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See table of contents

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Article abstract

The purpose of this paper is to evaluate the impact of African regional blocs on African trade flows while allowing for spatial interdependence between trade flows. To this end, we derive a spatial gravity equation by removing the implicit assumption that trade flows between two trading partners are independent of what happens in the rest of the trading world. We estimate the border effects for five Sub-Saharan regional blocs (CEMAC, COMESA, ECOWAS, SADC and WAEMU). We decompose the border effect into two components: a trade-boosting intra-bloc effect and a trade-reducing inter-bloc effect. Our findings show that trade agreements produce positive effects on intra-bloc trade flows and these effects are particularly prominent when the blocs are advanced in their integration process. In addition, the spatial interdependence between trade flows is reflected in a negative relationship as implied by the theoretical model, suggesting a natural measure of spatial competition.

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TRADE AND AFRICAN REGIONAL AGREEMENTS: A SPATIAL ECONOMETRIC APPROACH

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RÉSUMÉ – Le but de cet article est d'évaluer l'impact des blocs régionaux africains sur les flux commerciaux africains tout en permettant l'interdépendance spatiale entre les flux commerciaux. À cette fin, nous dérivons une équation de gravité spatiale en supprimant l'hypothèse implicite que les flux commerciaux entre deux partenaires commerciaux sont indépendants de ce qui se passe dans le reste du monde commercial. Nous estimons les effets de frontière pour cinq blocs régionaux sub-sahariens (CEMAC, COMEA, ECOWAS, SADC et WAEMU). Nous décomposons l'effet frontière en deux composantes : un effet intra-bloc stimulant le commerce et un effet inter-bloc réduisant le commerce. Nos résultats montrent que les accords commerciaux produisent des effets positifs sur les flux commerciaux intra-bloc et que ces effets sont particulièrement importants lorsque les blocs sont avancés dans leur processus d'intégration. En outre, l'interdépendance spatiale entre les flux commerciaux se traduit par une relation négative, comme le suggère le modèle théorique, indiquant une mesure naturelle de la concurrence spatiale.

ABSTRACT – The purpose of this paper is to evaluate the impact of African regional blocs on African trade flows while allowing for spatial interdependence between trade flows. To this end, we derive a spatial gravity equation by removing the implicit assumption that trade flows between two trading partners are independent of what happens in the rest of the trading world. We estimate the border effects for five Sub-Saharan regional blocs (CEMAC, COMESA, ECOWAS, SADC and WAEMU). We decompose the border effect into two components: a trade-boosting intra-bloc effect and a trade-reducing inter-bloc effect. Our findings show that trade agreements produce positive effects on intra-bloc trade flows and these effects are particularly prominent when the blocs are advanced in their integration process. In addition, the spatial interdependence between trade flows is reflected in a negative relationship as implied by the theoretical model, suggesting a natural measure of spatial competition.

INTRODUCTION

For more than two decades now we have witnessed the proliferation of regional blocs among developing countries (Collier and Venables, 2009). Their impact on trade flows is generally seen as positive in most developing countries especially in Africa which is marginalized in world trade. Through these regional blocs, African countries hope to increase the size of their markets and to secure the welfare associated with increased trade.

A number of authors have attempted to evaluate the effect of regional blocs on the trade flows of Sub-Saharan African countries. Foroutan and Pritchett (1993) compared actual trade with what a traditional gravity model would predict. They found that trade flows between African countries are not below expectations. The median Sub-Saharan African share of intra-trade averages 8.1% while the predicted value is just slightly lower at 7.5%. Carrère (2004) showed that African trade agreements have generated a significant increase in trade among members. Musila (2005) reported positive effects for ECOWAS and COMESA. According to Behar and Edwards (2011), SADC countries trade with each other more than twice as much as other pairs do. This literature claims that the regional agreements in Africa have slightly increased intra-zone trade flows.

Other authors argue, on the contrary, that regional agreements do not have a significant impact on trade flows. Longo and Sekkat (2004) showed that, besides traditional gravity variables, poor infrastructure, economic policy mismanagement, and internal political tensions have a negative impact on trade among African countries. Except for political tensions, the identified obstacles are specific to intra-African trade, since they have no impact on African trade with developed countries. Coulibaly and Fontagné (2006) analyzed the location of countries, whether they are landlocked or not, and the quality of their road infrastructures. They found that the lower the percentage of paved tracks between countries, the greater the impact of this infrastructure improvement on import flows. Geda and Kebret (2008), investigating the case of COMESA, showed that regional blocs had an insignificant effect on bilateral trade flows. The performance of regional blocs is mainly constrained by problems of variation in initial conditions, compensation issues, real political commitment, overlapping membership, policy harmonization, lack of diversification and poor private sector participation (Geda and Kebret, 2008). Introducing into the gravity equation a variable that captures informal markets trade, Agbodji (2007) argued that the existence of these markets significantly reduced formal trade across Sub-Saharan Africa. More recent works also highlight the poor quality of infrastructures to explain the low level of intra-African trade flows (Bosker and Garretsen, 2012; De Sousa and Lochard, 2012)

Several methods have been used to assess the impact of regional blocs, especially the gravity approach (Aitken, 1973; Sapir, 1981). Initially, there was no theoretical foundation for the gravity equation. The first theoretical development was given by Anderson (1979) and was based on constant elasticity of substitution (CES) utility.

Other theoretical frameworks were developed to account for the gravity relationship in the 1980s (Bergstrand, 1985; Helpman, 1984). These authors took into account two key determinants characterizing new trade theory models: economies of scale combined with product differentiation and transport costs. Baier and Bergstrand (2001) developed a gravity model based on monopolistic competition, whereas other approaches focused on Heckscher and Ohlin's model (Deardorff, 1998; Evenett and Keller, 2002), or technological differences between countries (Eaton and Kortum, 2002).

