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Résumé

L'objet de cette étude est d'évaluer l'impact des blocs régionaux africains sur les flux commerciaux, tout en prenant en compte l'interdépendance spatiale entre ces flux. À cet effet, nous dérivons une équation de gravité spatiale en relâchant l'hypothèse implicite que les flux commerciaux entre deux partenaires sont indépendants de ce qui se passe dans le reste du monde. Nous estimons les effets frontières pour six blocs régionaux en Afrique (CEMAC, COMESA, CEDEAO, SADC, UEMOA et la zone FRANC). Nos résultats montrent qu'excepté la zone FRANC et la CEDEAO, tous les autres blocs ont produit des effets positifs sur les flux commerciaux. Cependant, ces effets sont faibles sauf pour l'UEMOA et la CEMAC. En outre, l'interdépendance spatiale entre les flux commerciaux s'est traduite par une relation négative comme l'implique le modèle théorique, ce qui suggère une mesure naturelle de la concurrence spatiale.

Mots clés : Effets frontières ; Blocs régionaux ; Autocorrélation spatiale ; Afrique Sub-Saharienne.

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 six Sub-Saharan regional blocs (CEMAC, COMESA, ECOWAS, SADC, WAEMU and FRANC). We find that regional blocs have positive effects on African trade flows, although these effects are small except for WAEMU and CEMAC. We do not find any significant effect on trade flows for the FRANC and ECOWAS zones. 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.

Keywords: Border effects; Regional blocs; Spatial Autocorrelation; Sub-Saharan Africa.

Classification JEL : F12; R12; O55.

Trade and African Regional Agreements: a spatial econometric approach

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1 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 and experiencing a slowdown in economic growth. 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 Edward (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

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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.

Various other authors have further refined the gravity approach and incorporated other explanatory variables into the model. Baier and Bergstrand (2001) developed a gravity model based on monopolistic competition in which goods are differentiated by firm, whereas Anderson and van Wincoop (2003, 2004) suggested differentiation by geographical origin. Other approaches focused on Heckscher and Ohlin's model (Deardorff, 1995; Evenett and Keller, 1998), or technological differences between countries (Eaton and Kortum, 2002).

One of the most celebrated inferences from the gravity literature is McCallum's equation (McCallum, 1995). He found that trade between Canadian provinces was 22 times higher than trade between US states and Canadian provinces. But according to Anderson and van Wincoop (2003), McCallum's spectacular headline number results from the combination of a bias due to the omitted variables and the small size of the Canadian economy. McCallum's estimates therefore, suffer from omitted variable bias. The theory developed by Anderson and van Wincoop (2003, 2004) demonstrates 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". Thus, Anderson and van Wincoop (2003) introduced multilateral resistance variables into McCallum's equation. Feenstra (2002) included fixed effects to estimate multilateral resistance variables and Behrens *et al.* (2012) used spatial econometrics to control for multilateral resistance. The model of Behrens *et al.* (2012) makes it possible not only to control 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 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 and Pace, 2009).

The purpose of this paper is to evaluate the impact of African regional blocs taking into account spatial interdependence between trade flows. To this end, we estimate the border effects for six African regional blocs and for Africa as a whole: *Communauté Economique 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); West African Economic and Monetary Union (WAEMU) and Franc CFA[1] zone (see Table A in Appendix for the member countries of these blocs). The first five blocs are the main trade agreements in Africa (Carrère, 2004) while the Franc CFA zone is thought of as a Monetary Union.

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,[2] 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 Edward, 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

[1] *Communauté Financière Africaine*

[2] Because they have managed to establish common external tariffs and they each have a common currency.

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 2 presents the theoretical model. In Section 3, we discuss our empirical results and Section 4 concludes the discussions.

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

2.1 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 labor. Labor 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.

2.2 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. Labor is the only factor of production, and in order to produce q units of output, $cq + F$ units of labor 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:

$$\pi_j = \sum_k (p_{jk} - c w_j \tau_{jk}) Q_{jk} - F w_j \tag{3}$$

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

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

2.3 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:

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

At equilibrium, national income in country i is given by

$$Y_i = \sum_k m_i p_{ik} Q_{ik} = m_i p_i \overline{Q} \tag{6}$$

Solving for $m_i = Y_i/(p_i\overline{Q})$ and replacing it in equation (5), we eliminate the mass of firms that is unobservable and we obtain:

$$X_{ij} = Y_i Y_j \frac{Q_{ij}^{1-1/\sigma}}{\sum_k \frac{p_i}{p_k} Y_k Q_{kj}^{1-1/\sigma}} \tag{7}$$

