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The world trade network: Country centrality and the intra-Africa trade

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Abstract
Global trade is based on a group of multifaceted interactions between nations that can be modeled as an incredibly dense network of intertwined agents. On the one hand, this network might favor the trade performance of countries, but on the other, it can also discourage international trade. In this article, we investigate whether and how much the structure of the trade network may explain for the performances of intra-African trade among certain African nations. We calculated the centrality indexes for the nations and applied them to regression analysis. We then employ a negative binomial regression framework with these indicators as target regressors. In doing so, we also compare the effects of different measures of centrality- specifically, the degree centrality measures and the clustering coefficient. Our findings suggest that, albeit boosting the degree centrality index tends to improve the trade flows inside Africa, on average, the intra-African trade flow was shown to be negatively impacted by the clustering coefficient, which is congruent with theory and our predictions.

Keywords: World trade network, country centrality, trade, Africa

1. Introduction

As trade barriers gradually decay, the world becomes more interconnected as businesses look for prospects to sell to new markets and consumers choose to import a wide range of diverse goods. This is due to both the reduction in bilateral trade barriers (Hummel, 2007) [16] and the intensification of multilateral linkages across economies (Magerman *et al*., 2013) [19]. In terms of Africa's trade share in the world market, there exists ample evidence that, Africa is a minor contributor to global goods trade. For example, (Schmieg, 2016) [24] argue that African trade accounted for barely 2.4 percent of total global trade, which has shown increment to 2.6 percent in 2019 (UNCTAD, 2019) [26]. The problem related to African trade flow is not only limited to its insignificant contribution to the world but a large share of the existing trade itself takes place with the rest of the world than within Africa and it remains low compared to levels in other continents in the world. For instance the findings of (Olney, 2022) [22] indicates that the intra-continental trade share in Africa is only 12 percent while comparative figures for America, Asia, Europe, respectively, 47%, 53%, 69%.

The existing literature on African studies connect the poor performance of African trade to numerous factors such as limited capacity for production and restricted diversity of the economy (Venables, 2003) [27] tariff-related trade costs, poor infrastructure (Limão and Venables, 2001) [18] and poor institutional quality (de Groot *et al*., 2004; Nunn, 2007; Stolzenburg *et al*., 2019) [21, 25]. Even pieces of literature combining the above determinants have mainly focused on bidirectional impacts among trade relations, disregarding the multilateral dimension of trade in general. Nonetheless, bilateral trade is affected by all trade flows for both the exporter and the importer, not only the two countries under consideration.

Recent empirical works in the field such as (Bernard and Moxnes, 2018; Chaney, 2014; Magerman *et al*., 2013) [6, 11, 19], however contend that trade is inherently an interconnected activity because the overwhelming percentage of trading activities involve at least one large firm with multiple trading partners. It was in pioneering works of works of (Anderson and Wincoop, 2003) [1] the role of multilateral trade resistance (MTR) as a third-country effect was incorporated as a determinant of bilateral trade flows but the MTR in this model is not observable and has an influence on the intensive margin of trade, while even at the national level, the trade matrix contains a large number of zeros. Extending the work of AVw, (Melitz, 2008) [20] then implement the extensive margin into their model. In this study, the intensive and extensive effects of trade frictions on trade flows were separated.

As a trade-off, however, no third-country dependence is modeled. Despite the fact that many developing countries like African countries have bilateral trade flows that that have zero values, the AvW model did not consider this phenomenon (Magerman *et al*., 2013) [19].

The issue of multilateral trade resistance (MTR) is unobservable and conceptual in theoretical perspectives. The literature has offered a number of empirical methods to directly quantify the MTR. To begin with, AvW (2003) proposes that the model be estimated using an iterative NLS approach to solve MTR as a function of observables. However, the approach has not been generally implemented in the literature, owing to the likelihood of many equilibria in the existence of asymmetric trade flows and its computationally complex nature to extend panel data setup (Magerman *et al*., 2013) [19]. Other lines of literature such as (Baier and Bergstrand, 2009) [3] included remoteness term constructed as GDP-weighted averages of trade costs as proxies for the MR terms. However, AvW argue that this method is 'disconnected from theory', even if the distance term includes all observable trade costs rather than distance only. Furthermore, several empirical studies, (Redding and Venables, 2004) [23], have captured the MTR by incorporating dummies for importer and exporter. This is the most commonly utilized method of capturing the unobservable MTR term in trade research. This approach leads to consistent estimates of the gravity equation in the log-linear form and does not impose much structure on the underlying model (Head and Mayer, 2014) [15]. Others such as (Baier and Bergstrand, 2009) [3] on the other hand approximate MTR by a linear Taylor approximation to get tractable results. They subsequently show that the approximation error is small for most country pairs.