The disturbing common feature of the previously mentioned studies resides in the implicit assumption that trade flows between two trading partners are independent of what happens to the rest of the trading world. This is clearly a very strong assumption that is unlikely to hold and, therefore, may lead to biased and inconsistent estimates of the gravity equation. Paul Krugman (1991) pointed this out and presented a model of trade between two regions. Following the publication of his paper, several studies have tried to model space and to demonstrate how space, via transport costs, can explain several puzzles in international economics. Anderson and Van Wincoop (2003, 2004) show that the relevant export costs for exports from country i to country j, is the cost of exporting from i to country j relative to the cost of exporting from i to all other potential importing competitors of j. They demonstrate that after taking into account their size, trade flows between two regions decrease with their bilateral trade barrier, relative to the average barrier of the two regions in trade with their partners. The average trade barrier is called "multilateral resistance". Feenstra (2002) used an alternative method to control for multilateral resistance by including exporter and importer-specific fixed effects. A further method was introduced by Baier and Bergstrand (2009) and applied to free trade agreements by Behar and Cirera-i Crivillé (2013), which linearizes the Anderson and van Wincoop's system in such a way that multilateral resistance is captured by a linear function of observable trade costs. They use a Taylor-series expansion to solve for multilateral resistances. But this approach requires a normalization of the resistances to a reference country, so each computed multilateral resistance must be interpreted relative to a particular country that has to be chosen in advance. Kelejian *et al.* (2012) specify and estimate a generalization of the typical gravity model which includes country pair fixed effects, third country effects, endogenous regressors, and error terms that are both spatially and time autocorrelated. Behrens *et al.* (2012) takes into account the spatial interdependence between trade flows a spatial gravity model to control for multilateral resistance.

Furthermore, one notable characteristic of regional integration in Africa has been the multitude of regional integration initiatives and consequently the participation of African countries in several of these regional trade agreements (RTAs). Many African countries hold multiple memberships. Of the 54 countries, 27 are members of two regional groupings, 18 belong to three, and one country is a member of four. Only seven countries have maintained membership of one bloc. There are some obvious limitations to this overly-complex regional integration architecture. Multiple arrangements and institutions, as well as overlapping membership in the same region, tend to confuse integration goals and lead to counterproductive competition between countries and institutions (UNECA, 2008). Indeed, the RTAs pursue their own separate mandates and approaches to regional integration, imposing conflicting requirements on countries that are members of more than one grouping and wasting scarce administrative and financial resources.

The overlapping of regional blocs shows that what happens in one bloc depends on what happens in another bloc. This means that there is a spatial interdependence between trade flows. And yet, this interdependence can be the source of spatial autocorrelation or spatial heterogeneity. While spatial heterogeneity can generally be treated by using standard econometric tools, the presence of spatial autocorrelation substantially changes the properties of estimators and the statistical inferences based on these estimators (LeSage, 2008). If there is spatial interdependence, the model of Anderson and Van Wincoop (2003) and the subsequent studies are likely to yield biased estimators. Thereby, we use spatial econometrics tools to avoid this problem. The first model that takes into account the spatial interdependence is that of Behrens *et al.* (2012). This model makes it possible not only to control for multilateral resistance but also to take into account spatial interdependence between trade flows. In what follows, we draw on Behrens *et al.* (2012) to derive a spatial gravity equation from the quantity-based version of CES.

To the best of our knowledge, there are no analytical studies of African trade flows that take into account this interdependence. This paper aims to contribute to a wide literature on African regional agreements by assessing the effect of regional blocs on the trade flows of Sub-Saharan African countries. We put the main focus on spatial interdependence between trade flows by estimating the border effects for five African regional blocs: *Communauté Économique et Monétaire de l'Afrique Centrale* (CEMAC); Common Market for Eastern and Southern Africa (COMESA); Economic Community of West African States (ECOWAS); Southern African Development Community (SADC) and West African Economic and Monetary Union (WAEMU) (see Table A1 in Appendix for the member countries of these blocs). These five blocs are the main trade agreements in Africa (Carrère, 2004).

All of the previously mentioned blocs differ in their degree of integration. We consider that WAEMU and CEMAC are closely integrated compared to other blocs,[1] although intra-bloc trade still experiences difficulties (Goretti and Weisfeld, 2008; Martijn and Tsangarides, 2008). We expect a strong border effect for WAEMU and CEMAC. In terms of deeper integration, SADC is commonly viewed as the third most integrated bloc in Africa. Even if SADC countries do not form a customs union or do not have a common currency, they have nevertheless successfully implemented a free trade area (Behar and Edwards, 2011).

The aim of ECOWAS is to promote economic integration and cooperation with a view to creating an economic and monetary union for fostering economic growth and development in West Africa even if ECOWAS has not yet achieved its goals (Carrère, 2004; Musila, 2005). As regards COMESA, it tries to achieve the removal of all physical, technical, fiscal and monetary barriers to intra-regional trade and commercial exchanges. However, like ECOWAS, COMESA is struggling to achieve its goals (Geda and Kebret, 2008).

Our methodology consists in removing the implicit assumption that trade flows between two trading partners are independent of what happens in the rest of the trading world. The basic idea is to get rid of prices and price indexes by using inverse demand functions and the fact that price indexes depend on trade flows. By doing so, we obtain a gravity equation that depends exclusively on observable variables and on a spatial autoregressive structure in trade flows. We decompose the border effect into two components: a trade-boosting intra-bloc effect and a trade-reducing inter-bloc effect. Our findings show that trade agreements produce positive effects on intra-bloc trade flows and these effects are particularly prominent when the blocs are advanced in their integration process. With respect to the spatial effect, we find a negative relationship between trade flows that can be interpreted as spatial competition.

The remainder of the paper is organized as follows: Section 1 presents the theoretical model. In Section 2, we discuss our empirical results and Section 3 concludes the discussions.

1. The theoretical model

We follow Behrens *et al.* (2012) by deriving a system of gravity equations that does not depend on unobservable price indexes, yet encapsulates the general equilibrium interdependencies of the full trading system. To this end, we build upon a CES trade model like those of Dixit and Stiglitz (1977) and Krugman (1980). More specifically, we derive a gravity equation from the quantity-based version of the CES model by exploiting the fact that the price indexes are themselves implicit functions of trade flows. We obtain an implicit equation system that depends on

1. Because they have managed to establish common external tariffs and they each have a common currency.

observable variables only and that can be estimated using techniques borrowed from the spatial econometrics literature.

