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Food Prices, Road Infrastructure, and Market Integration in Central and Eastern Africa

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Abstract

Market integration is key to ensuring sufficient and stable food supplies. This paper assesses the impediments to market integration in Central and Eastern Africa for three food staples: maize, rice, and sorghum. The paper uses a large database on monthly consumer prices for 150 towns in 13 African countries and detailed data on the length and quality of roads linking the towns. The analysis finds a substantial effect of distance and share of paved road on the level of market integration, as measured by relative prices. Furthermore, the paper evaluates the additional domestic and cross-border impediments to market integration in the region and represents them on a regional map. The analysis finds heterogeneous levels of domestic market integration across countries and significant "border effects" for the majority of contiguous countries in the sample, which reveal that markets are more integrated within than between countries. Countries that are members of the same regional trade agreement have substantially "thinner" borders with other members. Finally, the analysis shows that countries with less integrated domestic markets and "thicker" borders with their neighbors also have a higher prevalence of food insufficiency. These findings support policy efforts in tackling domestic and border impediments to transactions such as reforming customs, simplifying nontariff measures, addressing corruption, improving the quality of roads, and deepening regional trade agreements.

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Food Prices, Road Infrastructure, and Market Integration in Central and Eastern Africa

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1. Introduction

Market integration is crucial from the perspective of food security. Many Sub-Saharan countries face occasional food shortages as a result of crop failure, which can be caused by drought or other climatic hazard. Integrated markets for staple foods provide a mechanism for reducing the adverse impacts of these shocks by allowing food to move quickly from surplus to deficit areas. The increased integration of food markets in developing countries is also considered to be of vital importance for agricultural transformation and economic growth (Fafchamps, 1992). In addition, Rashid and Minot (2010) argue that knowledge of spatial market integration can also help better design social safety net programs.[1]

An important step toward the implementation of well-targeted policies to improve regional market integration is to evaluate by how much trade in agricultural products is impeded by transport costs and transactions costs between domestic markets and at the border. In this paper we examine the effects of distance, road quality and additional impediments to market integration within and between thirteen countries of the East and Central African region[2] for three key staple foods: maize, rice, and sorghum.

The depth of market integration in a region is typically assessed by the volume of intra-regional trade. This is difficult in Africa because of the substantial volumes of informal trade in food that are not captured in official statistics. A recent report (USAID, 2013) suggests that official statistics in West Africa may underestimate flows of trade in food by as much as 60%.[3] Our paper uses an alternative procedure to assess the extent of regional market integration for basic food staples by examining food prices in different markets and the extent to which they differ between towns. In well-integrated and well-functioning markets, price differences should be arbitraged away through intra-regional trade so that price differences between towns should be bounded by transportation costs between the markets. Yet, policy regulations (e.g., export bans), border barriers, and other impediments to trade may prevent arbitrage and lead to large sustained price differences between locations.

We use a database of monthly prices of maize, rice and sorghum for 150 towns in 13 African countries between May 2008 and September 2009, and estimate, first, the extent to which distance and road quality (as proxied by the proportion of roads that are paved) impact

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[1] If markets are integrated, cash transfers are often better than food transfers because they create demand that maintains incentives for local food production. On the other hand, if markets are not integrated, then food transfers will generally work better.

[2] Burundi (BDI), Djibouti (DJI), Democratic Republic of Congo (DRC), Ethiopia (ETH), Kenya (KEN), Mozambique (MOZ), Malawi (MWI), Sudan (SDN), Somalia (SOM), Rwanda (RWA), Tanzania (TZA), Uganda (UGA) and Zambia (ZMB).

[3] Official statistics on trade in the East and Central African region suggest that there exist substantial flows among countries of our sample (see table A.10. in the appendix). Moreover, it is likely that informal trade is even higher. For example, according to a report from OECD (Lesser, C. and E. Moisé-Leeman, 2009), in 2006, Uganda's informal exports of agricultural goods to its five neighboring countries represented 75% of official agricultural export flows. In the Horn of Africa (Sudan, Ethiopia, Eritrea, Djibouti and North-East Kenya), Little (2005) notes that for some agricultural commodities — like livestock and grain — unofficial exports to neighboring countries in fact exceeded at times official trade by a factor of 30 or more, hence constituting over 95% of total trade in these commodities.

negatively on relative prices between towns. Second, we introduce a dummy for each country and for each pair of contiguous countries to evaluate additional domestic and cross-border impediments of market integration. Third, we estimate border impediments relative to domestic barriers in countries on each side of the borders. We show on a map the level of domestic integration in countries and the border effects. Fourth, we examine the correlation between our measure of domestic and cross border impediments to market integration and the state of adequacy of food supply in countries.

Our estimates suggest that road length and quality between towns as well as domestic and border frictions impede to a large extent market integration in the region. A distance of 298km between cities (the average inter-town distance in the sample) accounts for an increase in prices of about 42%. Moreover, ceteris paribus, if road quality between Rwanda and DRC (35.7% of roads between towns paved) improved to the level of road quality between Tanzania and Malawi (95.5% of roads between towns paved), price differences would be lower by 2.5%, as a result of better market integration.