This study employs the alternative empirical approach posited by (Bruyne *et al*., 2013b) [9] to capture MTR, notably network indicators. The HMR model, which accounts for firm heterogeneity but does not incorporate multilateral trade resistance, and AVw, which incorporates multilateral trade resistance but ignores firm heterogeneity, can be combined using network analysis. Using this strategy, we can naturally incorporate multilateral trade measures such as the number (extensive margin) and intensity (intensive margin) of trading partners into the bilateral models. In recent work (Chaney, 2014) [11] claims that companies could trade only in a location they have contact and they either search for trading partners directly, but also they can leverage their existing list of contacts to look for new partnerships distantly emphasizing the role of the trade network in augmenting bilateral trade flow.

Recent research has included some descriptive statistics of the World Trade Web (Bhattacharya *et al*., 2008; Fagiolo *et al*., 2010) [7, 14], but only serves as a standalone observation of the network itself. In this context, Benedictis, (2011) [4] provides a first attempt at integrating network analysis into gravity models, which was followed by works like (Antonietti *et al*., 2022; Benedictis *et al*., 2014; Bruyne *et al*., 2013a) [2, 5, 9]. In Africa, there are recent attempts of applying the concept of Networks to trade. For instance, Shepherd (2016) uses network measures to analyses the value chain connectedness and argues that it is important to consider not only a nation's performance but also of its neighbors. Most of the studies of trade flows undertaken in Africa follow the traditional gravity equations which model bilateral trade flows as a function of income and a vector of distance variables that have mostly concentrated on bidirectional repercussions between trading partners while overlooking the multilateral character of trade in general. Unlike traditional gravity models, this research makes use of network variables to assess the impact of third-country effects on intra-African export flows. This extends the empirical gravity literature pertaining to African studies on international trade. As a result, this study draws on the rapidly growing literature on networks to examine how African countries' intra-exports are influenced by their trading partners' interactions with one another and the remainder of the globe. This research contributes to the empirical gravity studies by incorporating and stressing the role of network indicators on the trading activity of African economies.

The remainder of this article is structured as follows. The data used for the empirical analysis is described in section 2. section three deals with description trade network. Section 4 presents an empirical methods for econometric analysis and section 5 discuses the main findings. concluding remarksa are provided in section 6.

2. Description of Trade Network

Literature defines the International trade Network as a graph representing the web of bilateral-trade relationships between countries in the world. Following M.E.J. Newman (2010), to represent the world trade web as a network, countries represent nodes or vertices while the bilateral trade flows between the trading partner countries/ nodes are given by links/edges between the nodes. Recent empirical findings in international trade indicate that the position of the country in the trade Network is fundamental in understanding and explaining trade flows between trading counties. Adjacency matrices are the most popular way to visualize networks. If n is the number of countries in our sample, the adjacency matrix A is a square matrix of dimensions $n \times n$ with elements A_{ij} such that A_{ij} takes a value of one if there is an edge from vertex i(exporting country) to j(importing country) and zero otherwise. If we attach weights to the links, however, for example by using, trade volume" measured by the level of exports and imports between a pair of vertices, we obtain a weighted network. The measure and analysis of centrality that measures how "central" a vertex is in the WTW is the first fundamental departure from the bilateral analysis in traditional gravity models, as this looks at the effect of a particular trading partner inside the whole network. There are numerous metrics or measures related to network analysis the focus of this study however is only the degree centrality and the clustering coefficients.

Degree is the number of total trading linkages (partners) in the bidirectional network, which is generally expressed as a percentage of the total number of possible links. The degree of the vertex i, k_i (the number of trading partners of country i in our study) is given by $k_i = \sum_{j=1}^{n} A_{ij}$; where A_{ij} =1 if there is a connection between counties i and j. Every node/country has an in-degree and an out-degree, which represent the number of import and export partners, respectively, if the trade network is directed. To reveal the outward multilateral resistance, p_i, we use the out-degree of an exporter, and similarly, for the inward multilateral resistance term P_j, we use the in-degree of an importer. The weighted-out degree K_i^{out} of node i given by $K_i^{out} = \sum_{j=1}^{n} V_{ij}$ and the weighted in-degree $K_j^{in} = \sum_{j=1}^{n} V_{ji}$ where $V_{ij} = A_{ij}$ multiplied by the export volume and $V_{ij} = A_{ij}$ is the total number active exporters. The weighted in-degree of the importers is similarly defined in a similar way.