1.1 *Consumers*

We consider an economy with n countries. Each country i is endowed with L_i consumers/workers and each one supplies inelastically one unit of labour. Labour is the only production factor so that L_i stands for both the size of, and the aggregate labor supply in country i. All consumers have identical and homothetic preferences over a continuum of horizontally differentiated product varieties (Anderson and van Wincoop, 2003). A representative consumer in country j solves the following problem:

$$\max U_j \equiv \sum_i \int_{\Omega_i} q_{ij}(\nu)^{\frac{\sigma-1}{\sigma}} d\nu \qquad \text{s.t.} \qquad \sum_i \int_{\Omega_i} q_{ij}(\nu) p_{ij}(\nu) d\nu = y_j \tag{1}$$

where $\sigma > 1$ denotes the constant elasticity of substitution between any two varieties; y_j stands for individual income in country j; $p_{ij}(\nu)$ and $q_{ij}(\nu)$ denote the consumer price and per capita consumption of variety ν produced in country i; and Ω_i denotes the set of varieties produced in country i. Since varieties produced in the same country are assumed to be symmetric, in what follows we alleviate the notation by dropping the variety index ν. Let m_k stand for the measure of Ω_k (i.e., the mass of varieties produced in country k). The aggregate inverse demand functions for each variety are given by:

$$p_{ij} = \frac{Q_{ij}^{-1/\sigma}}{\sum_k m_k Q_{kj}^{1-1/\sigma}} Y_j \tag{2}$$

where $Q_{ij} \equiv L_j q_{ij}$ denotes the aggregate demand in country j for a variety produced in country i; and where $Y_j \equiv L_j y_j$ stands for the aggregate income in country j.

1.2 *Firms*

It is assumed that the products are horizontally differentiated and that each variety is produced by a single firm only. The production of each variety is subject to increasing returns with a common technology for all countries. Labour is the only factor of production, and in order to produce q units of output, $cq + F$ units of labour are required, where c is the marginal cost and F the fixed cost. Since shipping varieties both within and across countries is costly, shipping one unit of any variety between countries j and k requires dispatching $\tau_{jk} > 1$ units from the origin country j, so that $p_{jk} = \tau_{jk} p_j$, where p_j is the mill price (Samuelson, 1952). A firm located in country j maximizes its profit, given by:

$$\pi_j = \sum_k (p_{jk} - cw_j \tau_{jk}) Q_{jk} - Fw_j \tag{3}$$

Using equation (2) in the profit maximization process of the firm yields $p_j \equiv cw_j \sigma/(\sigma - 1)$. Free entry and exit drive profits to zero, which implies that each firm must produce the break-even quantity

$$\sum_k \tau_{jk} Q_{jk} = \frac{F(\sigma - 1)}{c} \equiv \overline{Q} \tag{4}$$

1.3 *Equilibrium*

To derive the gravity equation, it is necessary to know the value of trade flows from country i to country j at equilibrium. This is given by $X_{ij} \equiv m_i p_{ij} Q_{ij}$. Using equation (2), we obtain:

$$X_{ij} = m_i \frac{Q_{ij}^{1-1/\sigma}}{\sum_k m_k Q_{kj}^{1-1/\sigma}} Y_j \tag{5}$$

From (5) we derive the following gravity equation[2]

$$X_{ij} = Y_j^{\sigma} \left[\sum_k \frac{L_k}{L_i} \left(\frac{\tau_{kj}}{\tau_{ij}} \frac{Y_k}{Y_i} \right)^{1/\sigma - 1} X_{kj}^{1-1/\sigma} \right]^{-\sigma} \qquad \forall i, j \tag{6}$$

which is a system of equations capturing the interdependence of all trade flows towards country j. To close the general equilibrium system, we impose the aggregate income constraints:

$$Y_i - \sum_k X_{ik} = 0, \qquad \forall i \tag{7}$$

As can be seen from expressions (6) and (7), all equilibrium trade flows (including flows X_{ii}) are related directly (as the varieties of products are substitutes) or indirectly (through the national income). In the following section, we derive a spatial econometric reduced form by linearizing (6) to obtain an estimable equation taking into account all these interdependencies.

2. See Behrens *et al.* (2012) for the formal derivation.

1.4 *Econometric specification*

To obtain an econometric specification, we take equation (6) in logarithmic form:

$$\ln X_{ij} = \sigma \ln Y_j - \sigma \ln \left[\sum_k \frac{L_k}{L_i} \left(\frac{\tau_{kj} Y_k}{\tau_{ij} Y_i} \right)^{1/\sigma - 1} X_{kj}^{1-1/\sigma} \right] \tag{8}$$

Clearly, there is interdependence across trade flows as X_{ij} depends negatively on the nominal sales of the other countries in market j. To obtain a specification that can be estimated using spatial econometric techniques, we linearize (8) around $\sigma = 1$. Doing so yields the following equation:

$$\begin{aligned} \ln Z_{ij} = & - \sigma \ln L - (\sigma - 1) \left(\ln \tau_{ij} - \sum_k \frac{L_k}{L} \ln \tau_{kj} \right) - \sigma \ln w_i \\ & - (\sigma - 1) \sum_k \frac{L_k}{L} \ln Z_{kj} \end{aligned} \tag{9}$$

where $Z_{ij} \equiv X_{ij}/(Y_i Y_j)$[3] is a GDP-standardized trade flow (but which we will refer to as trade flow for short); and where $L \equiv \sum_k L_k$ denotes the total population. Expression (9) reveals the essence of spatial interdependence in the gravity equation: *the trade flow X_{ij} from country i to country j also depends on all the trade flows from the other countries k to country j.* Several comments are in order. First, trade flows from i to j are affected by relative trade barriers, as measured by the deviation of bilateral trade barriers τ_{ij} from the population weighted average (second term). Put differently, relative accessibility matters. Second, trade flows from i to j are negatively affected by wages w_i in the origin country (third term). Higher wages raise production costs and make country i's firms less competitive in market j, thereby reducing trade flows. Last, trade flows from i to j decrease with trade flows Z_{kj} from any third country k into the destination market, because varieties are substitutes. This effect is stronger the closer substitutes the varieties are (i.e., the larger the value of σ). In our estimations, interdependence will be captured by an *autoregressive interaction coefficient*, and this coefficient can be seen as a measure of "spatial competition" encapsulating both aspects related to market power and consumer preference for diversity (via the parameter σ).

