Agricultural trade for food security in Africa: A Ricardian model approach

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1. Introduction

While regionalism and food security is a relatively neglected topic with a very limited literature (FAO 2003), the study assumes and aims at proving that regional trade can be an important tool to cope with international food dependency. Prospects to 2025 shown that future general food trends are likely to be positive but in some respects the world could be entering a more volatile situation (Dyson 1999). The paper evaluates the contribution of bilateral crop and food trade flows on welfare gain in Africa and food security[1] in this perspective. A number of 19 African countries and group of countries based on the Global Trade Analysis Project (GTAP) regional classification for Africa are involved. The total number of observations considering bilateral trade flows is 342. The study is built on the spatial equilibrium framework elaborated and applied in Eaton and Kortum - EK (2002) and Reimer and Li - RL (2009; 2010) to see how region trade can generate food surplus in some countries and cover the deficit in other countries. Each country is supposed to specialize in a subset of homogeneous staple agricultural products depending on productivity heterogeneities and geographic barriers. The model is then a Ricardian model on trade with multiple goods and countries specification which embeds a structure of gravity equation that relates trade flows to distance and others trade barriers.[2] The Ricardian trade theory offers a simple and yet powerful framework within which to address many positive and normative issue of international trade.

The rest of the paper is organized as follows: First, while describing the empirical models we define the data. Second the results are discussed and, finally, conclusions are drawn and some recommendations are given for food security policies.

2. Model and data

2.1 General Framework

The standard Ricardian model focuses on labor productivity and labor cost as the determinants of comparative advantage and states that each country will export those goods for which its relative output per worker exceeds its relative money wage rate in the respective industries (Golub and Hsieh 2000; Solocha 1991). This formulation, first applied by MacDougall (1951; 1952), was based on two-countries and two-goods specification with constant-return-to scale technologies. An important extension has been provided by Dornbusch, Fischer, and Samuelson - DFS (1977), who came up with a way of making the Ricardian model flexible, without modifying its basic features. Instead of working with a finite number of goods, they introduced a continuum of goods and demonstrated, under the assumption of Cobb-Douglas preferences, that a Ricardian model with a continuum of goods is highly tractable and can be used to analyze a variety of issue (Matsuyama 2000). The DFS model was extended by EK (2002) to an arbitrary number of countries by assuming that the labor productivities of each good and country are determined randomly given geographic barriers that distinguish each country.

We apply, here, a variant of EK Ricardian model (Eaton and Kortum 2002) of trade of agricultural products in Africa based in technology differences and geographic[3] characteristics among countries. EK (2002) specified a gravity equation from a Ricardian type of model, which explains trade based on a homogeneous primary factor and relative differences in technology across countries and goods. As in RL (2009; 2010), land is taken here as the main production factor for it is readily available in international database contrary to farm labor and the land rent is taken as the wage[4]. The productivity of a country in producing a given crop or food is represented by its total output per area of land (yield). The crop and food items, as part of agricultural sector and of main staple foods[5], for yield analysis are paddy rice, wheat, other grains (maize, millet, sorghum), fruits, and vegetables (bananas/plantain, cassava/potatoes); and soybean. After setting the baseline structure of the Ricardian model, the gravity estimates will be first yielded. Second, the parameters of yield variability, trade shares, land rental rates and agricultural product prices will be estimated. These findings will allow simulating the impact of the change in these parameters on welfare. Finally, the model will be linked to the concept of food security with regards to the volume of quantity traded and an Index of Food Security conditional on a threshold calorie intake above which a person has an adequate calorie requirement (Sumner 2000).

Following EK and RL (2009; 2010) , and along with the model, a producer country is indexed by i and a purchaser country is indexed by n. We denote country i's efficiency in producing food $j \in [0,1]$ as $z(j)$. The input cost for producer i is represented by the price of agricultural product land denoted w_i.[6] With constant return to scale, the cost of producing a unit of agricultural product j is then $w_i / z(j)$. Trade costs accounting for geographic barriers follow the "Iceberg" assumption saying that delivering a unit from country i to country n implied producing d_{ni} units in i. In each n country agricultural product purchasers or consumers are assumed to share and maximize the constant-elasticity-of-substitution (CES) utility function:

$$U_n = \left[\int_0^1 Q_n(j)^{(\sigma-1)/\sigma} dj \right]^{\sigma/(\sigma-1)} \qquad (1),$$

where $Q(j)$ is the amount of purchased goods, $\sigma \succ 0$ is the elasticity of substitution among agricultural products, n indexes the purchasing country. Expenditures in country n are constrained by an aggregated budget, X_n, or total spending.

By assuming a perfect competition market with goods being priced at marginal cost, the price that *n* pays for agricultural product *j* from country *i* is

$$p_{ni}(j) = \left(\frac{w_i}{z_i(j)}\right) d_{ni} \qquad (2).$$

In words it is the unit production cost multiplied by the geographic barrier and buyers in country *n* would buy the lowest price for agricultural product *j* across all source countries *i* as

$$p_n(j) = \min\{p_{ni}(j); i = 1,..., N\} \qquad (3),$$

where *N* is the total number of countries. We now define $Z(j)$ as a random variable. Since the price at which *n* can get agricultural products from *i* depends on $Z(j)$, price is also a random variable, denoted $P_{ni}(j)$. Since country *n* chooses the least-cost supplier, the distribution of prices has an extreme value distribution. The random variable $Z(j)$ has Fréchet extreme value distribution (Eaton and Kortum 2002) as:

$$F_i(z) = \Pr\left[Z_i \le z\right] = \exp(-T_i z^{-\theta}) \qquad (4),$$

where $T_i > 0$, $\theta > 1$, and $z > 0$. T_i refers to country i state of technology and governs the location of the yield distributions, with higher T_i meaning higher yield in country i. θ has the greatest influence on the yield distributions, with a lower θ implying a broader agricultural product yield distribution for each agricultural product in each country. The analysis of comparative advantage shows that high-productivity agricultural products will be exported and low-productivity agricultural products will be imported.

The price at which country i can supply country n is a random variable $P_{ni}(j)$. Its cumulative distribution function is derived by incorporating the price equation (2) into the yield distribution (4) for $p > 0$. As shown in EK (2002), the probability that country i supplies country n at the lowest price is

$$\Pr\left[P_{ni}(j) \le \min\{P_{ns}(j); s \ne i\}\right] = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \quad (5).$$

This equation shows that n's probability of buying from i is conditional on the state of technology (T_i), represented here by agricultural product yield, in country i, the trade costs between n and i (d_{ni}), and the cost of land in i (w_i). Then country i with higher state of technology, lower input cost and lower trade barriers would sell a wider range of goods in country n. Equation (5) is also related to the share of n's spending on agricultural products from i. Let X_n be country n's total spending on agricultural products, and X_{ni} be n's spending on agricultural products from country i, with $i = n$ when a country buys from home. Summing over all sources of supply gives $\sum_{i=1}^{N} (X_{ni} / X_n) = 1$. Due to the continuum of goods assumption, the share of country *n* expenditure that is devoted to staple foods from country *i* is equal to equation (5), which means

$$\frac{X_{ni}}{X_n} = \frac{T_i (w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N} T_i (w_i d_{ni})^{-\theta}} \qquad (6).$$

Equation (6) relates data on trade shares back to fundamental determinants of trade, including yield parameters (T_i and θ), geographic barriers (d_{ni}), and the price of agricultural product land (w_i). The price index for country *n* can be derived using the moment generating function for the extreme value distribution (Eaton and Kortum 2002). The result is

$$P_n = \left[\Gamma\left(\frac{\theta + 1 - \sigma}{\theta} \right) \right]^{1/1-\sigma} \left[\sum_{i-1}^{N} T_i (w_i d_{ni})^{-\theta} \right]^{-1/\theta} \qquad (7),$$

where Γ is the Gamma function used. P_n relates the actual price paid in country *n* back to the yield distributions, geographic barriers, and land rents.

We now consider the market for agricultural product land. Supplies of agricultural product land in each country L_i are taken as given, while returns to agricultural product land (w_i) are endogenous. The total domestic product derived from agricultural product land is $w_i L_i$. This is identically equal to the sum of country *i*'s sales: $w_i L_i = \sum_{n=1}^{N} X_{ni}$. Using equation (6), returns to agricultural product land can be expressed as a function of the exogenous underlying parameters:

$$w_i = \frac{1}{L_i}\sum_{n=1}^{N}\left\{X_n\left(\frac{T_i(w_i d_{ni})^{-\theta}}{\sum_{i=1}^{N}T_i(w_i d_{ni})^{-\theta}}\right)\right\} \quad (8),$$

w_i can be solved for using numerical methods.

