jt} + \dots + e_{ijt} \quad (4)$$

where ω_0 is an intercept, ω_4 is the coefficient of the QRTI of the exporting country, ω_5 is the coefficient of the QRTI of the importing country, and e_{ijt} is the error term.

Assuming ω_0 equals ω_0 , μ_{ij} equals e_{ij} , and $\omega_1 \ln T_{ij-1}$ equals $\omega_1 \ln T_{ij-1}$, merging Equations (2) and (4) without duplication would yield:

$$T_{ijt} = \omega_0 + \omega_1 \ln T_{ijt-1} + \omega_2 C_{it} + \omega_3 C_{jt} + \omega_4 D_{ijt} + \omega_5 Q_{it} + \omega_6 Q_{jt} + \mu_{ijt} \quad (5)$$

2.2.2. Modelling Policy Factor

Except for the marginal cost of production, trade cost measures all expenses incurred in delivering commodities to ultimate consumers^[45]. It is perhaps the main barrier to international trade. These costs encompass geographic, policy, institutional, and cultural factors^[46,47]. However, tariff and non-tariff restrictions imposed by trade policy may be the largest cost^[43]. In Africa, the average interstate border tariffs are 6.9%, with non-tariff barriers, such as sanitary and phytosanitary, and technical barriers to trade, accounting for 7.4%. Thus, the total cost of trade policy across Africa's 107 interstate land boundaries is 14.3%^[48]. In this regard, the African Continental Free Trade Area (AfCFTA), by eliminating tariff and non-tariff barriers, has the potential to increase intra-African exports by more than 81% and total exports by approximately 29% in 2035^[12,49]. However, since the AfCFTA has not been fully operationalized, it is worthwhile to examine the role of existing regional trading blocs on Africa's intra-trade performance. There are 8 regional trading blocs in Africa. Irrespective of this, this study only selects the major regional trading blocs in a particular region based on membership, without duplication to understand the effect of regional trading blocs on IAAEs. This means that the Arab Maghreb Union (AMU) will represent North Africa, the East African Community (EAC) is selected for East Africa, the Economic Community of West African States (ECOWAS) is selected for West Africa, and the Southern African Development Community (SADC) will represent Southern Africa because they have the highest number of members in their respective region. The reason for this selection criterion is to avoid overlapping membership, which is detrimental in declaring the study data as a panel in Stata. Empirically, studies^[46,50,51] have shown that regional trading blocs can explain export performance. Thus, Equation (5) is rewritten as:

$$T_{ijt} = \omega_0 + \omega_1 \ln T_{ijt-1} + \omega_2 C_{it} + \omega_3 C_{jt} + \omega_4 D_{ijt} + \omega_5 Q_{it} + \omega_6 Q_{jt} + \omega_7 RTB_{ijt} + \mu_{ijt} \quad (6)$$

where RTB means regional trading bloc and encompasses the AMU, the EAC, the ECOWAS, and SADC dummy variables. To single out the effect of the RTBs on intra-African agricultural exports, all the other variables in Equation (6) are treated as control variables.

2.3. Data Description

Data for this study span from 2006 to 2018 based on availability, especially on the QRTI. We can only access data for QRTI from 2006 to 2018. As such, data on IAAEs, GDP, and distance follow the same trajectory. Data on the variables in this study were collected from twenty-nine African countries as listed in **Table 1**.

2.3.1. Intra-Africa Agricultural Exports

The IAAE is the dependent variable in this study. Values for IAAEs were obtained from the Food and Agriculture Organization (FAO) Statistics database^[52]. The IAAE data is part of the detailed trade matrix data collected, processed, and disseminated by the FAO follow-

ing the methodology of International Merchandise Trade Statistics. A common challenge with export data is the prevalence of zero trade values, which can bias estimates if not properly adjusted^[53]. To account for zero trade values and deviate from Jang's work, the study collected multilateral exports data instead of bilateral exports data. That is, the IAAEs data comprises the total exports of the country i to all its j th partners across Africa. Aside from zero trade values, other issues, such as non-reporting and missing values, are also prevalent in export data. To correct for these, the study uses partner countries' (mirror) data, as in the case of Nigeria. The IAAEs' data consists of 13 data points collected from 2006 to 2018.

Table 1. Sampled African Countries.

Country (Column 1)	Country (Column 2)	Country (Column 3)
Algeria	Ghana	Namibia
Benin	Kenya	Nigeria
Botswana	Lesotho	Senegal
Burkina Faso	Madagascar	South Africa
Burundi	Malawi	Tanzania
Cameroon	Mali	Tunisia
Chad	Mauritania	Uganda
Côte d'Ivoire	Mauritius	Zambia
Egypt	Morocco	Zimbabwe
Gambia	Mozambique	

Source: Constructed by the Author.

2.3.2. Quality of Road Transport Infrastructure

The QRTI data was obtained from the World Economic Forum (WEF). The WEF provides the Global Competitiveness Index (GCI), which tracks the performance of countries and makes the data available to foster evidence-based academic research. The GCI contains data on road quality valued from 1 to 7, with 7 being the best quality of road.

Two sets of QRTI values are examined in this study. That is, the QRTI of the exporting and importing country. The QRTI includes the value for the annual quality of roads of the exporting country from 2006 to 2018. The QRTI value for the importing country is the average of all the quality of road values of all the countries that import from the country i in a year from 2006 to 2018

(<https://www.kaggle.com/datasets/weforum/global-competitiveness>). The data may not capture recent events, but it is sourced from WEF, a well-known, reliable data repository for QRTI. More recent QRTI data for Africa are unavailable, so available data are preferable to potentially error-prone and biased projections or interpolations.