As regards the functional form of trade costs, we assume that τ_{ij} is a log-linear function of distance, border effect, landlocked position/status, common language,

3. Doing so, we can control for a possible endogeneity of the two variables trade flows and GDP. See Emlinger *et al.* (2008)

common currency and an error[4] term as follows (Anderson and Van Wincoop, 2004):

$$\tau_{ij} \equiv d_{ij}^{\gamma} e^{\xi b_{ij} + \zeta e_{ij} - \varsigma l_{ij} - \eta c_{ij} + \varepsilon_{ij}} \tag{10}$$

where d_{ij} denotes the distance between country i and j; where b_{ij} is a dummy variable taking the value 1, if the flow X_{ij} takes place between a country belonging to a certain regional-bloc (like a monetary, economic or customary zone) and a country not belonging to this bloc, and 0 otherwise.[5] Where e_{ij} takes value 1, if at least one of the two countries is landlocked, and 0 otherwise (see Faye *et al.* (2004); l_{ij} is a dummy variable taking value 1, if both partners have a common language[6] and 0 otherwise (Melitz, 2008); and c_{ij} is an another dummy that equals value 1, if the two countries have a common currency, and 0 otherwise (Frankel and Rose, 2002). The terms ε_{ij} are assumed i.i.d error terms. Substituting equation (10) in equation (9) then yields the following equation:

$$\begin{aligned} \ln Z_{ij} = & -\sigma \ln L - (\sigma-1)\gamma \ln \widetilde{d}_{ij} - (\sigma-1)\xi \widetilde{b}_{ij} - (\sigma-1)\zeta \widetilde{e}_{ij} \\ & - (\sigma-1)\varsigma \widetilde{l}_{ij} - (\sigma-1)\eta \widetilde{c}_{ij} - \sigma \ln w_i - (\sigma-1)\sum_k \frac{L_k}{L} \ln Z_{kj} + \varepsilon_{ij} \end{aligned} \tag{11}$$

where $\widetilde{d}_{ij} \equiv d_{ij}/\Pi_k d_{kj}^{L_k/L}$ are relative distances; $\widetilde{b}_{ij} \equiv b_{ij} - \sum_k \frac{L_k}{L} b_{kj}$ are relative borders. More precisely, equation (11) reflects the trade resistance across blocs as compared to trade within blocs. $\widetilde{e}_{ij} \equiv e_{ij} - \sum_k \frac{L_k}{L} e_{kj}$ capture the relative effects of countries being landlocked; $\widetilde{l}_{ij} \equiv l_{ij} - \sum_k \frac{L_k}{L} l_{kj}$ are the relative impacts of a common language use; and $\widetilde{c}_{ij} \equiv c_{ij} - \sum_k \frac{L_k}{L} c_{kj}$ are the relative effects of a common currency use. As regards the error structure, there are many ways of modelling the error structure about which theory has little to say. Behrens *et al.* (2012) pointed out that he error terms exhibit some form of cross-sectional correlation as:

$\varepsilon_{ij} = \lambda \sum_k \frac{L_k}{L} u_{kj} + u_{ij}$, where $u_{ij} \equiv -(\sigma-1)\varepsilon_{ij}$ is an iid error term. Note that, from equation (11) all variables superscripted with a tilde are measured as deviations from their population weighted averages, that allowing us to implicitly control for multilateral resistance. Moreover, equation (11) allows us to capture a possible spatial autocorrelation in error terms.

Since wages are unobserved for most countries, rather than taking GDP per capita as proxies (as in Redding and Venables, 2004) which is clearly an endogenous variable in particular when we include intra-trade flow X_{ii}, we prefer to intro-

4. The error term can enter the model in many ways. Here we introduce it via the trade cost τ_{ij}. Doing so can be justified on the basis that trade costs are observed imperfectly.

5. This dummy is intended to estimate the border effect of different blocs in Africa, and is made more explicit below.

6. Here we consider each country's first official language only.

duce origin and destination country fixed effects following Rose and Van Wincoop (2001) and Feenstra (2002). Moreover, using the fixed effects approach allows us to control for possible omitted variables. That is, let δ_{1i} denote an indicator variable that is 1 if country i is the exporter,[7] and 0 otherwise; and let δ_{2j} denote an indicator variable that is 1 if country j is the importer, and 0 otherwise. Then our spatial econometric reduced form to be estimated is:

$$\begin{aligned}\ln Z_{ij} =& \beta_0 + \beta_1 \ln \widetilde{d}_{ij} + \beta_2 \widetilde{b}_{ij} + \beta_3 \widetilde{e}_{ij} + \beta_4 \widetilde{l}_{ij} + \beta_5 \widetilde{c}_{ij} + \beta_{6i}\delta_{1i} + \beta_{7j}\delta_{2j} \\ &+ \rho \sum_k \frac{L_k}{L} \ln Z_{kj} + \varepsilon_{ij}\end{aligned} \tag{12}$$

where $\beta_0 \equiv -\sigma \ln L < 0$ is the constant term; $\beta_1 \equiv -(\sigma-1)\gamma < 0$ is the distance coefficient of deviation from population weighted averages distances. Indeed, $\widetilde{d}_{ij}$ is a proxy variable for natural trade resistance which in turn is a composite of transport cost, transport time, and economic horizon. Consequently, it is hypothesized to have a negative effect on bilateral trade flows; $\beta_2 \equiv -(\sigma-1)\xi < 0$ is the coefficient that captures the border effect. Since the border effect reflects the trade resistance across blocs, we except a negative impact for its coefficient. $\beta_3 < 0$ is the coefficient of landlocked countries; $\beta_4 > 0$ captures the impact of common language; $\beta_5 > 0$ is the coefficient of common currency. β_{6i} are the coefficients of origin fixed effects; β_{7j} are the coefficients of destination fixed effects and $\rho \equiv -(\sigma-1) < 0$ is the spatial autoregressive coefficient. Since the trade flow X_{ij} from country i to country j also depends on all the trade flows from the other countries k to country j, we define the $n^2 \times n^2$ spatial interaction matrix, with $\mathbf{W} = [\mathbf{S}\ \mathrm{diag}(\mathbf{L})] \otimes \mathbf{I}_n$ where $\mathbf{S}$ is the $n \times n$ matrix whose elements are all equal to 1; $\otimes$ is the Kronecker product and $\mathrm{diag}(\mathbf{L})$ is defined as the $n \times n$ diagonal matrix of the L_k/L terms.[8] To be more explicit about $\mathbf{W}$, let $\mathbf{W}_{\mathrm{diag}} = \mathrm{diag}(\mathbf{L}) \otimes \mathbf{I}_n$ denote the matrix containing only the diagonal elements of $\mathbf{W}$. In accordance with Behrens *et al.* (2012), equation (12) can be rewritten in matrix form as follows:

