Re-examining South Africa's export to African countries: A spatial gravity model approach

Abstract

The objective of this study is to determine if South Africa's export in Africa is influenced by the proximity in terms of distance between importing countries. We apply the gravity model in the context of spatial econometrics for a cross-section of 38 African countries to which South Africa has exported from 2005 to 2014. Given that the paper adopts a "general-to-specific" estimation approach, it follows that a general spatial panel gravity model is estimated as a starting point. This model takes into account at the same time spatial dependence of bilateral export flows between South Africa and other African countries considered in the sample, the spatial diffusion of idiosyncratic shocks from countries that are in the proximity of destination countries in influencing export from South Africa, individual heterogeneity and time-persistence in the idiosyncratic errors. Results point out that spatial dependence of the export is not significant in the general model. However, findings of the spatial panel gravity model with lag of the dependent variable and spatial panel gravity model with autocorrelated errors suggest on one hand that South Africa's export to a destination is positively related to the average export flows from South Africa to other countries in the proximity of that destination country. On the other hand, there is spatial diffusion of shocks affecting South Africa's export flow to a destination as well as its time-persistence. The estimation also takes into account the regional trading blocks, of which the results show that countries belonging to SADC and ECOWAS are South Africa's important export destinations. These findings have relevance for South Africa's trade policy.

Keywords: *spatial, export, South Africa, Africa*

JEL Classification: C31, C33, F14, R12

1 Introduction

Intra-African trade is considered as one pillar for growth and development of the continent. Although its leaders envisioned, as early as in the 1960's with the formation of the then Organisation of African Unity, an Africa that trades with itself, it is worth noting that not much has changed since then. Africa is lagging far behind with respect to trade among its countries. For instance, the volume of trade among African countries is significantly lower compared to those of other regions in the world. Ideas have been put forward to address challenges that impede African countries to leverage on the potential of intra-regional trade. These ideas include amongst others, infrastructure development, in particular electricity and road infrastructure, industrialisation, diversification of economies, and economic integration.

In 2012, at the African Union's 18th Ordinary Session of the Assembly, the heads of States and governments took a resolution to establish the Continental Free Trade Area (African Union 2017). This culminated in the official establishment of the African Continental Free Trade (AfCFTA) in March 2018, whose objective includes, amongst others, expanding intra-African trade through harmonisation and coordination of trade liberalisation. In addition, Africa has a great deal of regional trade agreements than other regions. Therefore, it is understood that investigating intra-African trade is paramount to inform policy in this new era where African leaders' optimism and ambition to trigger development of the continent are high than ever.

Given that, trade is a multifaceted phenomenon and to delimit the scope of the analysis, the present paper focuses on one aspect, which is the investigation of bilateral export flows between South Africa and other African countries. Simply put, this paper seeks to answer this question: "*does proximity between destination countries influence bilateral export flows between South Africa and other countries on the continent[1]?*

Some studies have explored export (or trade) flows from South Africa to other countries, while others have also explored trade among African countries without necessary considering South Africa as the sole exporter. They include amongst others Jordaan and Eita (2011), Kagochi and Durmaz (2018), Matthee and Santana-Gallego (2017), Ngepah et al. (2018), Potelwa et al. (2016), Seid (2013), and Tansey and Touray 2010, and The DTI (2004). These studies applied gravity model in their empirical strategy to measure the determinants of

[1] This paper interchangeably uses destination, destination country and importer.

dyadic trade flows. One limitation of such approach, as noted by LeSage and Pace (2008) and Porojan et al. (2001), is its inability to take into account the influence of neighbours or networks in explaining trade flows between countries. In other words, there is an implicit assumption that bilateral export or trade flows are spatially random or independent. As pointed out by Tobler (1970) in the famous first law of geography: "*Everything is related to everything else, but nearer things are more related than distant things*", proximity between countries is an important element that must be taken into account in the analysis of flows, including trade. As a remedy, LeSage and Pace (2008) suggest that gravity model can be applied in the perspective of spatial econometrics. Such estimation strategy takes into account spatial dependence of dyadic flows. Few empirical studies have recently applied spatial gravity modelling as proposed by (LeSage and Pace 2008) or similar approaches to investigate trade flows (Chou et al. 2015; Hamzalouh et al. 2017; LeSage and Llano-Verduras 2014; Metulini 2013; Metulini et al. 2016; Patuelli et al. 2015; Yang et al. 2017).