Substituting $Q_{ij} = \frac{X_{ij}}{m_i p_{ij}} = \frac{X_{ij}\overline{Q}}{Y_i \tau_{ij}}$ into equation (7) and simplifying terms we obtain:

$$X_{ij} = Y_i Y_j \frac{\left(\frac{X_{ij}\overline{Q}}{y_i \tau_{ij}}\right)^{1-1/\sigma}}{\sum_k \frac{p_i}{p_k} Y_k \left(\frac{X_{kj}\overline{Q}}{Y_k \tau_{kj}}\right)^{1-1/\sigma}} = Y_j \frac{\tau_{ij}^{1/\sigma-1}\left(\frac{X_{ij}}{Y_i}\right)^{1-1/\sigma}}{\sum_k \frac{L_k}{L_i} \tau_{kj}^{1/\sigma-1}\left(\frac{X_{kj}}{y_k}\right)^{1-1/\sigma}}, \tag{8}$$

where we have an equilibrium relation $p_i/p_k = w_i/w_k$ and the aggregate income constraint $w_i = Y_i/L_i$. Equation (8) can be rewritten as follows:

$$X_{ij} = Y_j^{\sigma} \left[\sum_k \frac{L_k}{L_i} \left(\frac{\tau_{kj}}{\tau_{ij}} \frac{Y_k}{Y_i}\right)^{1/\sigma-1} X_{kj}^{1-1/\sigma}\right]^{-\sigma} \qquad \forall i, j \tag{9}$$

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:

$$Y_i - \sum_k X_{ik} = 0, \qquad \forall i \tag{10}$$

As can be seen from expressions (9) and (10), 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 (9) to obtain an estimable equation taking into account all these interdependencies.

2.4 Econometric specification

To obtain an econometric specification, we take equation (9) in logarithmic form:

$$\ln X_{ij} = \sigma \ln Y_j - \sigma \ln \left[\sum_k \frac{L_k}{L_i} \left(\frac{\tau_{kj} Y_k}{\tau_{ij} Y_i} \right)^{1/\sigma - 1} X_{kj}^{1-1/\sigma} \right] \tag{11}$$

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 (11) around $\sigma = 1$. Doing so yields the following equation:

$$\ln Z_{ij} = -\sigma \ln L - (\sigma - 1) \left(\ln \tau_{ij} - \sum_k \frac{L_k}{L} \ln \tau_{kj} \right) - \sigma \ln w_i - (\sigma - 1) \sum_k \frac{L_k}{L} \ln Z_{kj} \tag{12}$$

where $Z_{ij} \equiv X_{ij}/(Y_i Y_j)$ 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 (12) 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 and error term as follows (Anderson and van Wincoop, 2004):

$$\tau_{ij} \equiv d_{ij}^{\gamma} e^{\xi b_{ij} \epsilon_{ij}} \tag{13}$$

where d_{ij} denotes the distance between country i and j; and 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.[3] The terms ϵ_{ij} are assumed i.i.d error terms. Substituting equation (13) in equation (12) then yields the following equation:

$$\ln Z_{ij} = -\sigma \ln L - (\sigma - 1)\gamma \ln \widetilde{d}_{ij} - (\sigma - 1)\xi \widetilde{b}_{ij} - \sigma \ln w_i - (\sigma - 1) \sum_k \frac{L_k}{L} \ln Z_{kj} + \varepsilon_{ij} \quad (14)$$

where $\widetilde{d}_{ij} \equiv d_{ij}/\Pi_k d_{kj}^{L_k/L}$ are relative distances and $\widetilde{b}_{ij} \equiv b_{ij} - \sum_k \frac{L_k}{L} b_{kj}$ are relative borders. Finally, as Behrens *et al.* (2012) pointed out, error terms have the following structure: $\varepsilon_{ij} = \lambda \sum_k \frac{L_k}{L} u_{kj} + u_{ij}$, where $u_{ij} \equiv -(\sigma - 1)\epsilon_{ij}$ is an iid error term. 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 introduce 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, 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:

$$\ln Z_{ij} = \beta_0 + \beta_1 \ln \widetilde{d}_{ij} + \beta_2 \widetilde{b}_{ij} + \beta_{3i}\delta_{1i} + \beta_{4j}\delta_{2j} + \rho \sum_k \frac{L_k}{L} \ln Z_{kj} + \varepsilon_{ij} \quad (15)$$

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; $\beta_2 \equiv -(\sigma - 1)\xi < 0$ is the coefficient that captures the border effect; β_{3i} are the coefficients of origin fixed effects; β_{4j} 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.[4]

Equation (15) shows that we are dealing with a spatial model. What we have here is 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 what follows, we use this equation to estimate our empirical model.