$$\begin{aligned}(\mathbf{I} - \rho \mathbf{W}_{\mathrm{diag}})\mathbf{Z} =& \beta_0 \mathfrak{I} + \beta_1 \widetilde{\mathbf{d}} + \beta_2 \widetilde{\mathbf{b}} + \beta_3 \widetilde{\mathbf{e}} + \beta_4 \widetilde{\mathbf{l}} + \beta_5 \widetilde{\mathbf{c}} + \beta_6 \boldsymbol{\delta_1} + \beta_7 \boldsymbol{\delta_2} \\ &+ \rho(\mathbf{W} - \rho \mathbf{W}_{\mathrm{diag}})\mathbf{Z} + (\mathbf{W} - \rho \mathbf{W}_{\mathrm{diag}})\varepsilon.\end{aligned}$$

Since $\mathbf{I} - \rho \mathbf{W}_{\mathrm{diag}}$ is, by construction, an invertible diagonal matrix, we can premultiply by its inverse to obtain the following expression:

$$\begin{aligned}\mathbf{Z} =& \overline{\beta}_0 \mathfrak{I} + \overline{\beta}_1 \widetilde{\mathbf{d}} + \overline{\beta}_2 \widetilde{\mathbf{b}} + \overline{\beta}_3 \widetilde{\mathbf{e}} + \overline{\beta}_4 \widetilde{\mathbf{l}} + \overline{\beta}_5 \widetilde{\mathbf{c}} + \overline{\beta}_6 \boldsymbol{\delta_1} + \overline{\beta}_7 \boldsymbol{\delta_2} + \overline{\rho}(\mathbf{W} - \mathbf{W}_{\mathrm{diag}})\mathbf{Z} \\ &+ (\mathbf{I} - \rho \mathbf{W}_{\mathrm{diag}})\varepsilon.\end{aligned}$$

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7. The number of dummy variables relative to country fixed effects introduced is one less than the number of exporters, so as to avoid perfect collinearity.

8. It is worth noting that the interaction matrix comes structurally from the theoretical model of Behrens *et al.* (2012). Elements of this matrix are defined by share of populations L_k/L and not by some *ad hoc* definition of distance.

The elements between positions $(i \times n) + 1$ and $(i+1) \times n$ of $(\mathbf{I} - \rho \mathbf{W}_{\text{diag}})^{-1}$, given by $\left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}$, depend on the origin index i only which is fixed and identical for all destinations. Therefore, the components of the transformed (overlined) vectors of coefficients are given by:

$$\overline{\beta}_{1i} \equiv \beta_1 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}, \overline{\beta}_{2i} \equiv \beta_2 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1},$$

$$\overline{\beta}_{3i} \equiv \beta_3 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}, \overline{\beta}_{4i} \equiv \beta_4 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1},$$

$$\overline{\beta}_{5i} \equiv \beta_5 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}, \overline{\beta}_{6i} \equiv \beta_6 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1},$$

$$\overline{\beta}_{7i} \equiv \beta_7 \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}, \overline{\rho}_i \equiv \rho_i \left[1 + (\sigma - 1)\frac{L_i}{L}\right]^{-1}.$$

We obtain a specification with a distinct set parameters for each country. The full model, therefore, has a "club" structure since all parameters (including the spatial autoregressive ones) must be estimated locally for each country. Behrens *et al.* (2012) refer to this model as the *heterogeneous coefficients model*. Since one of our objectives is to assess the impact of different regional agreements, we don't need to estimate all parameters (including the spatial autoregressive ones) locally for each country. Therefore, we constrain all coefficients to be identical across countries, which Behrens *et al.* (2012) refer to as *the homogeneous coefficients model*. In addition, in most studies on gravity model the coefficients are supposed to be homogeneous across countries (Anderson and Van Wincoop, 2003, 2004; Baier and Bergstrand, 2001, 2009). Constraining the coefficients to be identical amounts to assuming that the diagonal elements of **W** are equal to zero in equation (12). In that case, the model simplifies substantially and can readily be estimated using standard spatial econometric techniques. Moreover, in the spatial econometrics literature, an observation is not neighbour to itself by convention, so that the diagonal elements are zero ($\mathbf{w}_{ii} = 0$) (see Anselin and Bera, 1998).

1.5 *Intra- and inter-bloc effects*

From equation (12) we decompose the border effect into two components: the trade-boosting intra-bloc effect and the trade-reducing inter-bloc effect of the border.[9] To disentangle the two components and to retrieve the full implied border effects (both intra-bloc and inter-bloc), we proceed as follows. First, we define the

9. Trade flows between a bloc member country and a non-member country.

border as the ratio of trade flows in a world with borders (Z_{ij}) to that which would prevail in a borderless world ($\overline{Z}_{ij}$). Using (9) and (10), we then have:

$$B_{ij} \equiv \frac{Z_{ij}}{\overline{Z}_{ij}} = e^{\theta[b_{ij}-\sum_k \frac{L_k}{L} b_{kj}]} \prod_k \left(\frac{Z_{ij}}{\overline{Z}_{ij}}\right)^{\rho \frac{L_k}{L}}, \tag{13}$$

where the term $e^{\theta[b_{ij}-\sum_k \frac{L_k}{L} b_{kj}]}$ subsumes the border frictions as a deviation from their population weighted average. Note that (13) defines a log-linear system of all the relative trade flows, which depend on all border effects. Let $\mathbf{B}$ stand for the $n^2 \times 1$ vector of $\ln(\frac{Z_{ij}}{\overline{Z}_{ij}})$ and let $\mathbf{b}$ stand for $n^2 \times 1$ vector of $[b_{ij} - \sum_k \frac{L_k}{L} b_{kj}]$. The log-linearized version of the system has the following solution, $\mathbf{B} = \theta(\mathbf{I} - \rho\mathbf{W})^{-1}\mathbf{b}$, which allows us to retrieve the border effect as the exponential of the foregoing expression.