The Clustering Coefficient on the other hand measures the average probability that two neighbors of a vertex are themselves neighbors or the clustering coefficient, in other words, expresses the predicted or average likelihood that a pair of i's trading partners is also a trading pair and engaged in trade. A larger clustering coefficient is likely to have a detrimental influence on trade flows. The more integrated a country's trading partners are, the more they prefer to trade substantially among themselves rather than with external allies, resulting in less bilateral trade between any of these business partners and the initial economy.

Following (Jackson, 2010), the clustering coefficient is specified as:

$$C_i = \frac{\sum_{i=1}^{n} a_{ij} a_{ik} a_{jk}}{\sum_{i=1}^{n} a_{ij} a_{ik}} \qquad 1$$

The portion of neighbors that are also connected is represented by a node's local clustering coefficient Ci. The clustering coefficient, Ci, ranges from 0 to 1, with 1 being the value if and only if all transitive triples that can come from node I are existent, and 0 otherwise.

3. Data

Data on African countries' export flows, along with several gravity indicators, are required for our empirical approach. The first set of estimates was based on data from the UN's COMTRADE database, which included export trade flows from 41 African countries. Data was collected for the period 2000-2018. Trade data is utilized to compute network indices using the free source tool Gephi (9.2), in addition to being used as a dependent variable. For the economic mass of countries, measured as GDP of both the exporters and importers in current US dollars, we use the WITS while data on bilateral distance and geographic indicators are also collected from the BACI dataset from CEPII.

4. Empirical approach

In what follows, we want to assess the role of the WTN on intra-African trade flows. At the same time, we want to control for additional socio-economic factors that can have an impact on the flow of Intra-African trade. The baseline model that we adopt to test for the role that network centrality has played in explaining the intra-African trade flows is the following:

$$Y_{it} = \beta_0 + \beta_{1,it} TNC_{it} + Z_{it}^{'} \beta_{zt} + \gamma_t + \varepsilon_{it} \qquad \ldots\ldots\ldots\ldots\ldots 2$$

Where Y_{it} is Export (Exp) from country *i* and in year *t*. The variable TNC_{it} stands for trade network centrality and represents a given centrality metric (respectively: weighted degree and clustering coefficient). More specifically, the weighted out degree of the exporter (lnwod_o), weighted in the degree of the importer(lnwod_d), the clustering coefficients of the exporter(cluster_o), and the clustering coefficients of the importer(cluster_d). Besides, Z is a vector of additional regressors that can explain the intra-African trade flows, namely GDP of both the exporters and importers (GDP-o and GDP-d), the bilateral distance between the capital cities of the trading partners (dis), sharing common boarder (contig), common official language (comlang-off), common colony (comcol), member to a world trade organization (wto), member of the regional trade agreement (rta) and others. The term γ_t is a series of year-specific dummies that capture the trend in the dynamics of trade flows for all our countries, while ε_{it} is the stochastic error component with zero mean and finite variance σ^2. We group the standard errors at the country level in order to account for the arbitrary within-group correlation of the data that is not observed.

Furthermore, to assess the effect of network variables on each margin independently, we deconstruct trade into extensive and intensive margins. In this study following empirical trade is decomposed into the most basic notion of margins, such that total trade equals the number of exported products times the average value per product exported. Mathematically;

$$X_{ijt} = n_{ijt} \bar{X}_{ijt}.$$

Where X_{ijt} denotes total bilateral trade between country i (African countries) and j (trading Partners) at time t, n_{ijt} represents the number of products exported from African countries to j counties at time t (measured as the number of HS6 product lines in this study) and $\bar{X}_{ijt}$ is the average value per exported product line. To examine the impact of Network and Institutional quality and institutional distance on each margin of trade, Equation (1) is re-estimated using each margin indicated in equation(3) as a dependent variable.