The contribution of this paper is twofold. First, it applies the approach of spatial panel gravity modelling to investigate export flows from South Africa to other African countries. By doing so, this paper seeks to understand whether these export flows are affected by the connectivity that exists amongst destination countries. Second, although there are some studies that examined South Africa's export flows, none of them really focuses on African countries as destination as importers. Hence, the present paper fills that gap by re-examining South African export in the context of intra-African trade. From a policy perspective, the aim of this paper is to establish whether South Africa can leverage the connectivity that exist between its trading partners in Africa to expand its export. The selection of South Africa as the reference country to study intra-African trade, in particular export is mainly due to its relatively developed manufacturing sector, which is the main contributing sector to export. In other words, South Africa is among few African countries that export manufactured goods to the continent. By in large, most African countries export natural resources out of the continent.

The remainder of the present paper is organised as follows. Section presents the spatial dependence characteristic of export flows, while the methodology adopted for the analysis is discussed in section 3. We discuss the results in section 4. The paper's conclusion drawn from the research question and results are presented in the last section.

2 Spatial dependence characteristic of bilateral export flows

We base our analysis on the gravity theory, as it is in most empirical studies, to achieve our objective. In this regard, it is worth noting that since the work by (Tinbergen 1962) gravity model has become a notorious and viewed as a sound framework that is applied in empirical research to answer various types of research questions related to flows, including trade from one geographical area to the other. Gravity model is used to study trade potential, detect natural trading blocks, and investigate the potential of trade creation and diversion from regional integration perspective, and so forth. For instance, The Department of Trade and Industry (2004) estimates a gravity models to investigate the potential of South Africa's export at an aggregate and sectoral levels.

However, in the past years, the gravity model has received various criticisms in spite of its notoriety, mostly precisely regarding its empirical specification. One criticism is that the empirical specification of the gravity model fails to account for spatial dependence or autocorrelation that exists in flows. In other words, trade flows are viewed are implicitly assumed to be spatially random. Porojan (2001) points out the flaws of the traditional gravity model. This author, while discussing in details the failure of the traditional gravity model to capture the spatial dependence of trade flows, draws a conclusion that the residuals of the traditional gravity model are spatially autocorrelation.

In line with the thinking put forth in Anselin (1988a), variables that are georeferenced don't necessarily obey the principle of randomness as it is always assumed in empirical studies. This means that bilateral export flows, which are by their nature georeferenced, cannot be assumed as spatially random. It is because they involve an importing country (or region) and another country (region) considered as exporter. Therefore, a bilateral export flow between an exporter and an importer, does not only involved these two, but also countries connected to them in one way or the other. In this paper, we refer to these interactions as third-country interactions because they emanate not from concerned exporter and importer for a given bilateral trade flow, but from countries connected to them. LeSage and Pace (2008) disentangle four types third-country interactions and provide a framework to specify a spatial gravity model that considers them.

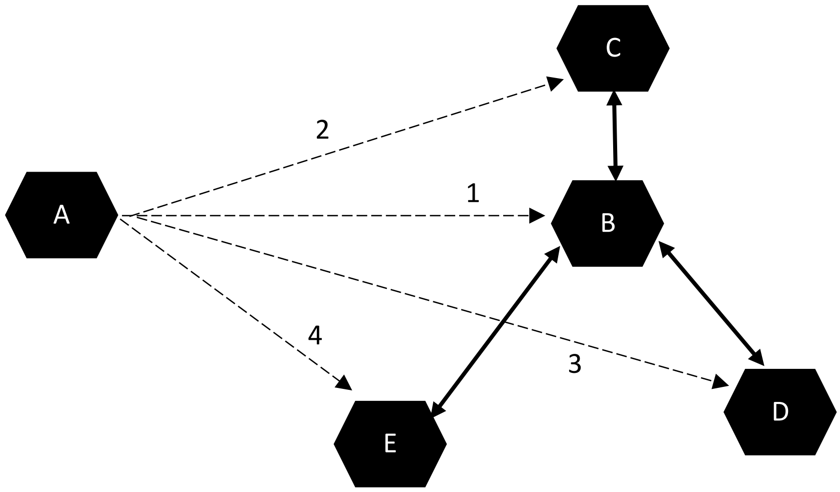

Figure 1. ***Schematic representation of bilateral export flows.***

Figure 1 above is a representation of bilateral export flows in a closed system of five countries, which are A, B, C, D and E. Country A is the sole exporter, whereas B, C, D and E are importers. The dashed arrows represent the bilateral export flows from A to importers, while reciprocal arrows depict closeness of other importing countries to B.

If one considers export from A to B as shown by dashed arrow 1 in Figure 1. We can say that it is influenced, among others, by the extent of interactions between B and other importers in its proximity. Interactions between close importers can be understood as contextual effects or similarities of preferences for import from country A. This is in line with Tobler (1970)'s first law of geography, which states that " *Everything is related to everything else, but near things are more related to distant things*". However, it is worth to note that although these interactions exist, it is difficult to observe them. One way of capturing the extent of interactions of other importers close to B is through the (spatially) weighted average of export from A to C, D and E or the error term in the specification model. The approach adopted in this paper consists of taking into account the third-country interactions in the analysis of South Africa's export to African countries as further discussed in the next section.