The basic model is represented by the system of equations (6), (7), and (8) which can be solved simultaneously for trade shares, agricultural product prices and land rental rates. The model is closed by considering trade balance and how the agricultural sector fits into the broader agricultural economy. We introduce a non-crop or food agricultural sector as a numeraire good. Total agricultural income for country *i*, denoted Y_i, equals agricultural product land income ($w_i L_i$) plus value added in the non-crop or food sector. The share that agricultural product income has of total agricultural income varies by country. Trade in agricultural products need not be balanced, which means that country *n*'s expenditure on agricultural products X_n is not necessarily equal to the income derived from this sector ($w_i L_i$). The share that country *n*'s expenditure on agricultural products (X_n) has of total agricultural spending is denoted α_n .

Counterfactuals are evaluated according to several criteria. One is the change in land prices, $w'_n - w_n$, where w'_n denotes the new land price that solves equation (8) under the counterfactual simulation. Higher land prices are positively correlated with welfare since this reflects rises in income on the supply side. Another criterion is the change in agricultural product prices $(P'_n - P_n)$, where P'_n, where *n* P' denotes the price that solves equation (7) under the counterfactual simulation. This price reflects the costs of purchasing on the demand side, and has a negative relationship with that country's welfare. A welfare measure that combines these two concepts is the change in real GDP of this sector, denoted $W_n = Y_n / P_n^{\alpha}$. For simplicity's sake a common α is used across countries. The percentage change in real GDP can be approximated by

$$\ln\frac{W_n'}{W_n} = \ln\frac{Y_n'}{Y_n} - \alpha\ln\frac{P_n'}{P_n} \approx \left(\frac{w_n' - w_n}{w_n}\right)\frac{w_n L_n}{Y_n} - \alpha\ln\frac{P_n'}{P_n} \quad (9).$$

The first and second terms on the right-hand side of equation (9) represent income and price effects, respectively. Equation (9) gives the net welfare change for counterfactual simulations.

2.2 Estimation of yield distributions

We will use two methods to estimate the parameters T_i and θ discussed above. The first method applies the maximum likelihood estimation technique base on the probability density function associated with equation (4) as

$$f_{ij}(z) = \theta * T_i * z_{ij}^{-\theta-1}\exp(-T_i * z_{ij}^{-\theta}{}_{i}) \quad (10).$$

Equation (10) can be made into an empirical likelihood function with an assumption of independence across countries (*i*) and agricultural products (*j*):

$$likelihood = \prod_{i-1}^{N}\prod_{j=1}^{J}\theta * T_i * z_{ij}^{-\theta-1}\exp(-T_i * z_{ij}^{-\theta}) \qquad (11).$$

Equation (11) describes the probability of observing a particular sample of yield z_{ij} given different values of T_i and θ. We use the yield outcomes for different agricultural products as a source of variation for estimation. To make the yield of different agricultural products comparable, we normalize z_{ij} by j's Africa average yield ($\sum_i output_{ij} \Big/ \sum_i L_{ij}$). In effect, this is average yield using national acreages as weights.

The second method estimates the parameters separately as in EK (2002) who used retail prices and defined a normalized trade share as follows:

$$\frac{X_{ni} / X_n}{X_{ii} / X_i} = \left(\frac{p_i d_{ni}}{p_n}\right)^{-\theta} \qquad (12).$$

With a logarithmic transformation, an ordinary least method (OLS) could be used to estimate the parameter θ the right-hand side $\ln\left(\frac{p_i d_{ni}}{p_n}\right)$ is measured as:

$$\ln\left(\frac{p_i d_{ni}}{p_n}\right) = \max 2\{\ln p_n(j) - \ln p_i(j)\} - \frac{\sum_{j=1}^{J}\{\ln p_n(j) - \ln p_i(j)\}}{j} \qquad (13),$$

where max2 means second highest. Yield data and crop/food prices are obtained from the United National Food and Agricultural Organization (FAO) statistical database.

2.3 Estimation of trade cost

Trade cost is closely related to the gravity equation and include all costs incurred in getting a good to a final user other than the marginal cost of producing the good itself. They are, among others,: transportation costs, policy barriers, information costs, contract enforcement costs, costs associated with the use of different currencies, legal and regulatory costs, and local distribution costs (Anderson and van Wincoop 2004). Using the trade equation (6), we follow Eaton and Kortum (2002) and normalize (X_{ni} / X_n) by the home sales of a buyer (X_{nn} / X_n) to get

$$\frac{X_{ni}}{X_{nn}} = \frac{T_i (w_i d_{ni})^{-\theta}}{T_n w_n^{-\theta}} = \frac{T_i}{T_n} \left(\frac{w_i)^{-\theta}}{w_n^{-\theta}} \right) d_{ni}^{-\theta} \qquad (14).$$

Now take the log

$$\ln\left(\frac{X_{ni}}{X_{nn}} \right) = \ln \frac{T_i}{T_n} - \theta \ln \frac{w_i}{w_n} - \theta \ln d_{ni} \qquad (15).$$

To make this more useful we adopt a measure of competitiveness, $S_i \equiv \ln T_i - \theta \ln w_i$, which corresponds to yield adjusted for land costs. We substitute S_i into equation (13) to get

$$\ln\left(\frac{X_{ni}}{X_{nn}} \right) = -\theta \ln d_{ni} + S_i - S_n \qquad (16).$$

In estimating equation (16), the S_i can be captured by way of country source dummies. With $\hat{T}_i$ and $\hat{\theta}$ from equation (11), we can recover an estimate of w_i. We estimate the effects of geographic barriers ($\ln d_{ni}$, the gravity equation) by including proxy variable typically employed in gravity equations specification such as distance, proximity, language and currency.[7,8] Distance is accounted for by using dummy variables representing different intervals of "great-circle distance" between capitals. Five distance intervals in miles are used: distance of 375 miles or less, distance of 375 to 750 miles, distance of 750 to 1500 miles, distance of 1500 to 3000 miles and distance of 3000 and more in miles. We also account for proximity by considering whether or not two countries share a border (*b*) or are contiguous. We add a dummy variable currency (*c*) that is 1 if the two countries use the same currency and 0 otherwise.[9] As in Rose and van Wincoop (2001) currency unions is assumed to occur where: (i) one of the countries does not issue its own currency and uses that of another (e.g., Namibia uses *Dollars* as currency but uses also the South Africa currency, *South Africa Rand*), and (ii) in multilateral currency unions (e.g., the African Financial Community (CFA) franc zones).[10] A dummy variable for countries having a common official language (l) is accounted for as it eases communication between people. In general multiple local and dialectic languages are spoken in African countries and impede communication between people of different regions even within the same country. The gravity equation includes as well an overall destination effect (m_n) representing the openness to imports. Substituting these in for $\ln d_{ni}$ in equation (16) gives

$$\ln\left(\frac{X_{ni}}{X_{nn}}\right) = S_i - S_n - \theta m_n - \theta d_k - \theta b - \theta l - \theta c + \theta \xi_{ni} \qquad (17).$$

The dummy variable associated with each effect is suppressed for notational simplicity. The error term is $\xi_{ni} = \xi_{ni}^2 + \xi_{ni}^1$, where ξ_{ni}^2 affects two-way international trade and has variance σ_2^2, with $\xi_{ni}^2 = \xi_{in}^2$, and 1 *ni* ξ and ξ_{ni}^1 affects one-way international trade and has variance σ_1^2. Under this error structure, diagonal elements of the variance-covariance matrix are $E(\xi_{ni}\xi_{in}) = \sigma_1^2 + \sigma_2^2$, while certain off-diagonal elements are $E(\xi_{ni}\xi_{in}) = \sigma_2^2$. This allows for "reciprocity" in geographic barriers; the disturbance concerning shipments from n to i is positively correlated to the disturbance concerning shipments from i to n. To avoid the dummy variable trap we impose $\sum S_i = 0$, and no overall intercept.

The remainders of the parameters are inferred from identities in the conceptual model. Using $S_i \equiv \ln \hat{T}_i - \theta \ln w_i$, we calculate the price of agricultural product land in country i as:

$$\hat{w}_i = \exp\left(\left[\ln \hat{T}_i - \hat{S}_i\right] / \hat{\theta}\right) \tag{18}$$

(18).

Using the result from equation (18) and data on X_{ni}, baseline agricultural product land estimates can be moved out of the land market identity that relates total production (exports plus production for domestic consumption) and land costs:

$$\hat{L}_i = \frac{\sum_{n=1}^{N} X_{ni}}{\hat{w}_i}$$

(19).