Note that (13) quite naturally depends upon where countries i and j are located. Four cases may therefore arise with respect to intra-bloc and inter-bloc trade. Let $\text{pop}_{\text{bloc}} \equiv \sum_{k\in \text{bloc}} \frac{L_k}{L}$ (resp., $\text{pop}_{\text{ROW}} \equiv \sum_{k\notin \text{bloc}} \frac{L_k}{L}$) stand for the regional-bloc (resp., the rest of the world) population shares. It is readily verified that[10]

$$\ln B_{ij} = \begin{cases} -\theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \in \text{BLOC}) \\ \theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \notin \text{BLOC}) \\ \theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \in \text{BLOC}) \\ -\theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \notin \text{BLOC}) \end{cases} \tag{14}$$

Equation (14) reveals several interesting points. First, the expressions for BLOC-BLOC and ROW-ROW can be interpreted as the *trade-boosting* effect generated by the presence of borders which increases trade flows within each bloc. The trade flows within each bloc will be larger in a world with borders than in a borderless world. The reason is that borders protect regional firms from competition and give them an advantage in the regional market. Second, the expressions for BLOC-ROW and ROW-BLOC can be interpreted as the *trade-reducing* effect of the border on trade flows across countries located in different blocs. The trade flows across blocs will be smaller in a world with borders than in a borderless world. Third, as in Anderson and Van Wincoop (2003), smaller blocs will have larger implied border effects than large blocs since their magnitude depends positively on the size of the trading partner, as measured by its share of population. The reason is that the border affects smaller blocs more than it does larger blocs, as it creates trade frictions for a larger share of the total demand served by its firms. Finally, the full border effect (combining the *trade-boosting* and *trade-reducing* effects), is given by $e^{-2\theta \text{pop}_{\text{ROW}}}$ for countries belonging to the bloc and by $e^{-2\theta \text{pop}_{\text{BLOC}}}$ for countries not belonging to the bloc.[11]

10. See Behrens *et al.* (2012)

11. In this study, we focus only on countries belonging to the bloc.

To measure the intensity of the border effect we are interested in the five main African regional blocs: WAEMU, CEMAC, ECOWAS, COMESA and SADC. The first two are simultaneously preferential trade blocs and monetary unions with a common currency (the franc CFA). WAEMU and CEMAC each have their own single currency (with the same acronym, franc CFA) and/each of which is pegged to the *euro*. Although these two currencies are commonly referred to by the same name (franc CFA) and have the same value, they are not interchangeable or mutually convertible, so this is not one common currency bloc but two juxtaposed blocs (Abdih and Tsangarides, 2010).

2. Empirical evidence

2.1 *Data and econometrics*

Our sample contains 150 countries with 22 500 pairs of trade flows; 37 of countries are African countries, 36 American countries, 34 Asian countries, 38 European countries and 5 Oceanic countries. The data set includes exports X_{ij} (including internal absorption X_{ii}) between countries, GDPs Y_i and Y_j of trading partners all measured in millions of US dollars for the year 2010. We then use cross-sectional data for the year 2010. We compute internal absorption as $X_{ii} \equiv \text{GDP}_i - \sum_j X_{ij}$. Trade flows are from the UN COMTRADE database.[12] GDP, national currency and population (also in 2010) data are obtained from the Penn World Table 7.0.[13] The data set also contains bilateral distances (in kilometers) between capital cities and are from the CEPII database.[14] They are computed using the great circle distance formula applied to the capitals' geographic coordinates. As regards the internal distances of the countries, we follow Redding and Venables (2004) by computing internal distances as $d_{ii} \equiv \kappa\sqrt{\text{surface}_i/\pi}$. As estimation results are known to be somewhat sensitive to the measurement of internal distance (Head and Mayer, 2002) we use $1/3$, $2/3$ and 1 for κ. However, since our results are quite robust to these different values of κ, we report only for $\kappa = 2/3$.[15] Landlocked position and language also come from the CEPII database. In our study, we constructed the theoretically implied interaction matrix $\mathbf{W}$ using the population share of each exporting country in our sample.[16] To deal with potential endogeneity of population shares, we use three–year lagged values of this variable. Results are robust with respect to different lags. We also ran the regressions using the "current year" (i.e., 2010), and results were little sensitive (with no change at all in the qualitative results). That why we report only the results for the year 2010.

Insofar as one of our objectives is to assess the impact of different regional agreements in Africa, we further have to deal with the well-known problem of zero

12. http://comtrade.un.org/
13. https://pwt.sas.upenn.edu.
14. http://www.cepii.fr/
15. Results using $1/3$ and 1 for κ are available upon request.
16. The interaction matrix $\mathbf{W}$ is normalized by its eigenvalues.

trade flows. The zero values found in the trade database correspond in fact either to a genuine zero flow or to a flow below a certain reporting threshold. The latter are very low and are therefore assimilated to absence of trade. Consequently, a subset of the observations are believed to represent censored values, which result in a truncated distribution for the dependent variable observations. Since there is no generally agreed-upon method for doing so (Anderson and Van Wincoop, 2004), we control for the potential zero flow outliers by including a dummy variable in all regression. Alternative methods have been used to control for zero trade flows like the Heckman procedure (such as Emlinger *et al.*, 2008). However, these methods are not known to perform better or to be theoretically more sound (Felbermayr and Kohler, 2006). We therefore both use a zero dummy variable and the spatial TOBIT to evaluate the robustness relative to the methodology used.