2.3.3. Control Variables

The GDP of the exporting country, the importing country, and distance are important variables that should be considered when modelling trade flows. Hence, they are captured in this study as control variables that help explain the flow of agricultural goods within the Africa trade corridor. Data on these variables were obtained from CEPII^[43,54]. The explanation of the variables used in this study is summarized in **Table 2** below:

Table 2. Summary of Data.

Variable	Description of Variable	Data Source	Reference
Intra-Africa Agricultural Exports	Total exports of food and agricultural goods within Africa.	FAOSTAT	Badiane and Odjo ^[55]
Quality of Road Transport Infrastructure of the exporting country	The quality of the road index of the exporter ranges from 1 to 7, with 7 being the highest quality.	WEF	Jang and Lopez ^[30]
Quality of Road Transport Infrastructure in importing countries	The quality of the road index of all importers ranges from 1 to 7, with 7 being the highest quality.		
Gross Domestic Product of the exporting country	Total output of a country in a year	CEPII	Fontagné et al. ^[24]
Gross Domestic Product of the importing countries	The total output of all importing African countries in a year.		
Distance	The distance between an exporter and the trading partners' cities.		

Source: Constructed by the Author.

2.4. Estimation Strategy

The first step in the estimation strategy is to test for cross-sectional dependence (CD). Because the data dimension in this research has twenty-nine cross-sections and a period of thirteen years. That is, the time dimension is small, while the number of cross-sections is large; it is more appropriate to use the Pesaran's^[56] test for CD^[57]. Thus, the Pesaran CD test is the main test employed in this study. However, to confirm the results of the Pesaran CD test, the Friedman's^[58] CD test was also employed.

The first-generation unit root tests are employed in this study, as informed by the absence of CD. Specifically, the Fisher-type test statistic that combines unit roots tests probability values from each cross-sectional unit i and allows cross-sectional differences in the lag length of the augmented Dickey-Fuller test was employed^[59,60]. Additionally, the Phillip-Perron augmented Dickey-Fuller test^[58-60] is also employed to affirm Fisher's result.

The diagnostic tests focus on the general issues of CD and stationarity of the variables, while assuming the presence of serial correlation because of the dynamic nature of the model specified in Equation (2). As such, a formal test for potential serial correlation using Pesaran et al.'s test^[61] was not conducted. In addition, the inclusion of the dependent variable (IAAE) as part of the in-

dependent variables in Equation (2) results in the problem of endogeneity. Thus, the GMM estimation technique was employed to estimate the regression model because it is appropriate to address the limitations of serial correlation and endogeneity. Thereafter, the long-run effect of the short-run statistically significant variables was estimated. For a robustness check, the study employed the pooled mean group estimator, which assumes short-run coefficients to vary and similar long-run coefficients^[61]. Moreover, to assess the reliability of the two-step SGMM estimations, the study compares the pooled ordinary least squares (OLS) (POLS), the fixed effects (FE), and two-step difference SGMM estimates, and also conducts post-estimation tests such as the Sargan and Hansen tests for instrument validity and the test for second-order serial correlation.

Figure 2 depicts the estimation strategy employed in this study. The strategy comprises four key steps. First, the study employed Pesaran and Friedman's CD test to check for CD. Second, the test for stationarity of the variables is conducted to avoid spurious results using first-generation unit root tests (Fischer's augmented Dickey-Fuller and Phillips-Perron tests). The third step shows the correction of serial correlation and endogeneity using the two-step SGMM, as well as its long-run implications. Finally, to examine whether the short-run results are robust, the pooled ordinary least squares, fixed effects, and two-step difference SGMM results were com-

pared. In addition, the test for valid instruments and the serial correlation test were also carried out. To validate

the short and long-run results, the study also employed the pooled mean group estimator.

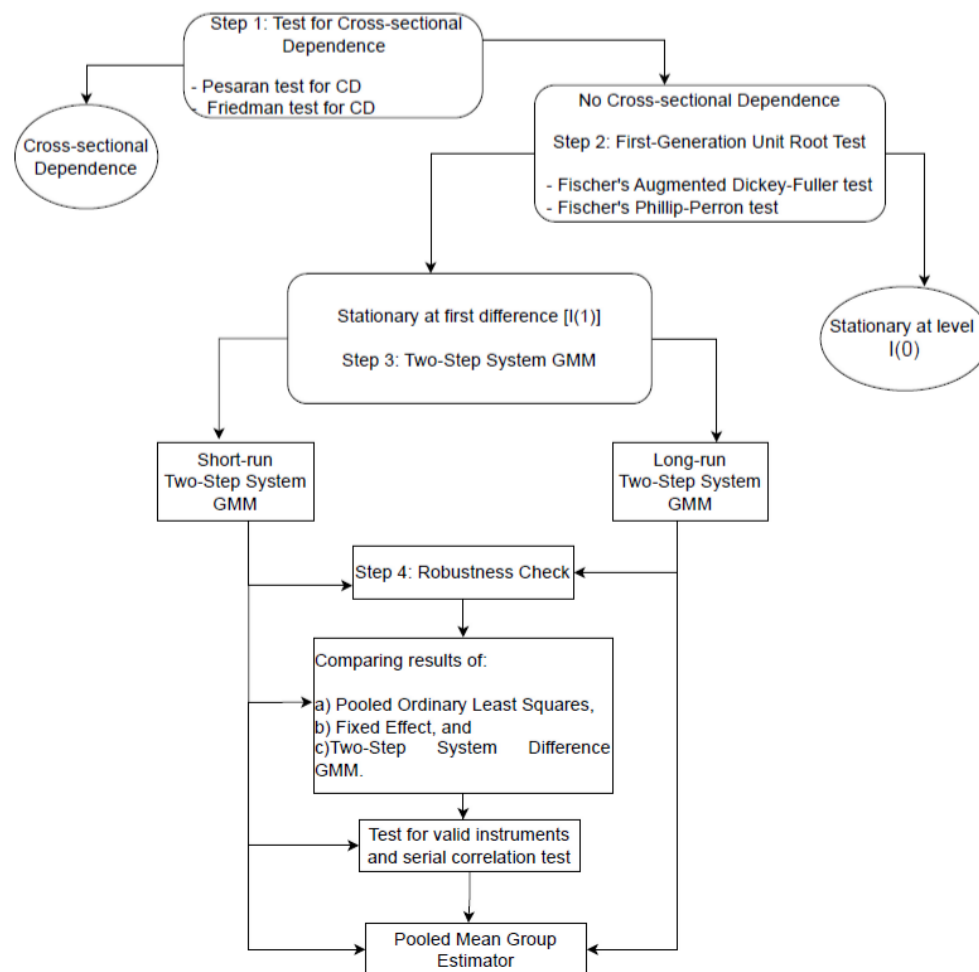


Figure 2. Estimation strategy flowchart.