Finally, we need to estimate α_n, which is the share that spending on agricultural products (X_n) has of all agricultural spending. We first calculate this for individual countries using bilateral trade flow data from the GTAP, then find a unified α by taking a GDP-weighted average.

The estimation of the all parameters of the general model will allow an analysis of the factors that are connected to Africa trade flows. Some simulation analysis based on these baseline parameters will be conducted to show the impact of any change on land rental rate, crop/food prices and welfare.

3. Empirical results and discussion

3.1. Trade flows and Yield variability in Africa

Following the *GTAP Sectoral Classification* (GSC2) and considering total imports (in Africa and the rest of the world) of some crops and foods[11], an African country imports from the others African countries 9.96 % on average. This rate is very low in comparison with crop trade in the world where imports from the other countries as a share of total imports are 76 % on average(Reimer and Li 2010). Intra-regional trade in Africa as a share of total foreign trade has traditionally been low compared to other regions with a proportion of only 8.4 per cent in 1993 (FAO 2003). Despite geographical proximity, African countries trade more with the European Union (EU) than with other African economies (Longo and Sekkat 2004). Considering total crops and foods spending within Africa (domestic spending and imports in Africa), the share of intra-African imports is only 2.29 % on average in 2004. The average spending on crops and foods as a share of total spending is very high. This shows that the known "home bias" in consumption is more important in Africa, but as in EL (2002) and RL (2010) the specification adopted deals with this issue by accounting for overall consumption.

The last column in Table 1 shows the estimated parameters $\hat{T}_i$, the state of technology, in approach 2 that range from 3.49 for Egypt to 0.55 for the Rest of South Central Africa. In approach 1 the $\hat{T}_i$ estimates range from 21.83 for Egypt and 0.10 for the Rest of South Central Africa. From the $\hat{T}_i$ estimates with approach 2 in Table 1, the countries who present the highest average yields and absolute advantage in trading crops and foods are Egypt, South Africa, Morocco, Zambia, Zimbabwe and Senegal. The highest crop and food productivities are found in Northern and Southern Africa while countries in the central Africa region have the lowest productivities. But a higher value of $\hat{T}_i$ does not mean a greater competitiveness in African markets as shown in equation (6) due to possible high land prices or geographic barriers.

Yield variability is higher in the world crop sector than in manufacturing sector (Reimer and Li 2009). In our model for Africa, the yield variation parameters ($\hat{\theta}$) governing comparative advantage are 2.62 and 2.84 for, respectively, approach 1 and approach 2. They reflect that crop and food productivity is more heterogeneous in Africa than in the world. Greatly increased yield variability seems generally related to semi-arid environments and Africa has high and increasing annual variability. Almost all African countries have been affected by increased aridity, particularly since the 1980s (Sharon E.Nicholson 2001) and climate change[12] resulting in increased frequencies of drought poses the greatest risk in agriculture (Sivakumar, Das, and Brunini 2005). In the twentieth century, the African continent experimented wide change in temperature and rainfall (Mike et al. 2001). Although the adoption of a common agricultural technology is expected to reduce spatial yield variability but on a world-wide scale this is not yet happening because the benefits of the agricultural technology are by no means uniformly available (Tarrant 1987). As most countries grow many of the same food crops, especially maize, there are latent differences in their comparative advantages, even within the same sub-regions (Diao et al. 2006), leading to sub-regional trade opportunities. Sub-regional trade could therefore be a relatively efficient way of smoothing out the impacts of abiotic stresses on production and prices at country and sub-regional levels (Binswanger-Mkhize and McCalla 2010).

<INSERT TABLE 1 HERE>

3.2. Determinants of bilateral trade

Table 2 Table 2 shows the results of the estimation of bilateral trade equation 17. The adjusted R^2 is 0.68 and 63 % of the variables are significantly different from zero. Geographic barriers estimates such as distances, border and language are all contributive to crop and food trade flows in Africa. The coefficients associated with distances are all highly negative. African crop and food trade flows are then strongly inhibited by distance. The coefficient for the smallest distance of 375 miles or less in the model is -6.64, and the magnitude of the coefficient heightened with the distance, the coefficient for the largest distance of 3000 miles and more is -12.5. This is not surprising for trade barriers are higher in developing countries than in industrialized countries (Anderson and van Wincoop 2004). For the same distance coefficients the range is, for world trade, -3.10 to -6.06 in EK (2002) in manufacturing goods sector and -5.52 to -10.26 in RL (2010) in agricultural crops sector. In addition to the high variability of yield, long distances make prohibitive barrier costs for exporting countries.[13] Trade in Africa takes the longest—45 days on average to export and 59 to import. Typical regulations in Africa require 18 signatures to export and 28 to import (World Bank and IFC 2006). The cost of transport is significantly higher in sub-Saharan Africa than elsewhere, due to a combination of poor roads, high fuel prices, and administrative procedures which cause delays (Rashid and Minot 2010). Hence the importance of building infrastructure, mainly targeting transactions costs in production of goods and services. Transportation and energy make up the largest proportion of indirect costs for businesses, weighing heavily on the competitiveness of firms in most African countries in which investment climate surveys were conducted. Particular focus would be on how to reduce the high costs associated with the remoteness of landlocked countries to facilitate trade with neighbors, as well as with the rest of the world. It is clear that there will be a need to look beyond individual country borders and adopt a regional approach to coordinate cross-border infrastructure investment, maintenance, operational management, and use (for example, power pooling) to lower costs (Ndulu et al. 2007).

Sharing language has the expected positive sign. Especially in Sub-Saharan Africa, language differences may raise marketing costs and, even, make integrated market inefficient (Rashid and Minot 2010). Unlike in some papers (Eaton and Kortum 2002; Martinez-Zarzoso 2003; Reimer and Li 2010) dealing with world trade, border has a positive influence on trade between African countries. Despite lot of obstacles to trade caused by bad roads, excessive check points between neighboring countries, sharing a border impact positively intra-African trade. In Africa, language, cultural difference and border are important factors that attenuate the negative impact of distance on trade. Having the same currency does not play an important role in stimulating trade volume in Africa even if the coefficient of the variable *currency* is positive as expected.

<INSERT TABLE 2 HERE>

The estimates of the $-\theta m_n$, the overall destination effects or openness to imports, show that South Africa, the Rest of Eastern Africa, Morocco and Egypt are more open to imports when factors that could inhibit it are taken into account. The importance of geographic barriers is reflected here. Zambia seems particularly open given the percentage share in African import market but it appears that this result is due to its proximity to seven others countries. The other extreme case of Morocco deserves attention for the country seems closed to others African countries. Not only Morocco is far from the others African countries, but its competitiveness in the market of crops and foods is high compared to most African countries. Hence it will be costly for many African countries to export to the Moroccan market. The least open countries to imports in Africa are Madagascar, Uganda, the Rest of South Central Africa and Nigeria, with -4.84, -3.09, -2.96 and -2.89, respectively. Richer countries like South Africa are more competitive and open to imports (Figure 1) meaning there ability to access to improved technologies and the existence of better infrastructure, low tariff and non tariff barriers among others factors.

<INSERT FIGURE 1 HERE>

Regarding the estimates of S, the measure of competitiveness, South Africa is the most competitive ($S_{\text{SouthAfrica}}$ = 3.14) country for crop and food exports in Africa. It is followed by the Rest of Eastern Africa, Egypt and Morocco with, respectively, 2.39, 1.88 and 1.77. The least competitive countries are Uganda, Madagascar, Ethiopia, Malawi, Zambia and Zimbabwe with, in order, -2.38, -2.10, -1.84, -1.64, -1.43 and -1.30. A country could have a good productivity or yield and its competitiveness hampered by high costs and, even, has low productivity associated with high costs. The African countries who present both openness to imports and competitiveness to exports in the crop and food sector are South Africa, the Rest of Eastern Africa, Egypt, Morocco and the Rest of West Africa.

3.3. Autarky

To extend the analysis of openness to imports, we carry out here a simulation of effects of the extreme case of autarky in welfare. Under autarky there is no specialization, each country is producing the full range of goods and equate their production and consumption. Table 3 summaries, then, the results when geographic barriers reach their autarky level, i.e. $d_{ni} \rightarrow \infty$ for $n \neq i$. The results show that three of the four least open to imports (Table 2), Madagascar, Nigeria and the Rest of South and Central Africa, record no change in their welfare. But 84 % of countries/regions suffer from welfare loss. The average decrease in welfare is 1.64 % for all countries. The maximum fall is recorded by Zimbabwe (-11.83 %) followed by Mozambique (-9.80 %), the Rest of South African Custom Union (-4.05 %) and South Africa (-2.25 %). In Zimbabwe and South Africa, the welfare loss mainly stems from higher increase of crop and food prices that mitigates the increase of the return to land. In Mozambique and the Rest of South African Custom Union, even though crop and food price decrease, the return to land decreases more. In all Africa prices fall, on average, by 2.22 % and the returns to land drop, on average, by 3.60 %. Higher negative impact of autarky could be expected if inter African trade was important.