3 Methodology

3.1 Non-spatial panel gravity model

Different empirical specifications of gravity model exist in the literature to study bilateral exports (imports) flows between geographical units. It is beyond the scope of the present paper to discuss their theoretical foundations. However, the paper adopts the empirical specification recently proposed by Baltagi et al. (2014) as shown in equation (1) below.

Before going into some details of the said model, it is worth noting that in general, the specification of gravity model considers *n* number of geographical units (i.e. countries, regions, states) that are at the same time exporters and importers such that the vector of export trade flows has n^2 observations. Nevertheless, local gravity models where there is one exporter (importer) and multiple importers (exporters) are found in the literature. Our specification resembles the latter where South Africa is the only exporter to multiple importers in Africa. In this regard, the basic specification theorises that export from South Africa to an African country is proportional to their economic sizes and inversely related to the distance between them.

$$Y_{ijt} = \beta_0 \frac{X_{it}^{\beta_1} X_{jt}^{\beta_2}}{D_{ijt}^{\beta_3}} \quad (1)$$

where *t (t=1,..T)* indexes years, *i* indexes South Africa and *j (j=1,…N)* indexes importing countries. Y_{ijt} is export from South Africa to *country j* in Africa at time *t*; X_{it} and X_{jt} are the economic sizes of South Africa and *country j* at time *t*. It worth noting that this study uses per capita gross domestic products are proxies of economic sizes of both the exporter and importer. D_{ijt} is the centroid distance in metres between South Africa and importers. β_0, β_1, β_2 and β_3 are unknown parameters of the deterministic equation (1). While β_1 and β_2 measure the degree of pull factors in explaining bilateral export between South Africa and destination countries, the parameter β_3 measures the extent of resistance or cost to export. In this regard, it is expected that that the former will be positive and the later negative.

We first apply the log-transformation, and then add the error term as shown in Equation (2) to obtain a linearized stochastic version of the basic gravity model[2].

$$\log Y_{ijt} = \beta_0 + \beta_1 \log X_{it} + \beta_2 \log X_{jt} + \beta_3 \log D_{ij} + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = \mu_j + e_{ijt} \quad (2)$$

where e_{ij} is the composite error term, which includes importers' unobserved time-invariant heterogeneity μ_j and ε_{ij} disturbances assumed to be *i.i.d.*

[2] We have removed time subscript t from the variable D because centroid distances between South Africa and importer as it is further discussed in the next section are time-invariant.

Equation (3) shown below is an augmented version of the non-spatial panel gravity model after adding other variables.

$$\log Y_{ijt} = \beta_0 + \beta_1 \log X_{it} + \beta_2 \log X_{jt} + \beta_3 \log D_{ij} + \beta_4 \log R_{it} + \beta_5 L_j + \beta_6 C_j + \beta_7 EC_j + \beta_8 SA_j + \beta_9 EA_j + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = \mu_j + e_{ijt} \quad (3)$$

where variables are as in equation (2). Nevertheless, few variables are added to the model in line many empirical studies. These include, R_{it} which is a vector representing exchange rate between American dollar to South African rand. *L to EA* are five dummies for the following regional trading blocks applicable to importers: the Southern African Development Community (SADC), the Economic Community of West African States (ECOWAS), the Common Market for Southern Africa (COMESA), the Eastern Africa Community (EAC) and share of common official language between South Africa and the destination countries. In other words, L is equal to one if the importer uses English as official language and zero others. Similarly, if the importer belongs to SADC, the dummy variable SA takes the value 1 and so forth.

Furthermore, equation (3) is the starting point of our empirical specification strategy. In essence, the specification in equation (3) implicitly assumes that distance between importers does not influence South Africa's export to any African countries. In other words, South Africa's export is spatially random or independent and/or there is no diffusion of shocks among importers. In this regard, we test the null hypothesis of non-spatial and non-serial autocorrelation of its residuals. Details on the formulation of these tests are found in Anselin et al. (1996) Baltagi et al. (2007) and Elhorst (2009). Furthermore, equation (3) is estimated with random effects for two main reasons. First, the application of fixed effects estimator will wipe out some time-invariant variables in the model such as centroid distances between South Africa and destination countries. For instance, Millo (2014) encountered similar challenge and opted for random effects estimator. Lastly, countries considered in the analysis are, but a portion of African countries for which data is available for the period of the analysis.