When spatial autocorrelation is present in econometric specification, OLS is no longer appropriate: the estimators obtained by this method are not convergent if there is a lagged endogenous variable and they are inefficient in the presence of spatial autocorrelation (Anselin, 1988; Anselin and Bera, 1998). The method widely used is the maximum likelihood (Lee, 2004; LeSage, 2008).[17]

In the next section, we perform several estimation procedures depending on the structure of error terms. First, we estimate the model (12) without spatial interdependence (i.e. $\rho = 0$) using OLS. Secondly, we estimate two versions of the spatial autoregressive model (12): (i) a Spatial Autoregressive model (SAR) where errors ε_{ij} are assumed to be iid, (ii) a General Spatial Model (GSM) where errors have a spatial autoregressive structure $\varepsilon_{ij} = \lambda \sum_{k \neq i}^{n^2} w_{kj}\varepsilon_{kj} + u_{ij}$. In this last case, we approximate the moving average by a more general autoregressive error structure. Finally, in order to treat the zero trade flows issue, we use a zero dummy in OLS, SAR and GSM specifications and we use a spatial TOBIT (see LeSage (2008) and Xu and Lee (2015) for a recent discussion of the asymptotic properties of the spatial TOBIT).

2.2 *Results*

Our empirical model is the model (12) where we add dummies relative to the customs unions (CEMAC and WAEMU), free trade areas (SADC and ECOWAS) and a common market (COMESA) to measure the trade-boosting effect and the trade-reducing effects. We also introduce some control variables as described below. Table 1 displays the full results.

The estimation of equation (12) shows that WAEMU and CEMAC are not significant using OLS and SAR (Table 1 column 1 and 2). Distance negatively affects trade flows, suggesting that distant countries tend to trade less with each other. Distance is a proxy for transport costs and time so that a long transport time increases the costs of packaging perishable goods.

17. For estimation we used James Lesage's Econometrics Toolbox which is available at http://www.spatial-econometrics.com/.

TABLE 1

ESTIMATION RESULTS

Model	OLS	SAR	SAC	TOBIT
distance	−1.486***	−1.479***	−1.378***	−1.852***
	(0.022)	(0.020)	(0.022)	(0.024)
WAEMU	−0.236	−0.250	−0.459**	−0.882***
	(0.217)	(0.187)	(0.190)	(0.225)
ECOWAS	−0.519***	−0.513***	−1.539***	−0.554***
	(0.143)	(0.121)	(0.124)	(0.143)
CEMAC	−0.403	−0.411	−0.536*	−0.931**
	(0.646)	(0.324)	(0.311)	(0.373)
COMESA	−0.438***	−0.434***	−0.315***	−0.736***
	(0.116)	(0.091)	(0.097)	(0.103)
SADC	−0.701***	−0.702***	−0.720***	−0.593***
	(0.136)	(0.129)	(0.134)	(0.153)
landlocked	−0.429***	−0.424***	−0.306***	−0.427***
	(0.082)	(0.082)	(0.081)	(0.096)
language	1.069***	1.064***	0.860***	1.344***
	(0.052)	(0.049)	(0.042)	(0.059)
Currency	1.171***	1.164***	1.025***	0.414***
	(0.121)	(0.109)	(0.104)	(0.130)
Dummy-Zero	−3.569***	−3.562***	−3.556***	
	(0.047)	(0.040)	(0.040)	
ρ		−1.070***	−0.114***	−0.040**
		(0.037)	(0.005)	(0.021)
λ			−28.747***	
			(0.096)	
R^2	0.683			
AIC		−3.397	−3.273	−3.164
BIC		−3.287	−3.163	−3.068

NOTE: Standard errors are given in parentheses. *** significant at 1%; ** significant at 5% and * significant at 10%. The number of observations is 22 500. AIC and BIC stand for the Akaike and the Schwarz information criteria, respectively.

We note that the theoretical model predicts that the spatial autocorrelation coefficient ρ should be negative. This means that trade flow from i to j decreases with the value of sales X_{kj} from any third country k into the destination market, because varieties are gross substitutes. Since spatial interdependence is captured by the spatial autoregressive coefficient in our estimating equations, this coefficient may be interpreted as a measure of "*spatial competition*" encapsulating both aspects of market power and consumer preference for diversity. Moreover, since the estimate for the parameter ρ is significantly different from zero, least-squares estimates are biased and inconsistent. In what follows we will focus on the results given by the spatial models (especially GSM and TOBIT models) that result from the theoretical model.

As regards the border effects, the coefficients associated with all relative borders are negative and significant. These coefficients allow us to capture relative trade resistance due to regional blocs. To assess the magnitudes of impacts arising from regional blocs, we turn to the summary measures of intra-bloc effects, inter-bloc effects and total impacts presented in Table 2.

TABLE 2

BORDER EFFECTS

Area	**WAEMU**	**ECOWAS**	**CEMAC**	**COMESA**	**SADC**
			OLS		
Intra	1.261^{ns}	1.642	1.493^{ns}	1.512	1.976
Inter	0.792^{ns}	0.608	0.669^{ns}	0.661	0.506
Full	1.592^{ns}	2.697	2.230^{ns}	2.287	3.905
			SAR FE		
Intra	1.279^{ns}	1.633	1.505^{ns}	1.506	1.977
Inter	0.781^{ns}	0.612	0.664^{ns}	0.663	0.505
Full	1.637^{ns}	2.667	2.267^{ns}	2.270	3.911
			SAC FE		
Intra	1.573	1.542	1.706	1.347	2.013
Inter	0.635	0.648	0.586	0.742	0.496
Full	2.474	2.377	2.910	1.815	4.052
			TOBIT FE		
Intra	2.385	1.699	2.526	2.003	1.779
Inter	0.419	0.588	0.395	0.499	0.562
Full	5.690	2.887	6.3840	4.013	3.165

NOTE: *ns* = not significant.

The results suggest that regional integration substantially increases trade between WAEMU countries. Indeed, our results show that trade between WAEMU countries is 5.7 times higher than trade between WAEMU countries and non WAEMU countries. Furthermore, the trade-boosting intra-bloc coefficient shows that the trade flows within WAEMU are 2.4 times larger in a world with borders (world with blocs) than in a world without borders (world without blocs). As regards the trade-reducing inter-bloc effect, we find that the trade flows across WAEMU are 0.4 times smaller in a world with borders than in a world without borders. Put differently, the trade flows across the blocs experience the border effect, which has the consequence of reducing these trade flows. For CEMAC, the full border coefficient indicates that trade flows within CEMAC are 6.4 times higher than trade flows across CEMAC. The creation of CEMAC boosts trade between member countries by 2.6 times and reduces trade flows with the rest of the world by a factor of 0.4.