A panel negative binomial regression model is used to estimate Eq(1). As is typical for count-data models, we test for overdispersion of our data, that is, for the possibility that the conditional mean could be lower than the conditional variance, often as a result of the existence of unobserved factors that could influence the trade flows. In this situation, the primary premise supporting the Poisson model's application is violated, and the negative binomial model more closely approximates the observed data. Following (Cameron and Trivedi, 1986) [10], a likelihood ratio test was employed to test whether the Negative binomial distribution is preferred over a Poisson distribution

5. Econometric results

Table 1 below is the results from NB and PPML models. One can easily see that evaluated by AIC and BIC the NB model performs better than the PPML. Besides, the PPML is not appropriate as the data has over dispersion.

The first column provides the results of the basic gravity variables which are expected results and significant. The result shows that while the income levels both at exporting and importing countries positively affect the intra-African trade, the bilateral distance between the trading partners significantly reduces the intra-African trade. The second specification included in the table below allows for the effect of the Linder term, to test the hypothesis that trading partners with a similar level of income have similar product tests and thus increase bilateral trade. The significant and negative Linder term indicates that higher income disparity between the trading partners reduces bilateral trade which is consistent with the theory. The estimated basic gravity model in column (1) shows that the GDP of the exporters and importers which are a proxy for market size positively and significantly affects intra-Africa trade. Specifically, a 1% percent increase in GDP of the exporter and importer increases the intra-Africa trade by 0.988% and 0.381% respectively. The result is comparable with the coefficient of the variables in African countries' international exports. Similarly, the coefficient of the bilateral distance between pairs of African trading countries shows that a 1% increase in the bilateral distance reduces intra-African trade by about 2.85% which is much higher than its corresponding effect on African international exports. Column(2) incorporates the Linder term (linder) to test the Linder hypothesis that states countries of similar income relatively trade more among themselves. As can be seen from column (2), following the inclusion of the Linder term, the magnitude, sign, and significance of the basic gravity variables in specification (1) remain stable. Since the variable is a measure of income difference, a higher value of the variable is expected to decrease intra-Africa trade if the hypothesis holds. As expected, the coefficient of the Linder term is negative and statistically significant, indicating that country pairs with lower income differences are relatively trading more among themselves as they develop the same preferences and hence productions. The finding indicates that the Linder hypothesis holds in intra-Africa trade.

Table 1: Basic Results

	(1)	(2)	(3)	(4)	(5)
Variables	**NB**	**NB**	**NB**	**NB**	**PPML**
lngdp_o	0.988***	0.998***	0.939***	0.934***	0.271
	(0.0876)	(0.0876)	(0.0871)	(0.0870)	(0.176)
lngdp_d	0.381***	0.396***	0.416***	0.425***	-0.0876
	(0.0807)	(0.0809)	(0.0812)	(0.0810)	(0.132)
lndist	-2.853***	-2.855***	-2.171***	-2.185***	-1.158***
	(0.0310)	(0.0310)	(0.0448)	(0.0456)	(0.153)
linder		-0.00971***	-0.0106***	-0.0141***	-0.0276*
		(0.00358)	(0.00365)	(0.00367)	(0.0151)
contig			1.223***	1.446***	0.703***
			(0.0782)	(0.0795)	(0.201)
comlang_off			0.449***	0.490***	1.127***
			(0.0595)	(0.0607)	(0.220)
comcol			0.274***	0.227***	-0.662***
			(0.0631)	(0.0642)	(0.222)
col45			-2.385***	-2.464***	-1.120***
			(0.477)	(0.477)	(0.418)
wto			0.445***	0.547***	-1.722***
			(0.116)	(0.118)	(0.613)
COMESA				0.899***	0.916***
				(0.0869)	(0.300)
SADC				0.253***	1.240***
				(0.0930)	(0.378)
ECCAS				0.745***	0.953***
				(0.122)	(0.364)
ECOWAS				0.377***	0.0848
				(0.0995)	(0.466)
rta			0.616***		
			(0.0625)		
Constant	5.440***	5.142**	-0.194	-0.606	15.68***
	(2.067)	(2.069)	(2.095)	(2.095)	(4.411)
Observations	32,311	32,311	32,311	32,311	32,311
R-squared					0.703
Exporter FE	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
AIC	375116.7	375111.4	374394.9	374337.8	9.62e+08
BIC	376030.5	376033.5	375367.4	375335.4	9.62e+08
Overdispersion (α)	8.090***	8.089***	7.905***	7.89***	

The standard errors are reported in parenthesis. All models have an importer, an exporter, and a year dummy. * denotes significance at the 5% level, ** at the 1% level, and *** at the 0% level. The panel spans the years 2000 through 2018. COMESA, SADC, ECCAS, and ECOWAS are the acronyms for the Regional Economic Communities (RECs) to which the majority of African countries belong, and a dummy variable is used to account for them.