One issue regarding specification in equation (3) consists of the implicit assumption that bilateral export flows between South Africa and other African countries are spatially random or not correlated. Some studies oppose this idea and advocate for a specification that takes into account spatial dependence (Beenstock et al. 2015; LeSage and Pace 2008; Lesage and Thomas-Agnan 2015; Porojan 2001). In this regard, our approach consists of estimating a general spatial panel gravity model as an alternative that takes into account spatial dependence of the dependent variable, spatial and serial autocorrelation of errors as discussed in the next section.

3.2 Spatial panel gravity models

Equation (4) represents the general spatial panel gravity model. It is related to what Millo (2014) refers to as SARSEM2SRRE because its encompasses spatial lag of the dependent variable, spatial and first-order serial correlation of the idiosyncratic errors.

$$\log Y_{ijt} = \beta_0 + \lambda(I_T \otimes W_N) \log Y_{ijt} + \beta_1 \log X_{it} + \beta_2 \log X_{jt} + \beta_3 \log D_{ij} + \omega A_{jt} + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = \mu_j + e_{ijt}$$

$$\varepsilon_{ijt} = \rho(I_T \otimes W_N)\varepsilon_{ijt} + \nu_{ijt}$$

$$\nu_{ijt} = \psi \nu_{ij,t-1} + \mu_{ijt} \quad (4)$$

where I_T is an identity matrix of dimension T, W_N is an N *by* N spatial weight matrix of constant inverse distances between pairs of importers, λ is the spatial autocorrelation coefficient, A_{jt} is the matrix of all five dummies with ω being the vector of the corresponding parameters of these dummies. The remainder of variables and parameters are as in equation (3). However, the disturbance term is the sum of time-invariant importers' random effects μ_j of *i.i.* $\sim N(0, \delta^2)$, and the idiosyncratic error ε_{ijt}, which follows Kapoor et al. (2007)'s structure. In other words, both the random effects and a portion of the idiosyncratic error are spatially correlated with ρ ($|\rho| < 1$) being the spatially autoregressive coefficient. The remainder of the idiosyncratic error v_{ijt} is serially correlated (of first-order) with ψ ($|\psi|$<1) its corresponding coefficient.

The introduction of the spatial weight matrix W_N into the model warrants an explanation. This matrix is exogenously constructed to capture the spatial interactions between importers. Simply put, the spatial weight matrix is important to assess the idea put forth by Griffith and Jones (1980) that "*flows associated with a destination are enhanced or diminished in accordance with the propensity of attractiveness of its neighbouring destination locations*". In general, criteria such as contiguity and distance between geographical units (i.e. countries) are used to construct this matrix. For the purpose of this paper, we use the inverse centroid distances between pairs of importing countries. In this way, the influence that a third country can have on export flow from South Africa to a given country decays with the distance between that third country and the importer. The spatial weight matrix is row-standardised and its diagonal elements set to zero so that a *country j* does influence itself. In this regard, its elements are as follows.

$$w_{jk} = \begin{cases} d_{jk}^{-1}, & for\ j \neq k \\ 0, & for\ j = k \end{cases}, \quad \text{with } j, k=1,..N$$

$$d_{jk} = \sqrt{\left(g_j - g_k\right)^2 + \left(h_j - h_k\right)^2} \tag{5}$$

where d_{jk} is the centroid distance between importers *j* and *k*, (g_j, h_k) and (g_j, h_k) are the latitudes and longitudes for *countries j* and *k* respectively.

Moreover, equation (4) adds some important dimensions into the specification, which are the focus of this paper. It entails that export from South Africa to *country j*, in addition to economic sizes and distance, depends, on one hand, on the average export from South Africa to other importing countries close to *country j*. This is captured by the parameter λ. For instance, if *lambda* is significantly positive (negative), it shows that South Africa's export to *country j* is enhanced (diminished) by the attractiveness of other importers in the proximity of *country j*, all other things being equal. On the other hand, the specification in equation (4) takes into account that unobserved heterogeneity of importing countries or random effects together with a component of the idiosyncratic errors are spatially correlated and captured by parameter ρ, whereas the remainder of the idiosyncratic error is time-persistent as captured by ψ.