3.4. Elimination of geographic barriers

The second column in Table 3 shows the situation in zero-gravity, i.e. all geographic barriers are eliminated ($d_{ni} = 1$ for all n and i). Africa trade volume would be forty-fold its volume in 2004 with an extreme expansion of 3956%. All African countries will experiment important net welfare gains. Zimbabwe benefits more from this perspective with 272.88 % of net welfare increase succeeded by Madagascar (210 %) and Malawi (207 %). Open countries to imports lose their size-based edge with smaller increase of net welfare. Among these countries that have absolute comparative advantage, the Rest of West Africa has the lowest rise given its low state of technology compared to Egypt, Morocco and South Africa for instance. The average net welfare increase in Africa is 115 % thanks to a crop and food price decrease of 76 % on average. Then the elimination of geographic barriers is favorable for food trade in Africa. Within SSA there are many physical and institutional impediments to cross-border trade within SSA, including differences in food safety requirements, rules of origin, and quality and product standards. More important, trade in food staples was for long discouraged by national food policies that placed a high priority on self-sufficiency, and vestiges of these policies still prevail in many countries mainly after a choc in the international market such the food crisis in 2007-2008. Governments are, as well, very prompt to inflict export bans whenever they fear food shortages in their own market discouraging large-scale private investment in cross-border trading capability (Binswanger-Mkhize and McCalla 2010; Dorosh, Dradri, and Haggblade 2009).

3.5. Effects of yield increase as agricultural productivity growth

Despite impressive gains in yields over the past 50 years in most of the world, large and economically exploitable yield gaps remain in many places, especially in the developing world and nowhere more so than in sub-Saharan Africa where food supply is the most precarious. Global demand modeling to 2050 predicts large real price sensitivity to yield growth rates, with significant price increases if current rates cannot be increased (Fisher, Byerlee, and Edmeades 2009). In Table 4, the effects of a yield change are displayed. A yield increase of 30% in Western Africa would increase net welfare by 5.66 % due to prices drop of 8.59-8.75%. African trade would improve slightly by 0.54 %. A yield increase of 30% in South Africa would increase net welfare by 5.42% with a price decrease of 6.06%. It will affect Zimbabwe with +1.03% of net welfare change and a price drop of 4.17%. But Africa trade could be reduced by 1.70%. In this latter counterfactual, both consumers and producers will benefit from yield increase with land rental rates increasing by 2.70 %. In the former counterfactual the producers' gains are modest (0.08 – 0.26 %).

<INSERT TABLE 4 HERE>

Yield increase could be a major source of income growth and yield gap is important in Africa meaning that the brink of the potential yield is not reached yet. For instance, in the SRV, the rice potential yield of improved varieties developed in the 90s is 9-12 tons per hectare, while the average yield in the region is between 5 and 6 tons per hectare in the period 2001/02-2008/09 (SAED 2009). TFP is a major determinant of long-term price trends. Most productivity increases have been ultimately passed on to consumers through lower prices. Declining real prices of food staples for 1961-2006 at an annual average rate of 1.8 percent for wheat, 2.6 percent for rice and 2.2 percent for maize in world markets has been a major source of poverty reduction, given that food staples make up a large share of expenditures of the world's poor (Fisher, Byerlee, and Edmeades 2009; World Bank 2008).

3.6. Land increase effects

In Table 5 cultivated area is estimated at 211 million ha, or 27 percent of the cultivable land on the continent. The Sudano-Sahelian Region is the region with the greatest potential in terms of cultivable land, but only 19 percent of this is exploited compared with more than 40 percent in the Northern, Gulf of Guinea and Indian Ocean Islands Regions (FAO 2005). According to UNEP/GRID-Arendal (2006), a FAO study estimated the potential land area for rainfed crops, excluding built up areas and forests – neither of which would be available for agriculture – to 300 million hectares. If the potential is realized, it would mean an increase ranging from 150 – 700% percent per region. Out of the total land area in Africa, only a fraction is used for arable land (see Figure 2).

<INSERT FIGURE 2 HERE>

For irrigated areas, the irrigation potential of the continent is estimated at more than 42.5 million ha, considering irrigation potential by basin and renewable water resources. One-third of this potential is concentrated in two very humid countries: Angola and the Democratic Republic of the Congo (see Table 6). The untapped potential areas in Africa are then enormous.

<INSERT TABLE 5 HERE>

<INSERT TABLE 6 HERE>

From our staple food trade model, an increase of 30% of areas in Western Africa under cultivation of the staple foods considered here will generate a net welfare increase of around 17 % due to a contraction of crop and food prices and rental rates of 22.36 – 22.85 %. This will be followed by an increase of Africa trade by around 2 %. For the same increase in South Africa lands, the net welfare increase is roughly the same (16.28 %) imputable to drop of food and crop prices and land rental rate of more or less 17 %. The connection with Zimbabwe economy will cause an increase of net welfare by 3.21 % for this latter with a decrease by 12% and 10 % in food and crop prices and land rental rate respectively. This improvement in South Africa and Zimbabwe negatively affect the welfare in Mozambique (-1.58 %) and shrink African trade by 4.19 % (Table 7).

<INSERT TABLE 7 HERE>

3.7. Liberalized import policy

Table 8 reports the results when the others African countries reduce their import costs to the level of South Africa, the most open to imports. This performance will profit to all African countries in term of net welfare gain. Countries with lower import costs record modest welfare gain of only 1.21 % for Egypt, 1.25 % for Morocco, 2.23 % for the Rest of West Africa and 4.38 % for South Africa. While Egypt and South Africa go through the most important increase of prices, in order, 19.66 % and 16.67 %; Morocco has an increase of 5.90 % and the Rest of Western Africa has a moderate decrease of price (-1.01 %). Less competitive countries like Uganda, Zimbabwe, Mozambique and the Rest of South African Custom Union record the maximum rise in welfare mainly due to crop and food price decrease of 84.43 %, 87.82 % 74.43 % and 75.12 % respectively. For the majority of countries/regions, crop and food import liberalization within Africa give the same pattern of buyers' price and producers' price, except for the Rest of West Africa and the Rest of Eastern Africa. In these two countries the fall of crop and food prices comes with a higher increase of land rental rate in absolute value (Table 8).

<INSERT TABLE 8 HERE>

3.8. Food security implications

In SSA, approximately 90% of all calories consumed as food are produced within the region; most food is in fact produced within the countries where it is consumed. A few coastal cities import significant quantities of grain and meat, but much of the continent consumes virtually no imported food. Many interior countries are almost entirely self-sufficient, except for a few luxury goods consumed by urban elites. Uganda, for example, imports less than 2% of its total calorie consumption (Gollin 2010). But the historical trend of increased per capita food production and consumption at the global level resulted in a reduction of the proportion of undernourished people in developing countries from 37 percent in 1969–71 to 17 percent in 2002–04. Most of the reduction occurred in the first two decades of this period; indeed, from the 1990–92 base period, the proportion of undernourished fell by only 3 percentage points. In sub-Saharan Africa, recent progress in reducing the prevalence of undernourishment is noteworthy. For the first time in several decades the share of undernourished people in the region's population declined significantly, from 35 percent in 1990-92 to 32 percent in 2001-03, after having reached 36 percent in 1995–97. While Central Africa experienced a dramatic increase in both the number and prevalence of undernourishment, Southern Africa, West Africa, East Africa and Nigeria saw a decline in the prevalence of undernourishment. The success seems to come from the combination of good economic growth performances with a significant expansion of per capita agricultural and food production (FAO 2006). Calorie supply is shown to be an increasing function of per capita GDP (Figure 3). Despite the encouraging development, the task facing sub-Saharan Africa remains daunting. Sub-Saharan Africa accounts for 25 percent of the undernourished people in the developing world, and it has the highest proportion (one-third) of people suffering from chronic hunger.[14] In 14 countries in the region, 35 percent or more of the population were chronically undernourished in 2001-2003. Even if increasing number of undernourished people in SSA is driven mainly by natural and human-induced disasters, and devastating war; there is a clear negative correlation between countries' income per capita and prevalence of undernourishment in the population (FAO 2007) . Empirical evidence confirms that sustained economic growth leading to increased productivity and prosperity at the national level results in reduced hunger. But cross-country studies of developing countries suggest that economic growth alone, in the absence of specific measures to combat hunger, may leave large numbers of hungry people behind for a long time, particularly in rural areas. Numerous studies have provided evidence that the impact of economic growth on reducing hunger and poverty depends as much on the nature and distribution of the growth as on its scale and speed. Some 70 percent of the poor in developing countries live in rural areas and depend on agriculture for their livelihoods, either directly or indirectly. In the poorest countries, agricultural growth is the driving force of the rural economy. Particularly in the most food-insecure countries, agriculture is crucial for income and employment generation. Agricultural growth is, therefore, a critical factor in hunger reduction.