Column 3 includes cultural and historical ties between trading partners (common border, Common official language, and common colony) and having a common regional trade agreement (rta) and the effect of economic integration such as if both countries are members of the world trade organization (WTO), where all variables are consistent with our prior expectation. Besides following the inclusion of these variables, the coefficients and significances of the basic gravity variables in the preceding columns remain stable.

Column (4) disintegrates the regional trade agreement (rta) variable into five major regional trade integrations in Africa namely AMU, COMESA, ECOWAS, SADC, and ECCAS. While the Regional Economic Communities in Africa are not limited to the aforementioned ones, these happened to be our choice because they are where most African countries belong. While the AMU is used as a base category, column 4 includes the remaining 4 regional trade agreements in Africa and the results indicate that all regional trade agreements enhance intra-trade in Africa. In terms of the magnitude, intra-COMESA trade is high followed by ECCAS. As can be seen from the table above, the Regional Economic Communities (RECs) sometimes termed as regional trade agreements generally seem to enhance intra-Africa trade. Column 5 estimates the data with PPML but the results from PPML are not used here because the data is found to have overdispersion in which case PPML is not appropriate.

Inter-African trade and the effect of trade networks

This section extends the aforementioned analysis and focuses on the explanatory role of trade networks on intra-African trade. Since the data is found to have overdispersion, the discussions will be based on the NB model.

Table 2: Trade Network and Intra-African trade

	(Basics)	**(Degree Centrality)**	**(Clustering Coefficient)**	**(All)**	**(5)**
Variables	**NB**	**NB**	**NB**	**NB**	**PPML**
lngdp_o	0.934***	-0.224***	0.839***	-0.234***	-0.0356
	(0.0870)	(0.0813)	(0.0881)	(0.0811)	(0.140)
lngdp_d	0.425***	0.202***	0.448***	0.207***	-0.492***
	(0.0810)	(0.0732)	(0.0817)	(0.0733)	(0.119)
lndist	-2.185***	-2.079***	-2.214***	-2.090***	-1.155***
	(0.0456)	(0.0408)	(0.0453)	(0.0407)	(0.153)
linder	-0.0141***	-0.0178***	-0.0109***	-0.0174***	-0.0255*
	(0.00367)	(0.00323)	(0.00369)	(0.00324)	(0.0150)
contig	1.446***	1.627***	1.494***	1.646***	0.695***
	(0.0795)	(0.0727)	(0.0794)	(0.0728)	(0.198)
comlang_off	0.490***	0.599***	0.474***	0.604***	1.135***
	(0.0607)	(0.0539)	(0.0602)	(0.0538)	(0.218)
comcol	0.227***	0.252***	0.237***	0.250***	-0.657***
	(0.0642)	(0.0579)	(0.0637)	(0.0578)	(0.221)
col45	-2.464***	-2.811***	-2.309***	-2.786***	-1.118***
	(0.477)	(0.405)	(0.473)	(0.405)	(0.412)
wto	0.547***	0.649***	0.331***	0.603***	-1.693***
	(0.118)	(0.105)	(0.115)	(0.105)	(0.624)
COMESA	0.899***	1.061***	0.966***	1.079***	0.911***
	(0.0869)	(0.0791)	(0.0864)	(0.0791)	(0.304)
SADC	0.253***	0.425***	0.398***	0.439***	1.225***
	(0.0930)	(0.0846)	(0.0927)	(0.0845)	(0.377)
ECCAS	0.745***	0.616***	0.824***	0.634***	0.935**
	(0.122)	(0.115)	(0.128)	(0.116)	(0.367)
ECOWAS	0.377***	0.449***	0.434***	0.455***	0.0889
	(0.0995)	(0.0882)	(0.0990)	(0.0882)	(0.458)
lnwod_o		1.361***		1.361***	0.642***
		(0.0298)		(0.0294)	(0.126)
lnwid_d		0.482***		0.467***	1.277***
		(0.0555)		(0.0555)	(0.168)
cluster_o			-18.90***	-5.207***	-0.342
			(0.681)	(0.622)	(0.657)
cluster_d			0.804	0.846*	-0.340
			(0.505)	(0.466)	(0.473)
Constant	-0.606	-6.470***	15.54***	-2.654	-1.306
	(2.095)	(1.947)	(2.248)	(2.081)	(3.506)
Observations	32,311	28,887	32,311	28,887	28,887
R-squared					0.793
Exporter FE	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES
AIC	374337.8	362878.2	373554.3	362807.9	7.21e+08
BIC	375335.4	363879	374568.7	363825.3	7.21e+08
Overdispersion (α)	7.89***	5.67***	7.697***	5.65***	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