2.5. Two-Step System Generalized Method of Moments Model

Given that the data comprises a small time and a large cross-section, this study is open to various estimation techniques such as POLS, FE, and the GMM estimation technique. However, because the specified model is dynamic, the use of a typical POLS model is limited because the lagged dependent variable serving as an independent variable will be correlated with the error term. This violates the OLS property of no serial correlation, hence results in bias and inconsistent estimates^[62]. The FE model corrects for serial correlation using robust standard errors, but it is limited because it cannot solve the problem of heterogeneity and endogeneity in the ex-

planatory variables^[62]. Thus, the study employed the GMM estimation technique to estimate the regression model because it controls for serial correlation, heterogeneity, and endogeneity in panel data analysis.

Hansen^[63] was the first to put forward the GMM estimation method. The difference GMM was later introduced by Arellano and Bond^[64], who improved upon it. In the context of a difference GMM, a set of lagged independent variables is employed as instruments to calculate the corresponding variables in the difference equation. Subsequently, Blundell and Bond^[65] asserted that the problem of persistence in the independent variables can negatively impact the small-sample and asymptotic features of the difference estimator. Thus, a system estimator known as the two-step SGMM estimator is created

by combining the difference estimator with the original estimator. Employing the moment conditions, the difference estimator is computed as follows:

$$E[y_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \quad (7)$$

$$\text{for } s \geq 2, t = 3, \dots, T$$

$$E[X_{i,t-s}(\varepsilon_{i,t} - \varepsilon_{i,t-1})] = 0 \quad (8)$$

$$\text{for } s \geq 2, t = 3, \dots, T$$

To employ the lagged differences of the independent variables as instruments in the level equation, two requirements must be met. First, there is no serial correlation in the error term. Second, although there is an association among the levels of the independent variables and the error term specific to a country, there is no association between variations in the independent variables and the error terms. Consequently, the stationarity properties listed below are generated:

$$E[y_{i,t+m}\gamma_i] = E[y_{i,t+n}\gamma_i] \quad (9)$$

$$\text{and } E[X_{i,t+m}\gamma_i] = E[X_{i,t+n}\gamma_i]$$

for all m and n .

The extra level regression moment conditions are:

$$E[y_{i,t-s} - y_{i,t-s-1}(\gamma_i + \varepsilon_{i,t})] = 0 \text{ for } s = 1 \quad (10)$$

$$E[X_{i,t-s} - X_{i,t-s-1}(\gamma_i + \varepsilon_{i,t})] = 0 \text{ for } s = 1 \quad (11)$$

Thus, the moment conditions in Equations (10) and (11) are used for obtaining the two-step SGMM estimator.

2.5.1. Long-Run Effect Computation

The QRTI deteriorates over time, and if not properly maintained, it will reduce the trade flow benefits. Thus, the issue of sustainability is critical in this respect. To account for the sustainability of QRTI and its precise measurement on a year-by-year or cumulative total basis, the study calculates the long-run effect of the QRTI and standard error combined^[66]. Thus, arithmetically, the long-run effect calculation for an independent variable appearing with its present value, say w_t , is given as:

$$w_t / (1 - \text{estimated coefficient on the lagged dependent variable}) \quad (12)$$

NOTE: The long-run effect is only calculated for the short-run statistically significant variables.

2.5.2. Test for Instrument Validity

Two types of tests are used to validate the two-step SGMM estimator^[64,65]. These are the Sargen and Hansen test for weak instruments and the second-order serial correlation test. In the first test, for both test statistics, a probability value of less than 5% signifies a weak instrument. The second test is the AR (2) test for the presence of second-order autocorrelation. A probability value of less than 0.05 indicates that the model suffers from second-degree serial correlation.

2.6. Trend Analysis

2.6.1. The Relationship between Intra-African Agricultural Exports and Their Determinants

From **Figure 3**, the trends consistently and clearly indicate a positive relationship between the QRTI for both importers and exporters and intra-African agricultural exports. Exporter flows increase as road infrastructure quality improves, underscoring the crucial part that infrastructure plays in fostering access to markets and trade competitiveness^[67,68]. Similarly, there is a significant positive relationship between the volume of exports and the GDP of both importers and exporters. This implies that larger economies with greater purchasing power and production capabilities are more likely to participate in agriculture-related trade^[69]. However, the trend for geographical distance tends to be fairly constant, which suggests that the size of the economy and infrastructure improvements now have a more significant impact on international trade than geographical proximity. This is especially evident in the African context, where borders and the quality of transportation are more important in determining trade outcomes than geographical distance^[3].