Historical trends towards increased food consumption per capita globally and particularly in developing countries will, according to FAO scenarios, continue in the near future. However, they will continue at a slower rate than in the past as more and more countries approach medium high levels. The average of the developing countries may rise from the current 2 650 kcal per person per day, in 2006, to 3 070 kcal by 2050. By the middle of the twenty-first century, more than 90 percent of the world‘s population may be living in countries with per capita food consumption of more than 2 700 kcal per day, compared to 51 percent at present and only 4 percent three decades ago. As in the past, great improvements in China and a few other populous countries will continue to play a significant role in these developments. However, not all countries are likely to achieve adequate food consumption levels. This is especially the case for countries that currently have high rates of undernourishment, high population growth rates, poor prospects for rapid economic growth and often meager agricultural resources. Today, 32 countries are in this category, with an average undernourishment rate of 42 percent. The population of these poor countries is expected to increase from the current 580 million to 1.39 billion by 2050, and food consumption could, under fairly optimistic assumptions, increase from the current 2 000 kcal/person/day to 2 450 kcal in the next 30 years. This will not be sufficient for good nutrition in several of these countries, hence the conclusion that reducing undernourishment may be a very slow process in these countries.

<INSERT FIGURE 3 HERE>

As we defined food security above many study have stressed the importance of trade in a way that it augments domestic supplies, reduces supply variability, foster economic growth, makes more efficient the use of world resources and allows global production to take place in those regions most suited to it. On average the crops and foods we used in this study provided 1419 Kcal/capita/day in Africa in 2004 (FAO 2010). We found a positive and significant correlation (43%) between GDP per capita and total Kcal/Pers/Day. A positive and significant correlation (66%) between quantities of crop and food imported and total Kcal/Pers/Day (Figure 4) is found as well. In Sub-Saharan Africa, calorie availability is found to have a significant positive impact on agricultural productivity, providing evidence of the interdependence of malnutrition, hunger, and agricultural growth (World Bank 2008). From these evidences agricultural trade in Africa could play a major role for Food Security in the continent. As we shown above for instance when the other African countries achieve the performance of South Africa, African trade would increase by 1525% and net welfare would increase on average by 38 %. Doubling African trade volume gives a welfare increase of 1.3% and a decrease of crop and food price of 6%.

<INSERT FIGURE 4 HERE>

Sustainable productivity growth is important as we saw that yield increase decreases food prices and has major welfare implications for Africa. In African context, a wild decrease of welfare is always damageable given the low GDP/capita.

4. Conclusion

In this chapter we saw that productivity is heterogeneous in African crop and food sector. Distance is the main impediment for African trade. Border and language have positive impact on trade in Africa. Overcoming disadvantages arising from geographic barriers will be necessary if

Africa is to stimulate trade within the continent. With much higher proportions of countries and populations in Africa being landlocked and resource rich, it is necessary to compensate for these disadvantages, primarily by closing the infrastructure gap and sustainable managing and using of resources. Growth of trading partners' economies in Africa has a very powerful influence. As the key transmission mechanisms are trade and capital flows, requiring greater openness, strengthening capabilities for taking advantage of the rapid growth in the African markets, and improving the investment climate to make African countries better destinations for global capital than in the past. An improvement of competitiveness could highly contribute to food security by stimulating trade and increasing total income in the agricultural sector. But Food Security is a complex, multi-dimensional concept and is most precise at the individual level. And another issue for food security is whether this economic growth are highly concentrated among the better-off, then household food security may worsen for many, despite higher overall rates of economic growth if the poorer are not benefitting from it.

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Table 1: Yield parameters of crops and foods.

	Africa 2004 yield data (Tonne/hectare)					Equation (13)
	Paddy Rice	Wheat	Oth. gr.[a]	Veg. frt.[b]	Soybean	T_i (Std. error)
Egypt	9.84	6.56	7.18	24.10	3.03	3.49 (0.89)
Ethiopia	1.85	1.49	1.11	5.47	0.42	0.72 (0.28)
Morocco	6.70	1.81	1.16	16.87	1.03	1.55 (1.08)
Madagascar	2.45	2.38	1.77	5.68	2.40	0.94 (0.19)
Mozambique	0.96	1.11	0.76	6.01	0.33	0.66 (0.35)
Malawi	1.17	0.75	1.02	13.09	0.64	0.73 (0.51)
Nigeria	1.42	1.07	1.37	8.33	0.90	0.78 (0.28)
Senegal	2.48	0.00	0.85	8.42	0.00	1.05 (0.42)
Tunisia	0.00	1.66	0.71	10.50	0.00	1.08 (0.65)
Tanzania	1.73	1.95	1.31	6.13	0.64	0.68 (0.21)
Uganda	1.30	1.67	1.48	7.09	1.01	0.80 (0.21)
Rest of South Central Africa	0.76	1.39	0.63	8.70	0.48	0.55 (0.28)
Rest of Central Africa	1.15	1.33	1.00	5.42	1.61	0.59 (0.10
Rest of Eastern Africa	3.33	2.17	0.81	8.27	0.79	0.82 (0.32)
Rest of South African Custom Union	3.40	0.90	0.53	8.56	0.00	0.96 (0.55)
Rest of West Africa	1.60	2.05	0.71	7.55	0.58	0.72 (0.23)
South Africa	2.29	2.03	2.96	20.88	1.61	1.84 (1.28)
Zambia	1.38	6.12	1.74	6.12	1.40	1.26 (0.84)
Zimbabwe	2.41	3.50	0.99	5.55	1.38	1.05 (0.49)
Average	2.64	2.30	1.53	8.71	1.08	

Note: Yield data and items are from FAO (2010). [a] Other grains: Maize, millet, sorghum; [b] Vegetables, fruits: Bananas/plantains, cassava/potatoes.

Table 2: Bilateral trade equation

Source of barrier	Coefficient	Estimate	p-value
dist1 [0,375]	$-\theta d_1$	-7.16	0.00
dist2 [275,750]	$-\theta d_2$	-8.80	0.00
dist3 [750,1500]	$-\theta d_3$	-10.43	0.00
dist4 [1500,3000]	$-\theta d_4$	-12.06	0.00
dist5 [3000, max]	$-\theta d_5$	-12.98	0.00
Border	$-\theta b$	1.38	0.00
Language	$-\theta l$	0.71	0.01
Currency	$-\theta$c	0.53	0.47

	Destination country			Source country		
Country	Coefficient	Estimate	p-value	Coefficient	Estimate	p-value
Egypt	$-\theta m_1$	2.68	0.00	S_1	1.88	0.00
Ethiopia	$-\theta m_2$	-0.40	0.54	S_2	-1.84	0.00
Morocco	$-\theta m_3$	2.89	0.00	S_3	1.77	0.00
Madagascar	$-\theta m_4$	-4.84	0.00	S_4	-2.10	0.00
Mozambique	$-\theta m_5$	-0.16	0.81	S_5	-0.44	0.31
Malawi	$-\theta m_6$	-1.36	0.03	S_6	-1.64	0.00
Nigeria	$-\theta m_7$	-2.89	0.00	S_7	-0.09	0.83
Senegal	$-\theta m_8$	0.28	0.68	S_8	0.04	0.93
Tunisia	$-\theta m_9$	1.25	0.05	S_9	0.69	0.10
Tanzania	$-\theta m_{10}$	-0.14	0.83	S_{10}	-0.03	0.94
Uganda	$-\theta m_{11}$	-3.09	0.00	S_{11}	-2.38	0.00
Rest of South Central Africa	$-\theta m_{12}$	-2.96	0.00	S_{12}	-0.30	0.49
Rest of Central Africa	$-\theta m_{13}$	-0.88	0.18	S_{13}	0.52	0.24
Rest of Eastern Africa	$-\theta m_{14}$	3.30	0.00	S_{14}	2.39	0.00
Rest of Sth African Custom Union	$-\theta m_{15}$	0.05	0.94	S_{15}	-0.32	0.45
Rest of West Africa	$-\theta m_{16}$	1.36	0.03	S_{16}	1.45	0.00
South Africa	$-\theta m_{17}$	6.65	0.00	S_{17}	3.14	0.00
Zambia	$-\theta m_{18}$	-0.91	0.16	S_{18}	-1.43	0.00
Zimbabwe	$-\theta m_{19}$	-0.84	0.18	S_{19}	-1.30	0.00

Note: Estimated by generalized least squares using 2001 data from the GTAP database for 342 observations. The specification is given in equation 17. Adjusted R^2 is 0.68.