A closer look at the table above, column (1) includes basic gravity variables, historical and cultural ties along with, and integration variables. The estimated coefficients of all standard trade flows variables are significant and their signs are consistent with the predictions of the the gravity model except for the variable common colonizer (col45) which takes a value of 1 if both countries shared a common colonizer after 1945 as its effect is significant and negative. The market/ Economic size represented by the GDP of African exporting countries and their trading partner countries significantly determines intra-African trade flows. Their effect is positive as expected and significant at 1& level of significance.

Column (2) includes the degree centrality measures represented by the weighted out-degree of the exporter and the weighted in the degree of the importers respectively, while column (3) incorporates the clustering coefficients of the exporters and importers. In column (4) all network statistics are included together. Following the inclusion of the natural log of weighted out the degree of the exporter and weighted in the degree of the importer in column 2, we notice that the control variable remains stable and both the degree centrality measures are found to significantly and positively affect intra-Africa trade which is consistent with the hypothesis. As the degree measures are in the lateral log, the interpretation of the coefficient is the same as elasticity. Therefore while a 1% increase in the weighted-out degree of the exporter increases intra-African trade by about 1.36%, a similar increment in the weighted-in degree of the importer increases intra-African trade flows by about 0.48%. The result shows that the competition effect measured by the coefficient of the out-degree centrality and the market openness measured by the weighted-in degree of the importer countries are found to significantly stimulate intra-African trade.

Next, we included the clustering coefficient of the exporters and the importers in the model in column (3). The idea behind including the clustering coefficient is to capture third country dependence which assumes that the higher the clustering coefficient, the more connected the country's trading partners are themselves and thus the lesser will be the trade with the original partner. The table above shows while the clustering coefficient of the exporting countries is negatively and significantly affects intra-African export, the coefficient for the destination countries clustering coefficient is not found to influence the intra-African export. Finally, column 4 combines the degree centrality and clustering indicators. The sign and significance remain stable except for a minimal change in coefficients. When the degree centrality and clustering coefficients are included jointly, the sign and significance, and magnitude of both the weighted-out degree of the exporters and the weighted-in-degree of the importers do not show change. On the other hand, while the sign of the coefficient of the clustering coefficients remains stable, the magnitude of the origin country clustering coefficient has shown a significant dropped. Finally, column (4) presents the estimated results using the PPML model which also shows that while the degree centrality measures positively and significantly affect the intra-Africa trade as expected, the influence of the clustering coefficient is not significant.

Trade network and margins of intra-African trade

As is discussed in the preceding sections, in this sub-section we decompose the intra-African trade into the intensive and extensive margins to analyze the effect of network indicators on each margin separately. Following (EATON *et al*., 2004) this study dissects the total export into its most basic components so that trade volume represents the number of products exported multiplied by the volume of trade per product exported. In this section, we extend the above analysis by decomposing the total trade into extensive and intensive margins and analyzing the effects of the trade network on each margin of intra-Africa trade. The model was re-estimated separately using the intensive and extensive margins as dependent variables. The first four columns of the table indicate the estimation of the intensive margin, whereas the estimation results of the extensive margin are demonstrated in the next four columns.