2.6.2. The Relationship between the Quality of Road Transport Infrastructure of Exporters and Importing Countries in Africa

Figure 4 depicts annual shifts in road transport infrastructure quality at the national level for importers as well as exporters in Africa between 2006 and 2018. For most countries, the infrastructural trend is generally

upward sloping. This implies that road transportation networks have been improving over the years. Positive patterns regarding regional cooperation and integration efforts were highlighted in most countries, demonstrating parallel development for both importer and exporter infrastructure, although some countries are encountering fluctuations or prolonged stalls. Although certain countries, such as South Africa and Botswana, consistently maintain improved infrastructure ratings, others, like Madagascar, Mali, and Chad, exhibit intense variation and lower average QRTI. Holistically, the trend lines illustrate gradual improvement in the quality of road transport infrastructure in Africa. This demonstrates the growing importance of facilitating regional trade and economic cooperation in Africa^[4].

2.6.3. Intra-African Agricultural Exports Trends

IAAEs for each African nation from 2006 to 2018 are highlighted in the panel of country-specific trend lines. Most countries have export volumes that are ei-

ther relatively stable or slightly increasing over the years. Although certain countries, such as Mauritania, Gambia, and Egypt, experience significant increases or periods of higher fluctuations, others remain stable. In light of differences in sectoral structure, trade policy, market access, and regional integration, export patterns vary significantly between countries^[70]. Several countries experienced significant shifts in their agricultural export performance during the period under study; in general, the trend is a moderate increase or stability (**Figure 5**).

2.7. Summary Statistics

The analysis begins by understanding the data through the interpretation of descriptive and correlation results. The findings from the correlation coefficients in **Table 3** show that the correlation coefficient for the QRTI and the GDP of importing countries is above 0.8. Thus, the presence of multicollinearity^[71] is most likely between the importers' QRTI and the GDP of importing countries, by extension, heterogeneity.

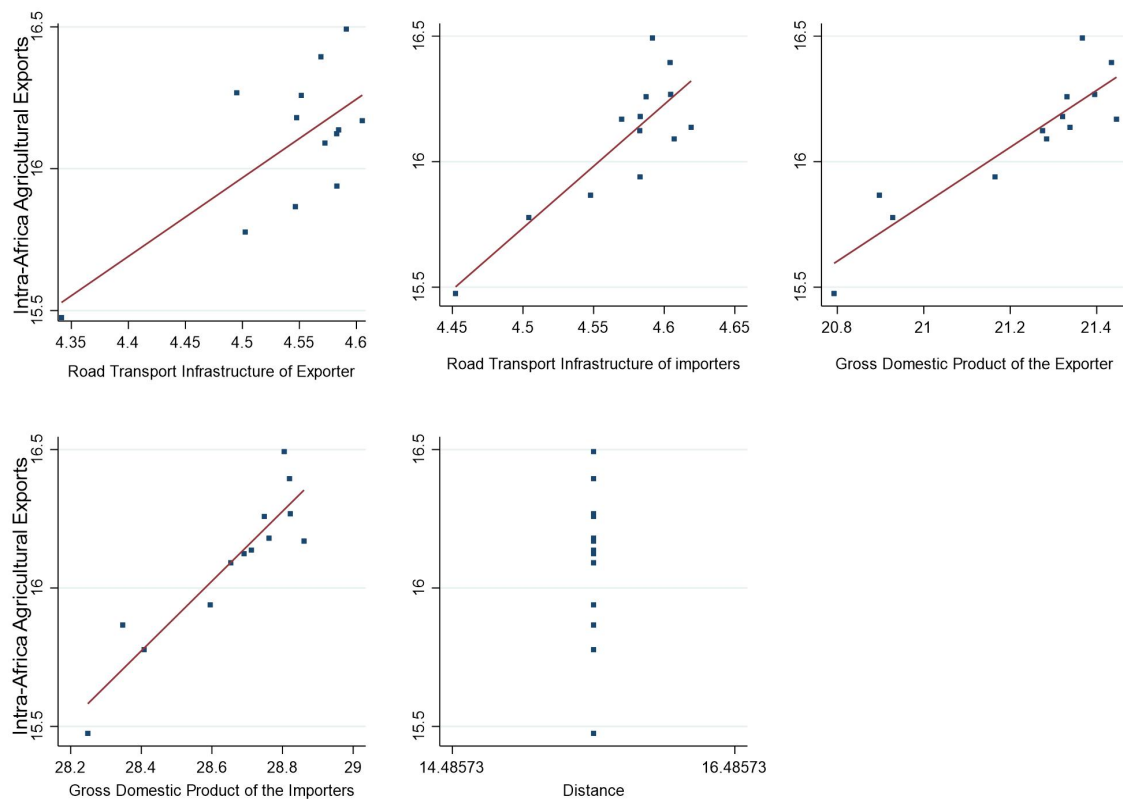


Figure 3. The relationship between IAAEs and their determinants.

Source: Constructed by the Author.