Table 3: Counterfactual 1 and 2: Large change in trade costs

	Baseline Autarky	Baseline to Zero Gravity
	% change in Net Welfare	% change in Net Welfare
Egypt	-0.01	55.04
Ethiopia	-0.26	141.21
Morocco	-0.03	59.93
Madagascar	0.00	210.08
Mozambique	-9.80	131.55
Malawi	-0.20	207.70
Nigeria	0.00	69.76
Senegal	-0.02	149.92
Tunisia	-0.03	78.61
Tanzania	-0.31	101.27
Uganda	-0.38	139.81
Rest of South Central Africa	0.00	123.42
Rest of Central Africa	-0.05	99.58
Rest of Eastern Africa	-0.41	54.27
Rest of Sth African Custom Union	-4.05	169.80
Rest of West Africa	-0.01	44.22
South Africa	-2.25	53.35
Zambia	-0.42	182.19
Zimbabwe	-11.83	272.88

Note: The percentage change in Africa trade is -100 % and + 3956 % in the two scenarios, respectively

Table 4: Diffusion of a Yield increase across countries

	South Africa Yield increases by 30%			Western Africa [(a)] Yield increases by 30%		
	Net Welfare	Crop and Food Prices	Crop and Food Land Rental Rates	Net Welfare	Crop and Food Prices	Crop and Food Land Rental Rates
Egypt	0.00	-0.16	-0.16	0.00	-0.03	-0.02
Ethiopia	0.00	-0.04	-0.04	0.00	-0.02	-0.01
Morocco	0.00	-0.08	-0.08	0.00	-0.02	-0.02
Madagascar	0.00	-0.02	-0.02	0.00	0.00	0.00
Mozambique	-0.58	-4.22	-3.99	-0.03	-0.16	-0.16
Malawi	-0.02	-1.02	-1.01	0.00	-0.05	-0.04
Nigeria	0.00	-0.09	-0.09	5.66	-8.59	0.26
Senegal	0.00	-0.06	-0.06	5.66	-8.64	0.20
Tunisia	0.00	-0.07	-0.07	0.00	-0.01	-0.01
Tanzania	0.00	-0.31	-0.31	0.00	-0.02	-0.02
Uganda	0.00	-0.08	-0.08	0.00	-0.01	-0.01
XAC[1]	0.00	-0.05	-0.05	0.00	-0.01	-0.01
XCF[2]	0.00	-0.04	-0.04	0.01	-0.16	-0.14
XEC[3]	0.00	-0.20	-0.19	0.00	-0.03	-0.03
XSC[4]	-0.08	-4.16	-3.84	-0.01	-0.16	-0.15
XWF[5]	0.00	-0.03	-0.03	5.66	-8.75	0.08
South Africa	5.42	-6.06	2.70	0.02	-0.20	-0.17
Zambia	0.05	-1.29	-1.21	0.00	-0.06	-0.06
Zimbabwe	1.03	-4.17	-3.49	0.04	-0.15	-0.13

[(a)]Western Africa regroups here Nigeria, Senegal and the rest of West Africa following the GTAP aggregation.

([1]) XAC: Rest of South Central; ([2]) XCF: Rest of Central Africa; ([3]) XEC: Rest of Eastern Africa; ([4]) XSC: Rest of South Africa Custom Union; ([5]) XWF: Rest of West Africa

Note: A yield increase of 30% in South Africa and Western Africa will, respectively, decrease African

Trade by -1.70 % and increase it by +0.54 %.

Table 5: Cultivable and cultivated areas in Africa

Region	Cultivable areas	Cultivated areas in 2002	
	(ha)	Area (ha)	In % of cultivable areas (%)
Northern	65 320 000	28 028 178	43
Sudano-Sahelian	208 256 000	38 764 012	19
Gulf of Guinea	119 860 000	54 964 000	46
Central	173 060 000	21 303 000	12
Eastern	82 853 400	30 869 000	37
Southern	113 678 650	32 950 000	29
Indian Ocean Islands	8 307 000	3 795 000	46
Africa	**771 335 050**	**210 673 190**	**27**

Source: FAO (2005), pp 13.

Table 6: Irrigation potential in Africa

Basin	Irrigation potential	% of Africa's potential	Regions
Congo/Zaire	9 800 000	23	Central, Eastern, Southern
Nile	8 000 000	19	Northern, Sudano-Sahelian, Central, Eastern
Niger	2 816 510	7	Northern, Gulf of Guinea, Central, Sudano-Sahelian
Zambezi	3 160 380	7	Central, Southern, Eastern
Lake Chad	1 163 200	3	Northern, Central, Sudano-Sahelian, Gulf of Guinea
Rift Valley	844 010	2	Sudano-Sahelian, Eastern
Senegal	420 000	1	Gulf of Guinea, Sudano-Sahelian
Volta	1 487 000	3	Gulf of Guinea, Sudano-Sahelian
Orange-Senqu	390 000	1	Southern
Shebelle-Juba	351 460	1	Sudano-Sahelian, Eastern
Limpopo	295 400	0.5	Southern
Okavango	208 060	0.5	Central, Southern
South Interior	54 000	0	Central, Southern
North Coast	2 199 050	5	Northern, Sudano-Sahelian, Eastern
West Coast	6 268 650	15	Sudano-Sahelian, gulf of Guinea, Central, Southern
South Coast	1 584 200	4	Southern
Central East Coast	1 927 460	4.5	Sudano-Sahelian, Eastern, Southern
Madagascar and Islands	1 534 990	3.5	Indian Ocean Islands
Africa	**42 504 370**	**100.0**	

Source : FAO (2005), pp 26.

Table 7: Diffusion of a Land increase in some regions across countries

	South Africa increases it lands by 30 %			Western African countries increase their lands by 30 %		
	Net Welfare	Crop and Food Prices	Crop and Food Land Rental Rates	Net Welfare	Crop and Food Prices	Crop and Food Land Rental Rates
Egypt	0.00	-0.40	-0.40	0.00	-0.06	-0.06
Ethiopia	0.01	-0.11	-0.10	0.01	-0.06	-0.05
Morocco	0.00	-0.21	-0.20	0.00	-0.07	-0.07
Madagascar	0.00	-0.07	-0.07	0.00	0.00	0.00
Mozambique	-1.58	-11.89	-11.24	-0.10	-0.58	-0.57
Malawi	-0.05	-2.76	-2.75	0.00	-0.17	-0.17
Nigeria	0.00	-0.23	-0.23	16.93	-22.36	-22.36
Senegal	0.00	-0.16	-0.16	16.92	-22.55	-22.56
Tunisia	0.00	-0.16	-0.16	0.00	-0.04	-0.03
Tanzania	0.00	-0.84	-0.83	0.00	-0.07	-0.07
Uganda	0.00	-0.22	-0.21	0.00	-0.04	-0.04
XAC[1]	0.00	-0.12	-0.12	0.00	-0.04	-0.04
XCF[2]	0.00	-0.11	-0.11	0.05	-0.59	-0.52
XEC[3]	0.01	-0.53	-0.52	0.01	-0.11	-0.10
XSC[4]	-0.12	-11.73	-10.83	-0.03	-0.57	-0.54
XWF[5]	0.00	-0.07	-0.07	16.92	-22.85	-22.85
South Africa	16.28	-16.65	-17.35	0.08	-0.74	-0.63
Zambia	0.16	-3.81	-3.56	0.01	-0.23	-0.21
Zimbabwe	3.21	-11.92	-10.01	0.13	-0.55	-0.46

([a]) Western Africa regroups Nigeria, Senegal and the rest of West Africa following the GTAP aggregation.

([1]) XAC: Rest of South Central; ([2]) XCF: Rest of Central Africa; ([3]) XEC: Rest of Eastern Africa; ([4]) XSC: Rest of South Africa Custom Union; ([5]) XWF: Rest of West Africa

Note: An increase of 30 % of land acreages for Western African countries and South Africa will decrease African Trade by -4.19 % and increase African Trade by +1.98 %, respectively.