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

[4] 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.

3 Border effects and estimation results

3.1 Border effects

Following Behrens *et al.* (2012), we decompose the border effect into two components: the trade-boosting intra-bloc effect and the trade-reducing inter-bloc[5] effect of the border. 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 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 (12) and (13), we then have:

$$B_{ij} \equiv \frac{Z_{ij}}{\overline{Z}_{ij}} = e^{\theta[b_{ij} - \sum_k \frac{L_k}{L} b_{kj}]} \prod_k \left(\frac{Z_{ij}}{\overline{Z}_{ij}} \right)^{\rho \frac{L_k}{L}}, \tag{16}$$

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 (16) 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 (16) 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. By definition:

$$b_{ij} = \begin{cases} 1 & \text{if } (i \in \text{BLOC and } j \notin \text{BLOC}) \text{ or } (i \notin \text{BLOC and } j \in \text{BLOC}) \\ 0 & \text{otherwise} \end{cases}$$

It is readily verified that:

$$\theta \left[b_{ij} - \sum_k \frac{L_k}{L} b_{kj} \right] = \begin{cases} -\theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \in \text{BLOC}) \\ \theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \notin \text{BLOC}) \\ \theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \in \text{BLOC}) \\ -\theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \notin \text{BLOC}) \end{cases} \tag{17}$$

The explicit solution for $\ln B_{ij}$ is then given by:

$$\ln B_{ij} = \theta[(\mathbf{I} - \rho\mathbf{W})^{-1}]_i \mathbf{b} = \theta[(\mathbf{I} + \rho\mathbf{W} + \rho^2\mathbf{W}^2 + \rho^3\mathbf{W}^3 + ...)]_i \mathbf{b} \tag{18}$$

[5]Trade flows between a bloc member country and a non-member country.

where $[(\mathbf{I}-\rho\mathbf{W})^{-1}]_i$ denotes the i-th line of the matrix. Using (17) and (18), and the fact that $\mathbf{W}$ is row-standardized and has a special structure implying that $\mathbf{Wb} = 0$, the border effects are finally given as:

$$\ln B_{ij} = \begin{cases} -\theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \in \text{BLOC}) \\ \theta\, \text{pop}_{\text{ROW}} & \text{if } (i \in \text{BLOC and } j \notin \text{BLOC}) \\ \theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \in \text{BLOC}) \\ -\theta\, \text{pop}_{\text{BLOC}} & \text{if } (i \notin \text{BLOC and } j \notin \text{BLOC}) \end{cases} \tag{19}$$

Equation(19) 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.

To measure the intensity of the border effect we are initially 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) but both are 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[6] (Abdih and Tsangarides, 2010). Therefore, in order to capture the impact of the franc on trade flows, we introduce into our model (15) a currency dummy FRANC, as in Frankel and Rose (2002) or Rose and van Wincoop (2001) and evaluate the border effect generated by this currency zone. Finally, we add AFRICA as a regional bloc although there is no continent-wide free trade area or customs union and we do not expect a strong border effect.

[6]In the rest of the paper, we call the two juxtaposed blocs FRANC.

3.2 Estimation results

Our sample contains 181 countries with 32761 pairs of trade flows. 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 2004). We compute internal absorption as $X_{ii} \equiv \text{GDP}_i - \sum_j X_{ij}$. Trade flows are from the CEPII database.[7] GDP and population (also in 2004) data are obtained from the Penn World Table 7.0.[8] The data set also contains bilateral distances (in kilometers) between capital cities and are from the CEPII database. 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 $\kappa = 2/3$.[9] In our study, we constructed the theoretically implied interaction matrix $\mathbf{W}$[10] using the total population of each exporting country in our sample.

To deal with the familiar problem of zero trade flows, first, we augment the trade flows by adding 1, such that their log is equal to zero. Then, we control for this adjustment by including a zero-flow dummy variable in the regression, which takes value 1 if the log-flow is zero and value 0 otherwise.