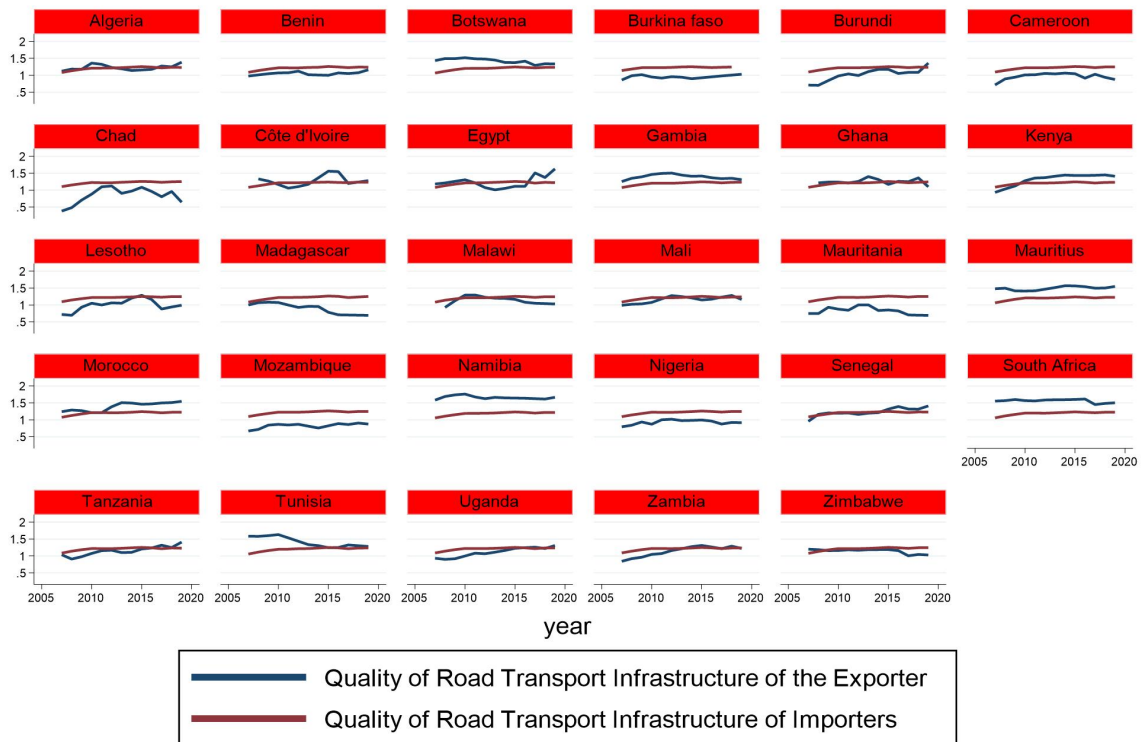


Figure 4. The relationship between the quality of road transport infrastructure of exporters and importing countries in Africa.

Source: Constructed by the Author.

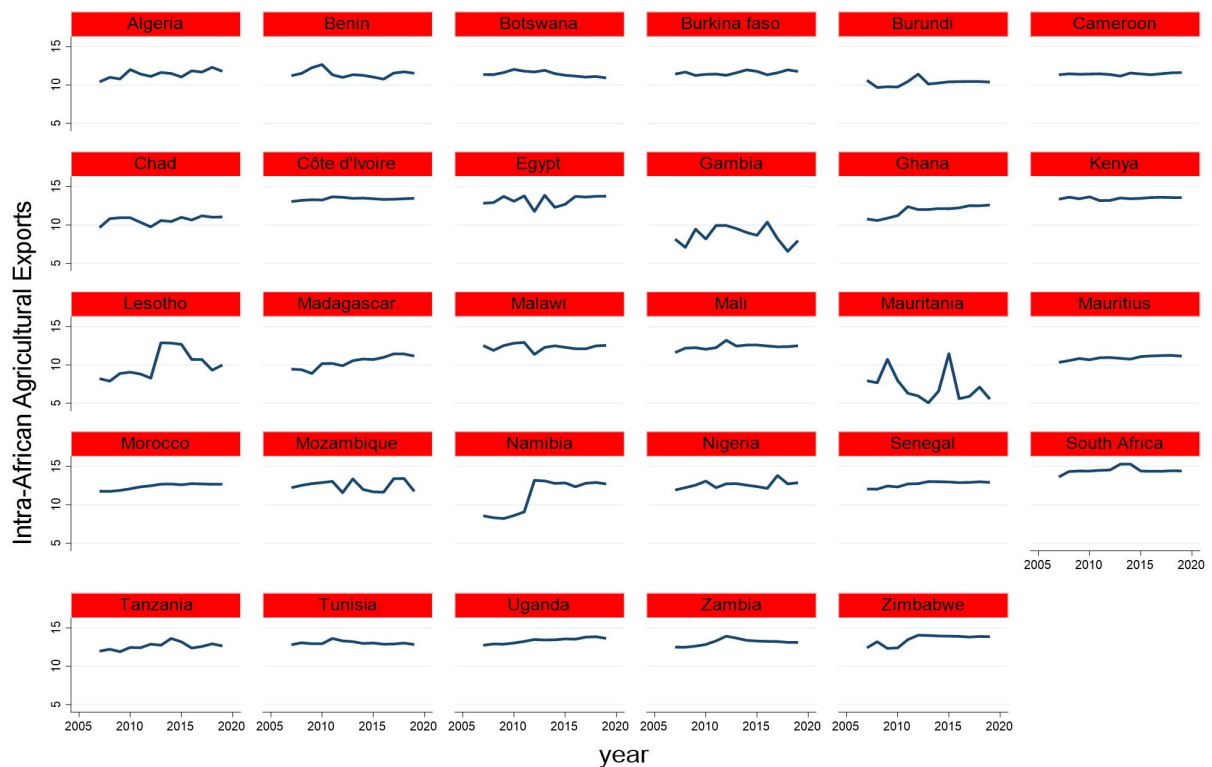


Figure 5. IAAEs trends.

Source: Constructed by the Author.

Table 3. Correlation Result.

Variable	(1)	(2)	(3)	(4)	(5)	(6)
(1) Intra-Africa Agricultural Exports	1					
(2) Quality of Road Transport Infrastructure of the exporting country	0.321	1				
(3) Quality of Road Transport Infrastructure of importing countries	0.0695	-0.0378	1			
(4) Gross Domestic Product of the exporting country	0.4806	0.1478	0.061	1		
(5) Gross Domestic Product of the importing countries	0.1584	0.1501	0.8231	0.1074	1	
(6) Distance	-0.0136	0.3451	-0.0901	0.0167	-0.0077	1

Source: Computed by the Author.

The descriptive result (**Table 4**) noted that all the mean values of the variables under consideration fall within the minimum and maximum limits. This shows that the variables are well-behaved and consistent. In addition, the wider variation of the variables from their mean values

depicts a vast difference in the performance of countries in Africa with respect to the variables under study. Furthermore, the standard deviations of the variables, except intra-Africa agricultural exports, are below the mean values, which sets the stage for our regression analysis.