Given that the present paper adopts the "general-to-specific" approach, we impose two restrictions to test the significance of the general model or equation (4) against two specific (restricted) spatial panel gravity models as set out in the next section.[3] First, we assume that the spatial lag of the dependence variable, the ratio of covariances of random effects and idiosyncratic error, and the serial autocorrelation of the idiosyncratic errors are statistically significant, whereas the spatial autocorrelation in the error terms is not. In other words, $\lambda \neq 0, \phi \neq 0, \psi \neq 0, \rho = 0$. Consequently, the general model, as specified in equation (4), is

[3] Though many restrictions can be imposed on the generalized model to obtain a range of specific specifications, we resorted to only two restrictions to answer the posed question in the present paper.

reduced to spatial gravity model with spatial lag, random effects and serially correlated idiosyncratic error, which is referred to as SAR2SRRE and depicted in equation (6).

$$\log Y_{ijt} = \beta_0 + \lambda(I_T \otimes W_N)\log Y_{ijt} + \beta_1 \log X_{it} + \beta_2 \log X_{jt} + \beta_3 \log D_{ij} + \omega A_{jt} + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = \mu_j + e_{ijt}$$

$$e_{ijt} = e_{ijt} + \nu_{ijt}$$

$$\nu_{ijt} = \psi \nu_{ij,t-1} + \mu_{ijt} \tag{6}$$

Last, let us assume that the spatial autocorrelation, serial correlation and the ratio of covariance matrices in the errors are statistically significant, whereas the spatial dependence in the dependent variable is not significant, that is $\lambda = 0, \phi \neq 0, \psi \neq 0, \rho \neq 0$. It means we can estimate the spatial panel gravity model with spatial autocorrelated random and idiosyncratic errors, and serially correlated idiosyncratic errors as shown in equation (7). This model is kwon is short as SEM2SRRE.

$$\log Y_{ijt} = \beta_0 + \beta_1 \log X_{it} + \beta_2 \log X_{jt} + \beta_3 \log D_{ij} + \omega A_{jt} + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = \mu_j + e_{ijt}$$

$$\varepsilon_{ijt} = \rho(I_T \otimes W_N)\varepsilon_{ijt} + \nu_{ijt}$$

$$\nu_{ijt} = \psi \nu_{ij,t-1} + \mu_{ijt} \tag{7}$$

It is important to note that, unlike with equation (6), there is no theoretical foundation per se of equation (7). However, it is just a strategy to build-in the nuisance spatial dependence and time-persistence of components of errors to ensure that efficiency in parameters as the remainder of the idiosyncratic errors would be random (Luc Anselin 1988b). The Maximum Likelihood (ML) method is used to estimate the three spatial panel gravity models, notably the SARSEM2SRRE, SARSRRE, and SEM2SRRE as described above. See Millo (2014) for a detailed discussion regarding the ML method in the context of spatial panel models. If it is found that either SARSEM2SRRE or SARSRRE is significant, the paper will also calculate direct, indirect and total effects of the independent variables from the standard posterior point estimates (LeSage 1999).

3.3 Data

The sample consists of South Africa's export to 38 African countries for the 2005-2014 period. Table 1 below shows variables used in the analysis. Total value of export from South Africa to African countries is the dependent variable. Covariates include, real per capita gross domestic product for South Africa and importing countries, pairs of centroid distances between South African and importing countries in meters, real exchange rate US dollar and South African rand (ZAR), and the rest are the five dummies that represent the multilateral resistance factors according to the literature on trade.

Export data is sourced from the South African Revenue Services, whereas we sourced information on gross domestic product and exchange rate from the World Development Indicators (World Bank 2018). Centroid distances between countries are calculated using information on countries' longitudes and latitudes[4]. Dummy variables are constructed based on official information on the websites of respective regional blocks.

Table 1. Variables used in the analysis

Variable	Description
Dependent	
Export	Annual total export from South Africa to *country j* in real terms South African Rand (ZAR)*
Independent	
US$/ZAR	Annual average exchange rate between US $ in ZAR
GDP/p_D	Per capita gross domestic product of the destination in real US $ (2000 price)
GDP/p_SA	Per capita gross domestic product of South Africa in real US $ (2000 price)
dist	Centroid distance between South Africa and *country j* in metres**
lang	Dummy of English language of the destination country(1=destination country j uses English, 0=otherwise)
com	Dummy if the destination country belongs to the Common Market of Southern Africa (1=destination country belongs to COMESA, 0=otherwise)
eco	Dummy if the destination country belongs to the Economic Community of West Africa (1=destination country belongs to ECOWAS, 0=otherwise)
sadc	Dummy if the destination country belongs to the Southern African Development Community (1=destination country belongs to SADC, 0=otherwise)
eac	Dummy if the destination country belongs to the Eastern Africa Community (1=destination country belongs to EAC, 0=otherwise)

[4] This information is downloaded from the Global Administrative Areas website: http://www.gadm.org

4 Discussion of results

Table 2 shows disparities between South Africa's export to African countries. Similarly, there are significant differences of income among African countries as shown by high value of standard deviation with respect to GDP_D.