Our empirical model is the model (15) improved by adding other variables relative to the factors of trade resistance or trade promotion such as customs unions (CEMAC and WAEMU), free trade areas (SADC and ECOWAS), a common market (COMESA), the FRANC zone, and a dummy for AFRICA. Thus, to bring out the trade-boosting effect and the trade-reducing effect we add dummies relative to the previously mentioned blocs.

Since, as already mentioned, CEMAC and WAEMU together form the FRANC zone, we first estimate our empirical model without the dummy relative to the FRANC zone to avoid multicollinearity with CEMAC and WAEMU dummies. Next, we reestimate our empirical model without the CEMAC and WAEMU dummies including instead the FRANC zone. Finally, each specification is estimated with and without fixed effects.

When spatial autocorrelation is modeled, 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 of errors. Other estimation methods are then necessary to find convergent and efficient estimators. The method widely used is the maximum likelihood (Lee, 2004; LeSage and Pace, 2009).[11] Table 1

[7] http://www.cepii.fr/anglaisgraph/bdd/gravity.asp.

[8] https://pwt.sas.upenn.edu.

[9] Results using 1/3 and 1 for κ are available upon request.

[10] The interaction matrix $\mathbf{W}$ is normalized by its eigen values.

[11] For estimation we used James LESAGE's Econometrics Toolbox which is available at

displays the full results:

Table 1 around here

The estimation of equation (15) without fixed effects shows that all variables are significant at 1% except SADC (see Table 1 columns 1 and 3). Including fixed effects, we find that AFRICA and ECOWAS are significant at 5% (Table 1 column 2) but ECOWAS is not significant when we introduce the FRANC dummy (Table 1 column 4) in place of CEMAC and WAEMU separately.

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.

We note that the estimated models without fixed effects are not given the signs predicted by the theoretical model for the spatial effect. The theoretical model predicts that the spatial autocorrelation coefficient 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. In what follows we will focus exclusively on the results given by models with fixed effects that result from the theoretical model.

As regards the border effects, the results are summarized in the following table:

Table 2 around here

The results suggest that regional integration would substantially increase trade between WAEMU countries. The coefficient associated with the full border effect gives the value 15.657. This finding means that trade flows within WAEMU would be almost 16 times higher than trade flows across WAEMU. The trade-boosting intra-bloc coefficient is 3.957, this coefficient means that the trade flows within each bloc would be larger in a world with borders (world with blocs) than in a world without borders (world without blocs) by 3.957. As regards the trade-reducing inter-bloc effect, we find that its coefficient takes the value 0.252. According to this coefficient the trade flows across blocs would be smaller in a world with borders than in a world without borders by 0.252. Put differently,

http://www.spatial-econometrics.com/.

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 would be 7 times higher than trade flows across CEMAC. The creation of CEMAC boosts trade between member countries by 2.624 and reduces trade flows with the rest of the word by 0.381.

The coefficients relative to the full border effect, intra-border effect and inter-border effect of these last two blocs capture both the customs union and the FRANC zone effects. We capture the impact of the FRANC zone in the next two columns of Table 1 and the results show that the full border effect is about 4. This means that intra-FRANC trade would be 4 times higher than trade between the FRANC countries and other countries. The trade-boosting intra-FRANC effect is 1.979. This means that the pegging of the currencies to the *euro* and the currencies having the same value reduce transaction costs and double intra-FRANC trade flows. For the trade-reducing effect, we find that trade across the FRANC border would be reduced by 0.505. If trade takes place between countries of the franc zone and countries outside the region both partners will experience the differences in exchange rates (except for EU members because the two currencies are pegged to the *euro*).

Note that when we consider WAEMU and CEMAC separately, we find high border effects for each bloc. However, when we take these two blocs together the estimated border effect is low. This difference can be attributed to the non-convertibility between the two franc CFA and the existence of tariff and non-tariff barriers between the two blocs.

Our estimations for SADC show that the coefficient of the full border effect is 3.301, the trade-boosting effect is 1.816 and the trade-reducing effect is 0.550. These results show that intra-SADC increased compared to non-SADC trade. Implementation of SADC led to an increase in intra-SADC and a reduction of 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 0.745. The trade-boosting intra-ECOWAS effect coefficient is 0.863 and the trade-reducing coefficient is 1.158. These results indicate a small border effect for ECOWAS despite the presence of all WAEMU countries (see Table A) and powerful neighbors (Nigeria and Ghana). Note that the trade-boosting effect is lower than the trade-reducing effect which means that ECOWAS' countries suffer from the border effect more than they benefit from it. As with ECOWAS, COMESA has small border effects. The coefficients relative to the full border, trade-boosting and trade-reducing are small. We find 1.294 for the full border; 1.137 for the intra-border and 0.878 for the inter-border. These results shows a lack of trading ties between COMESA countries.