Table 4. Summary Statistics.

Measurement and Variable	Expected Sign	Mean	Standard Deviation	Minimum	Maximum
Intra-African Agricultural Export (in million US\$)	-	346.14	478.27	0.0002	4419.27
Quality of road transport infrastructure of the exporting country (value ranked from 1 to 7)	Positive	3.35	0.84	1.464	5.827
Quality of road transport infrastructure of importing countries (value ranked from 1 to 7)	Positive	3.35	0.15	2.877	3.546
Gross domestic product of the exporting country (Current US\$ in million)	Positive	58.3	10.3	0.799	568
Gross domestic product of the importing countries (Current US\$ in billion)	Positive	90.73	10.69	60.39	118
Distance (in thousand km)	Negative	183.23	33.63	131.63	272.53

Source: Computed by the Author.

3. Result and Discussion

3.1. Diagnostic Test Results

The study conducted the test for CD^[56,58] with the null hypothesis of no CD. The probability values for the Pesaran (0.6246) and Friedman's (0.9822) tests are above the 0.1 threshold (**Table 5**). Hence, the study fails to reject the null hypothesis and confirm the presence of cross-sectional independence.

To avoid spurious regression that can lead to bias and inconsistent estimates, the study conducted the Fisher augmented Dickey-Fuller test and the Phillips-Perron augmented Dickey-Fuller test^[59,60]. These tests are first-generation unit root tests in the absence of CD. The null hypothesis of these tests is that there are no unit roots. From **Table 6**, Fisher's augmented Dickey-Fuller and the Phillips-Perron unit root test results suggest that intra-African agricultural exports, the quality of road transport infrastructure of the exporting country,

the quality of road transport infrastructure of importing countries, and the GDP of importing countries are integrated at the level. The GDP of the exporting country is stationary at the level for the Fisher's test, but stationary at the first difference in the Phillips-Perron test. However, distance is stationary at first difference in both tests. Thus, all the variables in both tests for unit roots are integrated at order one (**Table 6**).

In light of the result of the diagnostic tests conducted, the large cross-section and small time sample, the suspected serial correlation and endogeneity, and the likelihood of multicollinearity and heterogeneity obtained from our correlation result, the study employed the two-step SGMM as the estimation technique for this study because it fits the data set.

3.2. Regression Results

This section examines the short and long-run effects of the quality of road transport infrastructure on

intra-African agricultural exports, while also considering the role played by regional trading blocs in determining intra-African agricultural exports. To assess these relationships, the two-step SGMM, as the main estimation technique, was employed, while the pooled mean group estimator was used as a robustness check.

Table 7 reports results for Equations (2), (4), and (5) that explain the determinants of intra-African agricultural exports. Equation (2) is the baseline model. It

presents findings for the effect of the economic sizes of trading partners and distance on intra-African agricultural exports. Equation (4), is the infrastructure model, which presents results for the effects of the quality of road transport infrastructure on intra-African agricultural exports. A combination of Equations (2) and (4) variables produced Equation (5), which is the combined model, showing the infrastructural and non-infrastructural determinants of intra-African agricultural exports.

Table 5. Result for Cross-Sectional Dependence.

Test for Cross-Sectional Dependence	Coefficient	Probability Value
Pesaran	0.489	0.6246
Friedman	14.621	0.9822

Source: Computed by the Author.

Table 6. Stationarity Test Result.

Variable	Fisher Augmented Dickey-Fuller			Fisher's Phillip-Perron		
	Level	First Difference	Conclusion	Level	First Difference	Conclusion
Intra-Africa agricultural exports	105.05***	97.7162***	I(0)	144.96***	554.03***	I(0)
Quality of road transport infrastructure of the exporting country	128***	185.57***	I(0)	96.71***	228.06***	I(0)
Quality of road transport infrastructure of importing countries	344.89***	344.89***	I(0)	1369.18***	116.68***	I(0)
Gross domestic product of the exporting country	149.61***	204.20***	I(0)	57.26	405.22***	I(1)
Gross domestic product of the importing countries	368.26***	103.51***	I(0)	91.85***	251.94***	I(0)
Distance	4.63	72.19***	I(1)	5.2606	239.74*	I(1)

Note: * $p < 0.1$, *** $p < 0.01$.

Source: Computed by the Author.

Table 7. Dynamic Panel-Data Estimate, Two-Step SGMM, and Pooled Mean Group Results.

Intra-Africa Agricultural Exports	Equation (2)		Equation (4)		Equation (5)		PMG	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
Lag of Intra-Africa Agricultural Exports	0.345*** (0.07)	-	0.38*** (0.07)	-	0.31*** (0.10)	-	-	-
Quality of Road Transport Infrastructure of the exporting country	-	-	1.25** (0.61)	2.01** (0.93)	1.24** (0.50)	1.80*** (0.67)	-0.57 (0.55)	0.37** (0.15)
Quality of Road Transport Infrastructure in importing countries	-	-	1.84 (1.28)	-	1.36 (1.70)	-	-	-
Gross Domestic Product of the exporting country	0.45*** (0.09)	0.70*** (0.12)	-	-	0.43*** (0.10)	0.62*** (0.12)	-0.66 (0.48)	0.35*** (0.10)
Gross Domestic Product of the importing countries	-0.08 (0.23)	-	-	-	-0.42 (0.37)	-	-	-
Distance	-0.81 (0.54)	-	-	-	-1.35** (0.59)	-1.96*** (0.76)	2360.1 (5417.8)	14.31 (46.11)
Constant	12.05 (7.87)	-	3.67** (1.70)	-	24.73** (11.65)	-	-111.8 (12.3)	-
Number of countries	29	-	29	-	29	-	-	-
Number of Instruments	10	-	7	-	12	-	-	-

Table 7. Cont.