Table 2. Summary of descriptive statistics

Variable	Min	Max	Mean	STD
Export	4 261 776	26 134 899 105	2 429 424 288	4 460 445 238
US$/ZAR	6.36	10.85	8.02	1.32
GDP/p_D	721 468 737	452 284 522 880	36 476 598 797	68 376 857 457
GDP/p_SA	322 184 452 760	412 966 867 881	373 319 944 825	27 238 957 185
dist	1 207 042	7 517 381	4 502 279	1 649 296

Before delving into the actual discussion of gravity models, it is important to present some aspects of spatial dependence of South Africa's export to African countries as a preliminary assessment. The years 2005, 2010 and 2014 are selected to carry out this assessment, which is univariate and spatial. In other words, the analysis does not focus neither on the relationships between exports and its determinants per se nor on its time dynamics. However, the aim is to determine whether South Africa's export to an African *country i* is affected by South Africa's export to other African countries close to *country i*.

The evaluation of spatial dependence of South Africa's export requires that the determination of each destination's neighbours. This is done through the construction of a spatial weight matrix. As already mentioned in the previous section, this paper uses the spatial weight matrix based on inverse of centroid distances between destination countries.

Moran's I statistic is often used to assess the global spatial autocorrelation (Details of its formula can be found in Anselin (2003)). Results of the Moran's I statistic are reported in Table 3. It is worth noting that z-values correspond to the computed Moran's I after 999 permutations. It can be seen that the null hypothesis of spatial randomness of export for each year is rejected because the corresponding pseudo p-value are smaller. It implies that, in overall, import from South Africa by *an African country i* is affected by import from South Africa by other African countries in its proximity. This behaviour is also referred to as spatial dependence of crime.

Table 3. Univariate Moran's I statistics for export

Year	Moran's I statistic	pseudo *p*-value	z-value
2005	0.46	0.001	5.24
2010	0.49	0.001	5.59
2014	0.47	0.001	5.45

We report the results of the non-spatial panel gravity model in Table 4 below. The main aim is not to discuss per se its parameter estimates, rather to focus on the diagnosis of its residuals as shown in the bottom part of this table. However, before that it still important to note that coefficients of key variables are significant and present the expected signs. For instance, it can be seen that per capita gross domestic product of the importing country is positive and significant. This implies that one percent increase (decrease) of per capita gross domestic product in *country j* corresponds with 0.66 percent increase (decrease) of South Africa's export. Furthermore, the depreciation of South African rand against the US dollar correspond with an increase of South Africa's export to *country j*. This finding is intuitive in the sense that the depreciation is the rand can be considered as the price decrease of South African's goods, which is beneficial for importers. Some coefficients of dummy variables are positive and statistically significant.

Turning now to the spatial diagnosis results, we first note evidence of spatial autocorrelation in the residuals because the basic and robust LM statistics are statistically significant. Thus, the non-spatial gravity model is not suitable because it fails to take into account of the spatial dependence in the dependent variable as well as the spatial autocorrelation in the error. Second, the Baltagi et al. (2007)'s diagnostic tests also confirm that the significance of random effects, spatial and serial autocorrelation of the idiosyncratic errors taken altogether or individually.

Table 4. Results of non-spatial panel gravity model

Variable	Coefficient
intercept	15.16 (0.35)
US$/ZAR	0.47** (0.03)
GDP/p_D	0.66*** (0.00)
GDP/p_SA	0.13 (0.79)
dist	-1.51 (0.10)
lang	0.69* (0.08)
com	0.31 (0.42)
eco	0.72* (0.09)
sadc	1.96*** (0.00)
eac	-022 (0.67)
Adj. R^2	0.34
F-stat	23.03*** (0.00)
LM test for spatial lag dependence	4.21**
Robust LM for spatial dependence	6.97***
LM test for spatial error dependence	4.10**
Robust LM for spatial error dependence	6.86***
Pesaran local cross-section dependence Test	22.33***
Bsjk Joint test of random effects, serial correlation or spatial dependence in errors	1240.4***
Bsjk conditional test of serial correlation in errors	83.61***
Bsjk conditional test of random effects in errors	106.73***
Bsjk conditional test of spatial dependence in errors	10.21***

Figures in parentheses are probability values.

The foregoing findings with respect to spatial diagnosis lead to the estimation of spatial panel gravity models and we report their results in Table 5 below. These models take into account the fact that South Africa's export (dependent variable) to a *country j* is dependent of the average of South Africa's export to other African countries that are close to *country j* on one hand. On the hand, these modes also are specified to account for spatial and serial autocorrelation of the random effects and idiosyncratic innovations. Model 1 refers to the general spatial panel gravity model, whereas Models 2 and 3 refer to spatial panel gravity model with spatial lag and spatial panel gravity model with error term, respectively.