For the whole of Africa where there are virtually no trade agreements between all

African countries, we find a full border effect is 1.086. The trade-boosting effect and the trade-reducing effect are respectively 1.042 and 0.959. These results imply that the African countries trade twice as much with each other as with non-African countries. The intra-Africa trade is multiplied by 1.1 and the trade across continent would be reduced by 0.959.

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. Regional blocs mean not only are intra-trade flows increased but trade with other outside countries is reduced too. We note that regional integration is more advanced in WAEMU and CEMAC than in other regional blocs. The high border effect of WAEMU compared to the border effect of CEMAC can be explained by the fact that most CEMAC countries are oil exporters and they trade relatively less among themselves than the WAEMU countries do. Furthermore, WAEMU and CEMAC are a major export market 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 and COMESA 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.

4 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 General Spatial Model (GSM) that is estimated by familiar spatial econometrics techniques. We focused on six African regional blocs and on Africa as a whole. 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. As regards the FRANC zone, we do not find a significant border effect due to the non-interchangeability between the two franc CFA and the existence of tariff and non-tariff barriers between the two blocs. 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.

Although we found positive effects for regional blocs in Africa, these effects are small (except for WAEMU andCEMAC which have relatively high border effects). This low value of the border effects can be attributed to the weaknesses of infrastructure and the similarity in production structures: single-crop economies and an undiversified export sector. African countries are principally specialized in agricultural products or raw materials. This specialization makes them particularly vulnerable to climatic conditions and to variations in international prices. In addition, weak infrastructures (ports, roads, rail) in these countries increase transportation costs and constitutes an often greater obstacle to trade than tariff and non-tariff barriers in importing countries. These difficulties associated with low trade complementarity between African countries explain the relatively small proportion of intra-regional trade. Moreover, the existence of armed conflict also continues to impede intra-zone trade.

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Table 1: Estimation results

Dependent V.	$\ln Z_{ij}$	$\ln Z_{ij}$	$\ln Z_{ij}$	$\ln Z_{ij}$
Fixed effects.	NO	YES	NO	YES
distance	-1.167***	-1.484***	-1.162***	-1.483***
	(0.016)	(0.015)	(0.016)	(0.015)
Dummy-zero	-3.029***	-3.218***	-3.037***	-3.211***
	(0.000)	(0.000)	(0.000)	(0.000)
AFRICA	-0.335***	-0.056**	-0.362***	-0.024***
	(0.035)	(0.028)	(0.035)	(0.029)
COMESA	-0.684***	-0.143***	-0.672***	-0.161***
	(0.051)	(0.060)	(0.051)	(0.060)
ECOWAS	-0.351***	0.160**	-0.205***	-0.089
	(0.067)	(0.080)	(0.055)	(0.071)
SADC	-0.086	-0.635***	-0.078	-0.648***
	(0.061)	(0.091)	(0.061)	(0.091)
CEMAC	-1.033***	-0,998***		
	(0.077)	(0.159)		
WAEMU	-0.394***	-1.439***		
	(0.086)	(0.139)		
FRANC			-0.715***	-0.740***
			(0.057)	(0.075)
ρ	0.008***	-0.114***	0.010***	-0.114***
	(0.000)	(0.005)	(0.000)	(0.005)
λ	0.214***	-0.097***	0.210***	-0.097***
	(0.000)	(0.004)	(0.000)	(0.004)
AIC	-3.932	-3.344	-3.941	-3.346
BIC	-3.929	-3.249	-3.939	-3.252

Notes: Standard errors are given in parentheses. *** significant at 1%; ** significant at 5% and * significant at 10%. Columns 1 and 2 are the estimates without the FRANC zone and the last two columns represent the estimates with the FRANC zone. The number of observations is 32761. AIC and BIC stand for the Akaike and the Schwarz information criteria, respectively.

Table 2: Border effects

Area	AFRICA	CEMAC	COMESA	ECOWAS	FRANC	SADC	WAEMU
Intra	1.042	2.624	1.137	0.863	1.979	1.816	3.957
Inter	0.959	0.381	0.878	1.158	0.505	0.550	0.252
Full	1.086	6.889	1.294	0.745	3.919	3.301	15.657

Appendix

Table A: List of countries for each bloc

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

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