Table 8: Liberalized import policy

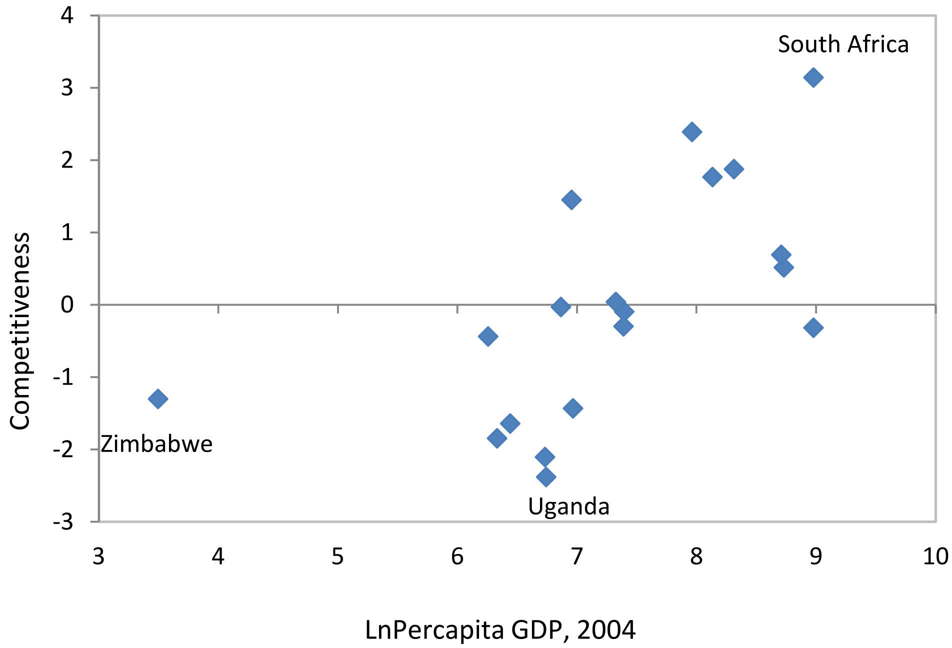
	Land is mobile across agricultural sectors			Land is immobile by agricultural sector		
	Net Welfare	Crops and Food prices	Crop and Food land area	Net welfare	Crops and Food prices	Crop and Food land rental rate
Egypt	0.39	-0.66	21.43	1.21	19.66	21.07
Ethiopia	76.35	-61.39	-87.79	31.32	-61.41	-43.26
Morocco	1.03	-1.71	7.04	1.25	5.90	7.99
Madagascar	74.11	-60.55	-92.47	24.48	-66.31	-58.54
Mozambique	155.57	-79.28	-65.18	102.32	-74.43	-13.20
Malawi	66.47	-57.47	-47.85	56.88	-61.25	-17.48
Nigeria	12.17	-17.53	6.26	13.54	-24.00	-6.01
Senegal	8.09	-12.23	-5.90	6.96	-12.09	-1.60
Tunisia	6.04	-9.37	-14.72	3.68	-10.64	-5.10
Tanzania	70.69	-59.22	-38.09	53.21	-55.53	-9.03
Uganda	223.93	-86.08	-22.25	198.36	-84.43	-2.52
XAC[1]	19.56	-25.90	-46.40	11.54	-37.07	-25.72
XCF[2]	41.95	-44.44	-51.21	29.56	-50.02	-24.03
XEC[3]	9.49	-14.11	43.02	15.82	-11.30	13.18
XSC[4]	159.52	-79.81	-74.16	98.86	-75.12	-19.65
XWF[5]	1.85	-3.03	8.38	2.23	-1.01	2.71
South Africa	0.00	0.00	56.67	4.38	16.67	24.90
Zambia	115.92	-72.51	-87.65	61.42	-72.81	-42.85
Zimbabwe	270.73	-88.90	-95.82	165.72	-87.82	-56.33

([1]) XAC: Rest of South Central; ([2]) XCF: Rest of Central Africa; ([3]) XEC: Rest of Eastern Africa; ([4]) XSC: Rest of South Africa Custom Union; ([5]) XWF: Rest of West Africa

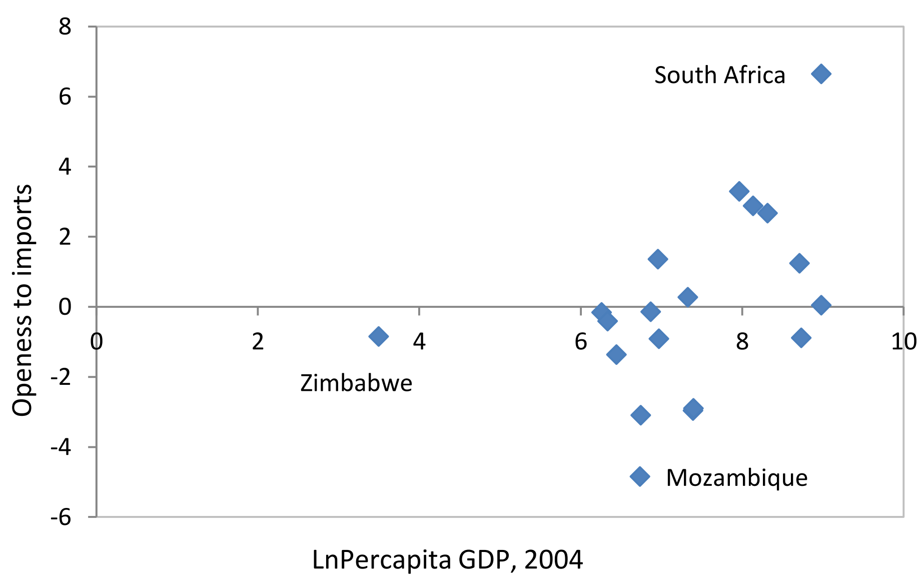
Note: Values are percentage changes. In both counterfactuals, import trade costs for each country are lowered to the level of the country that is most open in this regard (South Africa). African trade increases 1471 % and 1525 % in the left and right scenarios, respectively.

Figure 1: Estimated competitiveness, openness to import and per capita GDP

(a)

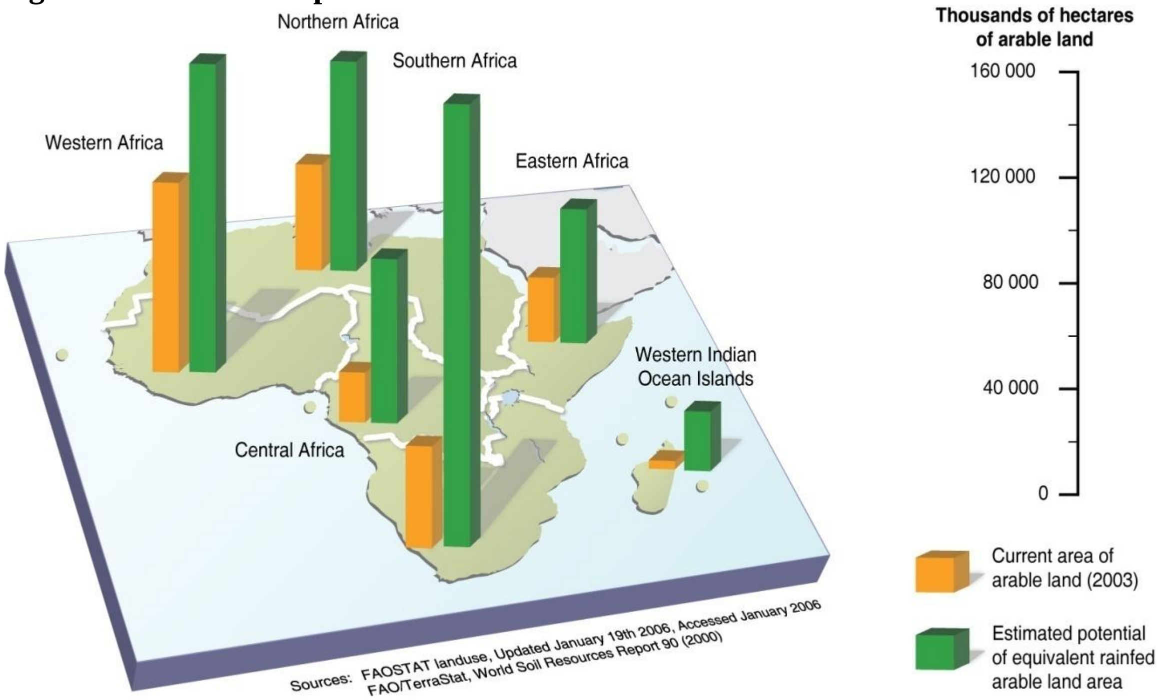


(b)