Table 3: Panel Gravity estimates on Intensive and Extensive Margins of Intra-Africa trade

		Intensive Margin			Extensive Margin			
Variables	**Basics**	**Degree**	**Cluster**	**Network**	**Basics**	**Degree**	**Cluster**	**Network**
lngdp_o	0.877***	0.411***	0.830***	0.449***	0.788***	0.586***	0.674***	0.568***
	(0.0964)	(0.0920)	(0.0981)	(0.0918)	(0.0490)	(0.0471)	(0.0482)	(0.0471)
lngdp_d	0.128	0.0187	0.120	0.0247	0.196***	0.133***	0.190***	0.127***
	(0.0886)	(0.0846)	(0.0891)	(0.0840)	(0.0437)	(0.0418)	(0.0427)	(0.0417)
lndist	-0.781***	-0.768***	-0.819***	-0.754***	-1.562***	-1.546***	-1.567***	-1.549***
	(0.0453)	(0.0433)	(0.0454)	(0.0433)	(0.0231)	(0.0218)	(0.0225)	(0.0218)
linder	-0.00420	-0.00244	-0.00528	-0.00200	-0.000223	-0.000878	0.000595	-0.000828
	(0.00416)	(0.00389)	(0.00420)	(0.00387)	(0.00210)	(0.00194)	(0.00206)	(0.00194)
contig	0.147*	0.165**	0.147*	0.167**	1.025***	1.057***	1.064***	1.067***
	(0.0840)	(0.0802)	(0.0837)	(0.0801)	(0.0406)	(0.0378)	(0.0394)	(0.0377)
comlang_off	-0.121*	-0.104*	-0.137**	-0.0997*	0.632***	0.646***	0.639***	0.649***
	(0.0642)	(0.0599)	(0.0638)	(0.0599)	(0.0319)	(0.0292)	(0.0311)	(0.0292)
comcol	-0.0262	-0.0254	-0.00898	-0.0261	0.533***	0.517***	0.526***	0.517***
	(0.0671)	(0.0632)	(0.0671)	(0.0631)	(0.0351)	(0.0323)	(0.0341)	(0.0322)
col45	-3.259***	-2.900***	-3.289***	-2.903***	-1.833***	-1.867***	-1.900***	-1.893***
	(0.683)	(0.601)	(0.679)	(0.600)	(0.243)	(0.213)	(0.232)	(0.212)
wto	-0.216*	-0.0341	-0.252**	0.00406	-0.126	-0.109	-0.247***	-0.147**
	(0.123)	(0.118)	(0.123)	(0.118)	(0.0776)	(0.0719)	(0.0749)	(0.0715)
COMESA	0.911***	0.918***	0.924***	0.912***	0.383***	0.384***	0.355***	0.379***
	(0.0901)	(0.0857)	(0.0903)	(0.0856)	(0.0483)	(0.0450)	(0.0470)	(0.0449)
SADC	0.662***	0.591***	0.713***	0.572***	0.534***	0.596***	0.592***	0.602***
	(0.0980)	(0.0943)	(0.0986)	(0.0940)	(0.0511)	(0.0479)	(0.0498)	(0.0478)

ECCAS	1.132***	1.016***	1.095***	1.028***	0.226***	0.235***	0.198***	0.236***
	(0.122)	(0.119)	(0.123)	(0.119)	(0.0609)	(0.0593)	(0.0594)	(0.0592)
ECOWAS	0.157	0.193**	0.146	0.200**	-0.0707	-0.0795	-0.0514	-0.0739
	(0.101)	(0.0952)	(0.101)	(0.0950)	(0.0535)	(0.0498)	(0.0520)	(0.0497)
lnwod_o		0.00779		0.0213		-0.0150*		-0.0185**
		(0.0232)		(0.0227)		(0.00900)		(0.00900)
lnwid_d		0.331***		0.359***		0.195***		0.195***
		(0.0601)		(0.0600)		(0.0332)		(0.0331)
cluster_o			-12.70***	5.617***			-16.59***	-5.050***
			(0.806)	(0.771)			(0.357)	(0.377)
cluster_d			0.133	0.580			-0.576**	-0.223
			(0.545)	(0.522)			(0.288)	(0.275)
Constant	-5.957***	-0.507	5.855**	-7.219***	-2.208*	-0.0661	13.17***	4.454***
	(2.302)	(2.285)	(2.483)	(2.484)	(1.147)	(1.128)	(1.202)	(1.203)
Observations	32,311	28,887	32,311	28,887	32,311	28,887	32,311	28,887
Exporter FE	YES	YES	YES	YES	YES	YES	YES	YES
Importer FE	YES	YES	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES	YES	YES