Starting with the general model or Model 1, it can be seen that some individual parameters are indeed determinants of export from South Africa to African countries. However, we note that the coefficient of spatial dependence, *lambda* cannot explain South Africa's export to an African *country j*. This suggests that, proximity that exists between importing countries does not influence South Africa's export to *country j*. On the contrary, we find that *phi*, *psi* and *rho* and statistically significant. This finding suggests the following. The assumption that the individual effects are uncorrelated with the other explanatory variables in the model is statistically sound. In addition, the unobserved individual effects (i.e. random effects) and a component of idiosyncratic error are spatially correlated, whereas another component of idiosyncratic error is time-persistent.

Table 5. Results of spatial panel gravity models

Coefficient	Model1	Model2	Model3
intercept	-14.01 (0.64)	-2.49 (0.81)	-9.38 (0.68)
US$/ZAR	0.42 (0.26)	0.21 (0.29)	0.34 (0.27)
GDP/p_D	0.68*** (0.00)	0.66*** (0.00)	0.68*** (0.00)
GDP/p_SA	1.48 (0.12)	0.49 (0.37)	1.09 (0.17)
dist	-1.26**(0.04)	-0.88 (0.13)	-1.13* (0.06)
lang	0.68** (0.04)	0.74** (0.03)	0.69** (0.04)
com	0.29 (0.41)	0.25 (0.47)	0.28 (0.43)
eco	0.63 (0.11)	0.77** (0.04)	0.69* (0.08)
sadc	1.87*** (0.00)	1.89*** (0.00)	1.87*** (0.00)
eac	-0.18 (0.71)	-0.23 (0.62)	-0.19 (0.69)
lambda	-0.18 (0.58)	0.3** (0.01)	
phi	4.89*** (0.00)	4.86*** (0.00)	4.86*** (0.00)
psi	0.62*** (0.00)	0.63*** (0.00)	0.62*** (0.00)
rho	0.45** (0.03)		0.34*** (0.00)

Figures in parentheses are probability values.

However, since *lambda* in Model 1 is not significant, we can conclude that the general spatial panel gravity model is not appropriate for the sample. It fails to capture simultaneously the spatial dependence in the dependent variable and spatial autocorrelation in the errors. On this basis, we now focus on Models 2 and 3, which are estimated after imposing restrictions mainly on the significance of *lambda* and *rho* as discussed in the section related to the methodology. With regard to results of Model 2, it can be seen that *lambda* is statistically significant at five percent level. This finding suggests that South Africa's export to an African *country j* is dependent on South Africa's export to other African countries in the proximity of *country j*, all other things being equal. We also notice that *phi* and *psi* are different from zero, respectively implying that the random effects are not correlated with the explanatory variables and there is time-persistence in the innovations. Also, as notes Millo (2014), we can conclude that variables used in the analysis do not suffer from non-stationarity, which if present could lead to spurious regression. This is because *psi* (0.63) is not that much close to one.

Although, some parameters in Model 2 are significant, unfortunately they cannot be used, as in non-spatial models, to gauge the reaction of export with respect to change in covariates. Instead, we will use results of Table 6 related to direct, indirect and total effects of covariates, which we discuss in the next discussion. Nevertheless, for now we focus on results of Model 3. We note that the coefficient of per capita gross domestic product in *country j* and centroid distance between South Africa and country j are statistically significant. They are also positive and negative respectively in accordance with the gravity theory. For instance, one percent increase (decrease) in *country j's* per capita gross domestic product corresponds with 0.68 percent increase (decrease) of South Africa's export to that country, all other things being equal. Whereas, a percent increase (decrease) in centroid distance between South Africa and country j leads to a decrease (increase) of 1.13 percent South Africa's export. We also notice that South Africa's per capita gross domestic product and exchange rate US dollar and ZAR do not explain individually South Africa's export to *country j*.

Still, results of Model 2 show that English, as the official language of both South Africa and the importing country, ECOWAS and SADC membership status of the importing country are significant in explaining South Africa's export. For instance, South Africa's export to country j increases (decreases) by the logarithm of 0.7 because country j uses English or is an ECOWAS member state. On the other hand, if the importing country is a SADC member state, South Africa's export increases (decreases) by the logarithm of 1.87, all other things being equal. Results of Model 3 also show that paramters *phi*, *psi* and *rho* are statistically significant. The implication of this finding is threefold. First, the assumption that the unobserved heterogeneity or specific effects of importing countries are uncorrelated with covariates is sound. Second, there is time-persistence of a component of the idiosyncratic error. Also, since *psi* does not approach one, we cannot suspect non-stationarity issue in the variables (Millo 2014). Lastly, random effects and a component of idiosyncratic error are spatially correlated à la Kapoor et al. (2007).