Our estimations for SADC show that the coefficient of the full border effect is 3.2, the trade-boosting effect is 1.8 and the trade-reducing effect is 0.6. These results show that intra-SADC trade increased compared with non-SADC trade. Implementation of SADC led to an increase in intra-SADC and a reduction in trade with non-members. Note that South Africa was initially not in this bloc but now it constitutes a dominant member as in Africa as a whole. The region is therefore more dependent on South Africa as a source of imports than as a market for exports.

For ECOWAS, the full border effect coefficient is 2.9. The trade-boosting intra-ECOWAS effect coefficient is 1.7 and the trade-reducing coefficient is 0.6. These results indicate a small border effect for ECOWAS despite the presence of all WAEMU countries (see Table A1) and powerful neighbors (Nigeria and Ghana). We find that trade flows within COMESA would be 4 times higher than trade flows across COMESA. The creation of COMESA boosts trade between member countries by 2 and reduces trade flows with the rest of the world by a factor of 0.5.

The coefficient relative to the landlocked countries is negative and significant, suggesting that landlocked countries lag behind their maritime neighbours in external trade. This can be attributed to distance from the coast and several aspects of dependence on transit neighbours such as neighbours' infrastructure, sound cross-border political relations, neighbours' peace and stability and neighbours' administrative practices. Landlocked countries not only face the challenge of distance, but also the challenges that result from dependence on passage through a foreign transit country, one through which trade from a landlocked country must pass in order to access international shipping markets. Landlocked countries are completely dependent on their transit neighbours' infrastructure to transport their goods to port. This infrastructure may be weak for many reasons, including lack of resources, mis-governance, conflict and natural disasters. Weak infrastructures (ports, roads, rail) in African countries increase transport costs and are often agreater obstacle to trade than tariff and non-tariff barriers in importing countries. Given the magnitude of infrastructure needs in Africa, it is acknowledged that to correct these shortcomings, regional and continental solutions are required.

We find a positive and significant coefficient for common language. This finding points out that common language promotes bilateral trade by facilitating communication and easing transactions. Two individuals who speak the same language can communicate and trade with each other directly whereas those without a sufficient knowledge of a common language must often rely on an intermediary or hire an interpreter. The additional complexity inherent in such a mediated relationship, the potential for costly errors and their increased cost may be large enough to prevent otherwise mutually beneficial transactions from occurring.

As regards the coefficient of common currency, we also find a positive and significant coefficient. This finding shows that common currency promotes bilateral trade by reducing the costs of international transactions. The intuition is that trade between areas that use a single currency is cheaper and easier than trade between areas with their own currencies.

Finally, it follows from all foregoing that regional blocs (whether customs unions, free trade areas, monetary unions, etc.) broadly have a positive effect on intra-trade flows. Trade within regional blocs is increased whereas trade with non-member countries is reduced. We note that regional integration is more advanced in WAEMU and CEMAC than in other regional blocs. Furthermore, WAEMU and CEMAC are a major export markets for the dominant countries in the two blocs (Cameroon for CEMAC and Senegal, Benin and Côte d'Ivoire for WAEMU). They are the prime export market for landlocked countries in both blocs. The small border effect for ECOWAS can be attributed to the failure by the members of these blocs to reduce both tariff and non-tariff barriers to trade. We also note that the border effect is high for the blocs that are well advanced in their integration process, and it is small for the blocs lagging behind in their integration process. We conclude that the more advanced the integration process is, the more member countries tend to trade with each other and to reduce their imports and exports with third countries.

CONCLUSION

In this paper we estimated the border effect by breaking it down into two components: the trade-boosting intra-bloc effect and the trade-reducing inter-bloc effect. To estimate both trade-boosting and trade-reducing effects we based our approach on Behrens *et al.* (2012) by deriving a gravity equation and taking into account spatial interdependence between trade flows. Doing so yields a spatial econometrics reduced form where we explore different specifications of error terms or the treatment of zeros trade flows (SAR, GSM and spatial TOBIT). We find that regional blocs (whether customs union, free trade area, monetary union, or whatever) have a positive effect on intra-trade flows. Regional blocs not only increase intra-trade flows but also reduce trade with other outside countries. We also note that the border effect is high for the blocs that are well advanced in their integration process, and it is small for the blocs lagging behind in their integration process. As regards the spatial effect, we find that the spatial interdependence between trade flows is reflected in a negative relationship. Moreover, we also control for common language, landlocked countries, and common currency and they are found to be important determinants as distance in explaining trade flows.

APPENDIX

TABLE A1

LIST OF COUNTRIES FOR EACH BLOC

CEMAC	COMESA	ECOWAS	SADC	WAEMU
Cameroon	Angola	Benin	Angola	Benin
CAR	Burundi	Burkina Faso	Botswana	Burkina Faso
Chad	Comoros	Cape Verde	RDC	Côte d'Ivoire
Congo	RDC	Côte d'Ivoire	Lesotho	Bissau Guinea
Equatorial Guinea	Djibouti	Gambia	Madagascar	Mali
Gabon	Egypt	Ghana	Malawi	Niger
	Eritrea	Guinea	Mauritius	Senegal
	Ethiopia	Bissau Guinea	Mozambique	Togo
	Kenya	Liberia	Namibia	
	Libya	Mali	Swaziland	
	Madagascar	Niger	Seychelles	
	Malawi	Nigeria	South Africa	
	Mauritius	Senegal	Tanzania	
	Rwanda	Sierra Leone	Zambia	
	Seychelles	Togo	Zimbabwe	
	South Sudan			
	Sudan			
	Swaziland			
	Uganda			
	Zambia			
	Zimbabwe			

NOTE: CAR = Central African of Republic. Botswana, Namibia, Swaziland are not in our sample. South Sudan and Sudan constitute a single country.

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