The results of decomposing the standard gravity factors show the regular determinants of export remain vital in both margins: the bilateral distance hurts both margins; while the majority of the traditional dummies have a positive impact on extensive margins as expected except they hurt the intensive margin. Whereas the coefficients of four variables (shared official language, common colony, col45, and WTO) are negative on the intense margin, the coefficients of the last two are also negative on the extensive margin, which is unexpected. On the other hand, the Linder effect doesn't seem to work on both margins of intra-African trade. Besides all the regional trade agreement dummies are found to significantly and positively affect intra-Africa trade except for ECOWAS, which becomes insignificant in both margins. The result shows that the influence of distance is approximately twice as large on extensive margins as it is on intensive margins. Similar findings by Bruyne, Magerma, & Hov, (2013) [9] were justified as once verities are traded, much of the distance borders will be overcome, thus the smaller effect of distance remains on the trade volume.

The next task is to look at the effect of Network statistics. A closer look at the degree centrality measures indicates that both margins are affected positively by all degrees except the negative effect of the outward degree of the exporter in the extensive margin which is unexpected. The positive and significant coefficient of the degree shows the better connected the partners are in the global trade network, the more the number of goods to be traded and the volume of trade. Turning to the clustering coefficient, except for the positive but insignificant coefficient of the clustering coefficient for the destination countries, the effect of the clustering coefficients are found to be negative on both margins of trade as expected. Looking at the size of the effect, the magnitude of the effect of the clustering coefficient is higher at the extensive margin as compared to the intensive one.

6. Conclusion

The influence of bilateral trade barriers on bilateral trade flows is widely documented in gravity research. Nonetheless, it has today become clear that bilateral trade is influenced by more than just bilateral costs. Thus contemporary study draws attention to the effect of third countries as determinants of international trade flows. In particular modern contributions have focused on these multilateral barriers to international trade. It is generally recognized that the network position of trading countries is becoming vital in explaining trade. We estimate the augmented gravity equation explaining inter-African countries' export flow employing the traditional gravity variables as well as our variables of interest-the network measures. The study examines the effect of trade networks on intra-Africa trade for the dataset covering 41 African countries for the year ranging between 2000 and 2018. The Poison family regression is used to estimate the gravity model in its exponential form because OLS results in biased parameters with significant zero trade flows, which is a common issue in undeveloped countries like the majority of African nations.

Weighted degree statistics of the trade network are estimated as out- and in-degrees of the origin and the destination countries respectively, quantifying the weighted number of trading partners. The finding of our study reveals a positive effect of the weighted-out degrees of the exporters on both overall and intra-African exports, which is as expected. The premise behind this reasoning is that because the country has more trading partners in general, the country's likelihood of trading with one trading partner specifically will be higher. This is consistent with HR's argument that countries should cover their costs to be competitive and trade internationally. Since the reporter's weighted out-degree quantifies global competitiveness, its positive impact on African trade is expected. The effect of in-degrees of the importers, which is a measure of importer trade openness, has a positive effect on overall and intra-African exports as well. The positive effect of this variable reflects the more open the importer is; a particular exporter likely trades with this open economy. By contrast, the clustering coefficients, which represent the clustering coefficient of the exporter and the clustering coefficient of the importer adversely affect bilateral trade. This is a signal of possible competition effects. The idea is, that the stronger the clustering value, the greater the competition an economy confronts as its trading partners participate in more intra-trade.

Furthermore, following the literature on international trade, we decomposed total exports into the intensive and extensive margins and examined the effect of the network variables on each margin of exports exclusively. Regarding the degrees, it is clear that both margins of exports are affected positively by weighted in-degree; the weighted out-degree has contrasting effects on both margins-while it reduces the intensive margin, it enhances the extensive margin. This shows that being well linked improves both the number of goods exported (the extensive margin), as well as the average volume of those exported goods. Besides, the clustering coefficient has a negative effect on both margins as expected indicating that local competition decreases the varieties in exported goods as well as the intensity of their exports.

7. References

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APPENDIX List of African included in this study

AGO	NGA
BDI	RWA
BEN	SEN
BFA	SLE
BWA	STP
CAF	SWZ
CIV	SYC
CMR	TGO
COG	TUN
COM	TZA
CPV	UGA
DZA	ZAF
EGY	ZMB
ETH	ZWE
GAB	MDG
GHA	MLI
GIN	MOZ
GMB	MRT
KEN	MUS
LBY	MWI
LSO	NAM
MAR	NER