As already discussed in the previous paragraphs, we report in Table 5 below direct, indirect and total effects of independent variables of Model 1. A direct effect measures the change of the South Africa's export to an African *country j* resulting from a change of individual independent variables, including feedback effects from importing countries close to *country j*. In other words, it is the impact passing through importers close to *country j* and back to the South Africa's export to the importer (*country j*) that instigated the change. The indirect effect is the change of the dependent variable affecting close importing countries because of change in independent variables in *country j*. Total effect is the combination of direct and indirect effects.

Table 6. Effects of independent variables

Variable	Direct	Indirect	Total
US$/ZAR	0.22 (0.24)	0.09 (0.39)	0.31 (0.26)
GDP/p_D	0.67*** (0.00)	0.28 (0.10)	0.95*** (0.00)
GDP/p_SA	0.49 (0.47)	0.21 (0.52)	0.70 (0.46)
dist	-0.88 (0.11)	-0.37 (0.31)	-1.26 (0.14)
lang	0.74* (0.06)	0.31 (0.21)	1.06* (0.07)
com	0.25 (0.60)	0.10 (0.66)	0.36 (0.60)
eco	0.78** (0.04)	0.33 (0.22)	1.11* (0.06)
sadc	1.91*** (0.00)	0.81 (0.22)	2.72** (0.01)
eac	-0.23 (0.63)	-0.10 (0.70)	-0.34 (0.65)

Figures in parentheses are probability values.

Direct effect of per capita gross domestic product of the importing country is positive and significant. This implies that one percent increase (decrease) of per capita gross domestic product of *country j* leads to 0.67 percent increase (decrease) of South Africa's export to *country j* taking account the feedback from close importing countries. The fact that the indirect effect of per capita gross domestic product of the importing country is not statistically significant implies that change of this variable in other importing countries close to *country j* does not have any spillover effects on South Africa's export to *country j*.

Language, ECOWAS and SADC have significant and positive direct effects on South Africa's export to *country j*. These findings suggest a positive relationship between South Africa's export to *country j* that uses English as official language or is a member state of the above regional blocks. None of the indirect effects for these dummy variables is statistically significant, which suggests that there is no spillover effects from importing countries using English or belonging to a trading block on South Africa's export to *country j*.

5 Conclusion

This paper uses the framework of spatial panel gravity models to assess South Africa's export to other African countries for the 2005 – 2014 period. We adopt this specification strategy in accordance with the recent developments international economics and spatial econometrics, which point out that trade flows are not necessarily spatially random or independent as previous empirical studies have implicitly assumed.

Hence, given a bilateral export from South Africa to *country j* in Africa, our objective by using this strategy is to understand whether it is, amongst others, determined by South Africa's export to other African importers close to *country j*. Another specification in this paper builds-in the spatial and serial correlation in the disturbances in recognition of spatial diffusion and time-persistence that characterise South Africa's export to a *country j*.

We follow the estimation procedure provided for in spatial econometrics literature and conclude the following. First, the diagnostic tests reveal the presence of spatial autocorrelation in the residuals the non-spatial panel gravity model. Based on this finding, the general spatial panel gravity model is estimated alongside specific spatial panel gravity models, notably the SARSRRE and SEM2SRRE.

After investigation of the key coefficients of these models, this paper concludes that specific then the general spatial panel gravity model are appropriate for the sample data. Simply, the non-significance of lambda is the main reason for dropping the general spatial panel gravity model. Results of SARSRRE and SERM2SRRE are discussed without necessarily choosing the best model as they are derived from different restrictions imposed on the general model.

Based on the results of SARSRRE this paper concludes that South Africa's export to *country j* in Africa increases (decreases) because of the attractiveness of other importers close to *country j*, all other things being equal. Per capita gross domestic product the use of English as official language, the membership to ECOWAS and SADC of the importing country are key determinants of South Africa's export to *country j*. Similarly, results of SEM2SRRE point out that the above-mentioned covariates explain South Africa's export to *country j*. Unlike in the SARSREE model, centroid distance is a determinant of South Africa's export to *country j*, all other things being equal.

The analysis carried out in this paper is, but one attempt to understand intra-African trade for which researchers and policy makers decry that it is not expanded significantly compared to other regions in the world. Various reasons are given for to explain this phenomenon. Attempt have been made to suggest actions that could remedy this situation and trigger the expansion trade among African countries. Without dismissing these arguments, the present paper argues that it is also important to understand what characterises trade among African countries, of which the influence of connectivity between importing countries is one aspect. In this regard, South Africa's export is taken as one specific case.

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