Intra-Africa Agricultural Exports	Equation (2)		Equation (4)		Equation (5)		PMG	
	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run	Short Run	Long Run
AR(1)	-2.02**	-	-2.15**	-	-2.03**	-	-	-
AR(2)	-0.46	-	-0.39	-	-0.54	-	-	-
Sargan <i>p</i> -value	0.62	-	0.58	-	0.66	-	-	-
Hansen <i>p</i> -value	0.80	-	0.68	-	0.68	-	-	-
Error correction term	-	-	-	-	-	-	-0.67*** (0.07)	-

Note: ** $p < 0.05$, *** $p < 0.01$. Values in parentheses represent standard error.
Source: Computed by the Author.

It is confirmed by the results from the two-step SGMM in the baseline, infrastructural, and combined models that the previous year's intra-African agricultural exports are associated with a 0.35, 0.38, and 0.31 percentage point increase in present intra-African agricultural exports, as indicated by the inelastic coefficients (0.35, 0.38, and 0.31) with uniform probability values of less than 0.01. This implies that present intra-African agricultural exports increase by approximately 0.35 percentage points on average, with a 1 percentage point rise in the present stock of quality of road transport infrastructure. Hence, the previous year's intra-African agricultural exports promote the current year's intra-African agricultural performance.

Similarly, the short and long-run elastic relationship of the quality of road transport infrastructure of exporting countries is also confirmed in the infrastructural and combined models with ($p < 0.01$) and coefficients of 1.25 and 1.24 in the short-run and 2.01 and 1.80 in the long-run. This means that, a 1 standard deviation increase in road transport infrastructure of the exporting country results in an average 1.24 to 1.25 and 1.80 to 2.01 percentage point increase in intra-African agricultural trade in the short and long run, respectively. The consistent elastic short and long-run relationship between the quality of road transport infrastructure and intra-African agricultural exports suggests that the quality of road transport infrastructure strongly and significantly enhances intra-African agricultural exports. The enhancement in intra-African agricultural exports rises sharply by approximately 0.66 percentage points on average in the long run. Thus, the underlying mechanism is that the improvement in the quality of road transport infrastructure in agricul-

tural production areas with poor road transport infrastructure can open up market linkages connecting production centers to major export routes^[72].

Furthermore, the construction of quality road infrastructure in regional centers will result in the relocation of agricultural industries to provincial agricultural production centers. This reduces travel time for farmers, truckers, traders, and exporters, and results in an efficient supply of agricultural produce to the market^[73]. This study result aligns with that of several previous studies^[30,46,51,74,75]. The sustainable long-term effect of the quality of road transport infrastructure on intra-African agricultural exports shows that the construction of new roads to open up market linkages and the rehabilitation of existing roads will further enhance the role of quality road transport infrastructure in promoting intra-African agricultural exports. In addition, improving the quality of road transport infrastructure of exporting countries also have positive spillover effects on economic growth, reducing poverty, inequality, and hunger.

The results from the baseline and combined models also show that the economic size of the exporting country is a driver of intra-African agricultural exports. The elasticity of intra-African agricultural exports with respect to exporters' GDP is approximately 0.45 and 0.43 in the short-run and 0.69 and 0.62 in the long-run, respectively. This implies that a move to increase the exporting country's income will, respectively, lead to a 0.44 and 0.66 percentage point increase in intra-African agricultural trade in the short and long run. This result is statistically significant at the 1% level.

The study further highlights the effects of regional trading blocs on intra-African agricultural exports. **Ta-**

ble 8 shows that the EAC, ECOWAS, and SADC have positive and significant coefficients in both the short and long-run. This implies that the formation of regional trading blocs in Africa leads to trade creation. Specifically, the EAC has short and long-run coefficients of 0.79 and 1.48, respectively. This suggests that the EAC is strong in facilitating trade, and its strength increased in the long-run. Similarly, the ECOWAS short and long-run coefficients are 0.54 and 0.95, respectively, implying that the ECOWAS strengthens intra-African agricultural exports, with more export expansion among member states in the long-run. In parallel, the short and long-run coefficients of the SADC are 0.60 and 1.08, respectively. This means that the SADC member states trade more amongst each other, and the volume of trade increases in the long-run. Thus, comparatively, the EAC is

more integrated than the SADC, followed by the ECOWAS. These findings are similar to those of Bakouan and Ouedraogo^[46] and Edris^[51]. Additionally, the diagnostic tests, such as the Hansen and Sargan tests, suggested that the estimating instruments are reliable, thereby reducing the likelihood of endogeneity.

In summary, the regression analysis provides insightful results on the role of the quality of road transport infrastructure, economic growth, and regional integration in promoting intra-African agricultural exports. These findings call for a balanced growth between economic and environmental sustainability. The promotion of green finance for the construction and rehabilitation of road transport infrastructure in exporting countries ushers plausible pathways to achieving green growth.

Table 8. Regional trading bloc impact on intra-African agricultural exports.

Variable	Short Run	Long Run
Control variables	Controlled	Controlled
Arab Maghreb Union	0.19 (0.51)	-
East African Community	0.79* (0.44)	1.48* (0.78)
Economic Community of West African States	0.54* (0.27)	0.95** (0.46)
Southern African Development Community	0.60** (0.29)	1.08** (0.49)
Constant	5.90*** (0.89)	
Number of countries	29	
Number of Instruments	11	
AR(2)	-0.23	
Sargan P-value	0.42	
Hansen P-value	0.28	
F-Statistic	14.66***	
Lag of Intra-Africa Agricultural Exports	0.47*** (0.08)	

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Values in parentheses represent standard error.
Source: Computed by the Author.