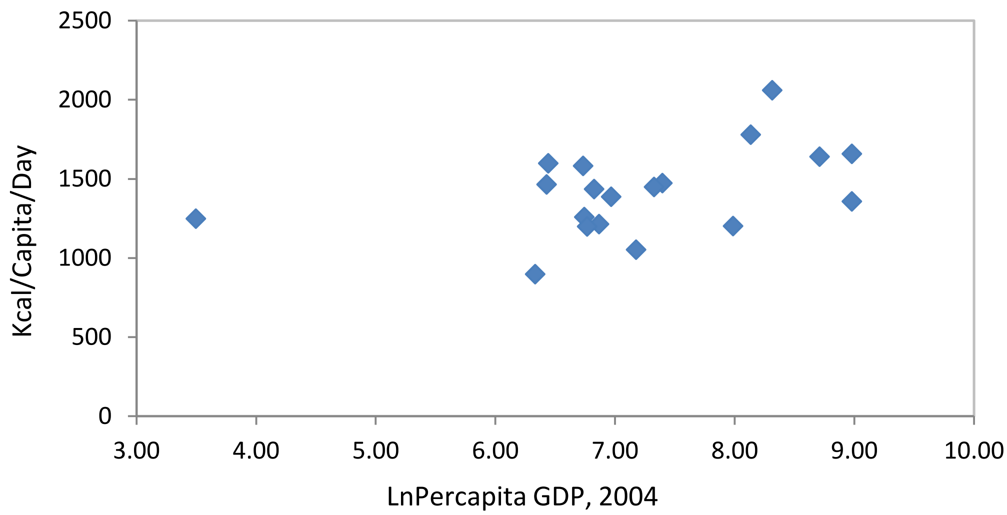
Source: Author results and FAO (2010)

Figure 2: Current and potential rainfed land in Africa



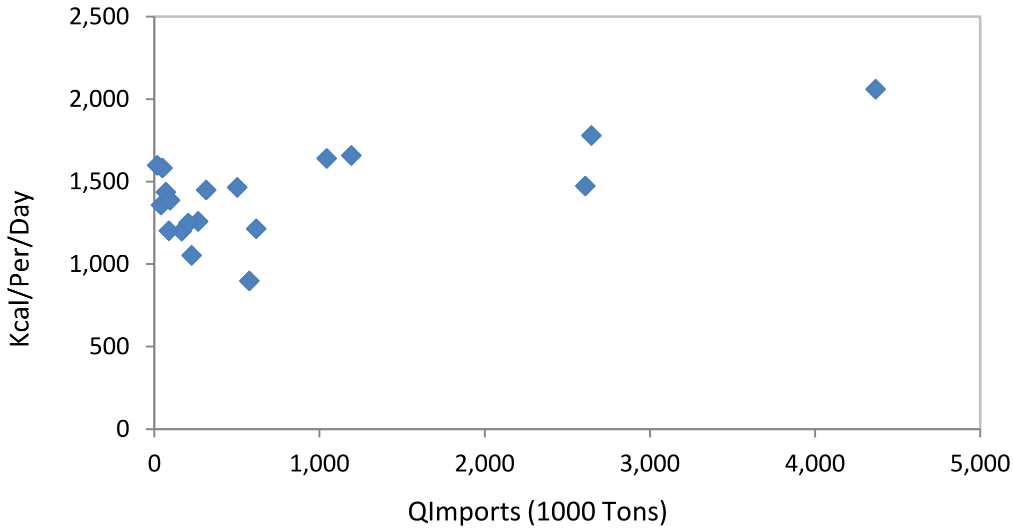
Source: UNEP/GRID UNEP/GRID-Arendal (2006), last access June 2011.

Figure 3: Scatter plot of Calorie supply and GDP/Capita in 2004 in Africa



Source: Author results and FAO (2010)

Figure 4: Scatter plot of calorie supply and Import in 2004 in Africa.



Source: Author results and FAO (2010)

[1] Food security is mainly designed to increase total quantity of energy consumed by an increase of production and consumption of staple foods. It is different from nutrition security which assures the quality and diversity of food essential for good health (FAO 2009) and depends on non-food factors such as sanitary conditions, water quality, infectious diseases and access to primary health care (Pinstrup-Anderson 2009).

[2] One advantage of a Gravity model is that it can be applied with readily available data, and then is not very demanding of data compared to the standard General Equilibrium model. And the rationale behind the standard gravity model is that trade is generated by mass or economic size, which is proxied by GDP, and is inhibited by distance, which increases transportation and other transactions costs (Bougheas, Demetriades, and Morgenroth 1999).

[3] Geographic barriers represent obstacles to easy trade flow such as transport cost, tariffs and quotas and, mainly, delay that are characteristics of trade in developing countries. Typical in Africa, these geographical constraints are more pronounced because of notorious border delays, higher overland transport costs and less trade activities between landlocked countries and coastal countries and within landlocked countries (Naude 2009). Intra-African trade is well explained by country size, per capita income, geography, and taxation of trade (Rodrik 1998).

[4] The Ricardian trade model differs from the others models of trade theory by considering labor as a homogeneous production factor and differences in technologies across goods and countries (Deardorff 2008), and one could incorporate additional immobile factor (Eaton and Kortum 2002). Here land is assimilated to labor as in Reimer and Li (2009; 2010) because it is viewed as a primary (non-produced) factor to meet an essential Ricardian Model assumption.

[5] "**A** staple food is one that is eaten regularly and in such quantities as to constitute the dominant part of the diet and supply a major proportion of energy and nutrient needs" (FAO 1995). The eight major food staples in Africa are maize, rice, wheat, millet, sorghum, cassava, yams, and bananas/plantains (World

Bank 2008). Staple-foods contribute for 40 – 80% of energy intake for most vulnerable population groups in developing countries (WFP 2009).

[6] In EK (2002) a production cost (c_i) in country i is composed of labor and intermediate inputs costs and is as $c_i = w_i^{\beta} p_i^{1-\beta}$, where w_i is the wage, p_i is an index of intermediate goods prices, and β is a constant share of labor in total inputs. As we do not model intermediate goods then $c_i = w_i$.

[7] Anderson and van Wincoop (2004) raise the issues of omitted variables and endogeneity that stem from the specification of the trade cost function. They state that variable such as membership in a currency union or regional trade agreement may not be exogenous. But this issue is overcome in EK (Eaton and Kortum 2002) by adopting a specification with dummy variables.

[8] The use of different currencies is a barrier to trade and for a detail of variables that proxy trade costs and their implications see Anderson and van Wincoop (2004).

[9] We opt for the variable currency as a proxy of economic community because it is difficult to separate the benefit of membership of a specific regional economic community. Many African countries belong to more than one regional economic bloc that grows difficulties for policy and program coordination and harmonization (Meyer et al. 2010).

[10] Using the same currency does not mean here using the same currency name like the *Shillings* one that is shared by Kenya, Tanzania and Uganda but with different exchange rate.

[11] The items we refer to for the trade flows (imports and exports) are from the GSC2 and are “Rice, not husked”, “Husked rice”, “ Wheat and meslin”, “Maize (corn)”, “Barley”, “Rye, oats”, “Other cereals”, “Vegetables”, “Fruits and nuts”, and “Oil seeds and oleaginous fruit”(Narayanan G, Dimaranan, and Mckenzie 2008). The trade flows analysis undertaken here is then based on these items.

[12] Global warming impacts in Africa are estimated to be considerably more adverse than predictions for the developed world, but less alarming than, for example, India and Mexico. There is also a growing view

that frequency and amplitude of extreme weather events may be increasing. All these happenings will negatively affect farmers and increase their risks (AusAID 2008).

[13] In another study Coulibaly and Fontagne (2006) show that distance in Sub Saharan Africa appears to be a geographical impediment for intra and extra-regional trade. They adopted an Armington approach to assess the importance of WAEMU (West African Economic and Monetary union) countries geographical and infrastructural disadvantages on their intra- and extra-regional trade flows with OECD (Organization for Economic Co-operation and Development) countries.

[14] The World Food Summit (WFS) established the target of reducing by half the number of undernourished people in the world by 2015, from a 1990–92 base period. The MDG target is to reduce by half the proportion of people who suffer from hunger, during the same time period (1990–2015).