3.3. Robustness Checks

The introduction of the lag of intra-African agricultural exports makes the model susceptible to at least first-order autocorrelation [AR (1)], but ideally not to second-order autocorrelation [AR (2)]. The AR (1) and AR (2) null hypotheses of no autocorrelation are tested. The results of the tests obtained, as shown in **Table 9** for Equations (2), (4), and (5), revealed that the probability values for AR (1) are statistically significant at 5%, confirming the presence of first-order autocorrelation as ex-

pected. However, the probability values for the AR (2) are not all statistically significant at the 5% level. Thus, we reject the null hypothesis of second-order autocorrelation. Hence, the efficiency of our models is confirmed.

Another common issue encountered in dealing with the two-step SGMM model is the use of weak instruments. Consequently, to test the validity of the instruments employed in the model, the study conducted the Sargan and Hansen test for valid instruments with the null hypothesis of group validity of the instruments. The results from **Table 7** show probability values for the Sar-

gan test for Equations (2), (4), and (5) (0.62, 0.58, 0.66) and the Hansen test (0.80, 0.68, and 0.68), respectively, are greater than 10% but far from 1. This implies that the models do not suffer from invalid instruments and overfitting. Hence, the study can conclude that the models are valid.

To test the appropriateness of using the two-step SGMM, the study tests for the presence of a persistent dependent variable in the model and whether the dependent variable exhibits a random walk. As a rule of thumb, where the coefficient of the lagged dependent variable tends to 1 for a large number of cross-sectional units and a small time, the two-step difference SGMM performs poorly as a result of the use of a weak instrument^[71]. Hence, the two-step SGMM should be used. Theoretically, this can be detected, according to Bond et al., when the estimated coefficient of the lag dependent variable in the two-step difference SGMM is closer to or below the fixed effect estimated coefficient^[76]. Consequently, comparing the results from **Table 9**, it is revealed that the coefficient of the lag of intra-African agricultural exports lies between those of the pooled OLS and fixed ef-

fect. Specifically, it is close to or below the fixed effect (that is, $0.2674 < 0.3937$). Hence, the internal validation of the robustness of the two-step SGMM estimator is confirmed.

The pooled mean group (PMG) estimator was also employed to test for the robustness of the regression models. The PMG was propounded by Pesaran et al.^[61]. This approach assumes uniform long-run coefficients with short-run coefficients permitted to vary across cross-sections. From **Table 7**, it is observed that the long-run coefficients of exporters' GDP and the quality of road transport infrastructure are positive and statistically significant at a 5% level, at most. This result is consistent with the long-run result obtained from Equations (4) and (5) for the quality of road transport infrastructure. Furthermore, the finding also confirms the long-run positive effect of exporters' GDP on intra-African agricultural exports in Equations (2) and (5). Finally, the error correction term is negative with a coefficient of 0.67. This indicates that short-run disequilibria are corrected at a speed of 67%. That is, there is a long-run relationship. We therefore conclude that our regression results are robust.

Table 9. POLS, FE, and Two-Step Difference SGMM results.

Variable	POLS	FE	Two-Step Difference SGMM
Lag of Intra-Africa Agricultural Exports	0.8139*** (0.0506)	0.3937* (0.1321)	0.2674** (0.1110)
Quality of Road Transport Infrastructure of the exporting country	0.3473 (0.2592)	0.3052 (0.5425)	-0.0941 (0.4237)
Quality of Road Transport Infrastructure in importing countries	-0.8341 2.4335	2.2388 (1.9560)	3.0925 (2.3207)
Gross Domestic Product of the exporting Country	0.1268*** 0.034	-0.1450 (0.1838)	0.1604 (0.2414)
Gross Domestic Product of the importing Countries	-0.1193 (0.4645)	0.3372 (0.4316)	-0.2177 (0.6331)
Distance	-0.4227 (0.2685)	-3.8786 (12.3450)	43.6275 (43.8432)
Constant	8.866 (9.2053)	44.9991 (148.8832)	-
Number of Observations	339	339	305
Number of Groups	-	29	29
Number of instruments	-	-	8
R-Squared	0.7989	0.368	-
F-statistic	103.61***	9.55***	6.37***

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Values in parentheses represent standard error; POLS means pooled ordinary least squares, and FE is fixed effects.
Source: Computed by the Author.

4. Conclusion and Policy Implications

The quality of road transport infrastructure is crucial for the movement of agricultural goods, especially

from rural areas with poor road transport infrastructure. Despite the prominence given to the quality of road transport infrastructure, studies that specifically examine the full length of the effect of quality road transport infrastructure on intra-African agricultural exports

are limited. This study examines the role of exporting and importing countries in improving the quality of road transport infrastructure to assess the short and long-term benefits of intra-African agricultural trade. To achieve this, data were collected from 2006 to 2018 and analyzed using the novel two-step SGMM, which captures both short and long-run effects. The study revealed that the quality of road transport infrastructure of importing countries does not play a role in determining intra-African agricultural exports. However, the quality of road transport infrastructure of the exporting country is the major driver of intra-African agricultural exports, especially in the long run. The results also highlight how green financing of road transport infrastructure projects can increase intra-African agricultural exports while reducing environmental degradation.

Hence, this study recommends the need to construct new roads and rehabilitate existing roads that connect farmers, truckers, and traders to export corridors on a sustainable basis, thereby achieving a long-term impact. However, for such growth to be environmentally sustainable, the political and institutional will of national authorities to support green financing and investment in road transport infrastructure should be strengthened. Moreover, funding of green road transport infrastructure activities and projects should be prioritized. Government authorities should de-risk green infrastructure projects to attract investment, especially in road transport infrastructure, and establish public-private partnership road infrastructure projects for the co-promotion of green road transport infrastructure investment projects.

Future studies could examine the effect of road transport infrastructure on regional trading blocs and global trade. Furthermore, future studies could interact road transport infrastructure with the regional trading bloc dummy variable to investigate their joint effects on trade. Lastly, a study specifically on the impact of green road transport infrastructure investment on trade will be a grey area for future research directions.

Author Contributions

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