Finally, controlling for distance and road quality, we find that countries have different levels of domestic and cross border impediments to food market integration. For example, and not surprisingly, DRC and Somalia are the countries with the lowest domestic integration while impediments to market integration are low within Tanzania and within Djibouti. Border effects are also substantial in the region. Price differences are estimated to be 7% larger between than within countries. However, this effect is not high compared to the effect of distance. Computing a distance equivalent as suggested by Engel and Rogers (1996), we estimate that crossing an average border in the region impedes market integration in the same amplitude than increasing the distance between cities by 8 km. Finally, our estimates reveal that member countries in a regional trade agreement (RTA) tend to have "thinner" borders than countries not party to an RTA. In particular, countries in the East African Community (EAC), the "deepest" agreement in the region, have very low border effects (sometimes insignificant). Finally, we find that our measures of domestic and cross border impediments to trade are positively related to the level of prevalence of food inadequacy in countries.

The rest of the paper is organized as follows. Section 2 provides a brief summary of previous studies of prices and border effects with a focus on Africa. Section 3 develops the empirical model and outlines the data. Section 4 presents and discusses the results. Section 5 relates measures of countries' domestic and cross border market impediments to market integration with an indicator of prevalence of food insufficiency. Finally, section 5 summarizes our main conclusions.

2. Existing Literature on Borders and Prices

This paper is closely related to the literature that estimates the impact of trade costs and border effects on deviations from the law of one price (or the relative law of one price) across countries (Engel and Rogers, 1996; Parsley and Wei, 2001; Aker et al, 2012; Broda and

Weinstein, 2008).[4] However, compared to a large strand of this literature, we have the advantage of having data available for similar homogenous goods across markets instead of broad price indexes or prices of differentiated goods By providing accurate estimates of firms' price changes and price stickiness at the product level, Imbs et al. (2003), Bils and Klenow (2004) and Nakamura and Steinsson (2008) have shown that pricing behavior can only be precisely studied by using price level data at the product level. Moreover, Broda and Weinstein (2008) underline that using prices at the product level leads to more accurate estimates of border effects and allows the level of market integration to be assessed through the absolute value of relative prices in level, which is a direct measure of deviations from the law of one price. That is why we use the absolute value of relative price to measure market integration. This indicator has been less popular in the literature because of the higher demands on the data, in particular with regard to highly disaggregated data. However, recently it has been used by Versailles (2012), Grafe et al. (2008) and Broda and Weinstein (2008), among others.

Despite their potential importance, border effects and regional market integration in low income countries have not been the subject of much research, in particular because of the requirement of high-frequency data on narrowly defined goods. In the Eastern and Southern Africa region, research efforts have focused on analyzing integration of agricultural markets at an intra-country level (Tostão and Brorsen, 2005; Atkin and Donaldson, 2013; Zant, 2013; Myers, 2013). Limited work has gone into evaluating how well integrated markets are at the regional level (Araujo and Brunelin, 2013; Mutambatsere, 2007; Versailles, 2012).

Among these papers, Versailles (2012) uses a similar approach to that adopted in this paper and measures the extent to which distance and border effects explain the lack of market integration between 39 cities located in Uganda, Rwanda, Burundi and Kenya for a large range of products. Araujo and Brunelin (2013) estimate the effect of distance and of border impediments on the standard deviation of relative prices in fourteen countries of West Africa for three to five staple foods between 2007 and 2011. Aker et al. (2012) estimate also the border effect between Niger and Nigeria for staple foods. As discussed below, compared to this literature, the magnitude of our estimated border effects on relative prices are similar to the findings of Versailles (2012) for staple foods and as in Aker et al. (2012) and Araujo and Brunelin (2013), we find also a strong effect of distance on market integration. Gorodnichenko and Tesar (2009) make an important critique of the methodology used to assess border effects from price-data. They point out that if relative price variability across locations within the same country differs systematically country-by-country, the border effect measured by a regression comparing within-country and cross-country price dispersion will be confounded by the divergence between two countries' internal price distributions. This is particularly relevant when evaluating border effects between a wide range of African countries, which are particularly

[4] This paper also builds on studies that estimate trade costs using price differences between cities (Atkin and Donaldson, 2013; Zant, 2013) and on the literature which measures market integration based on the spatial price equilibrium conditions using probability bounds models or threshold auto-regression models (Baulch, 1997; Zant, 2013; Myers, 2013).

likely to have highly heterogeneous price distributions. We take this into account and provide a lower and an upper bound estimate to each of our estimated border effects.[5] Moreover, not removing city-pairs where there is no motivation for trade (where structural price differences are lower than transport costs) could lead to underestimates of the impact of trade costs (Atkin and Donalson, 2013). As this bias is relatively more likely to occur when including city pairs, which are geographically far from each other, we limit the estimations to city-pairs which are not separated by more than 800km.[6]

Finally, we take into account the effect of road quality on the level of integration by using a highly detailed database on road infrastructure. This also complements the findings of Loveridge (1991), Minten and Kyle (1999), Coulibaly and Fontagné (2006) and Buys et al. (2010) on the impact of road quality on trade flows and market integration.

3. Methodology, Data and Trade Impediments in the Region

3.1. Theory and Empirical Model

The Law of One Price (LOP) states that, once converted to a common currency, commodity prices should be equal across locations when markets are fully integrated and when there are no transaction costs. In reality, the LOP rarely holds as there are costs of trading between any pair of towns. Therefore, transfer costs (comprising transportation, loading and unloading costs, and trader's profits) determine the extent to which the prices of a homogenous commodity in two geographically distinct markets can vary independently (Baulch, 1997). When trade takes place, two markets can be defined to be spatially integrated if the price in the buying market equals the price in the selling market plus the transportation and other transfer costs involved in moving the good between them.[7]

The extent of market integration can be assessed by distinguishing among three possible trade regimes (Baulch, 1997):

(i) When transfer costs equal the inter-market price differential and there are no impediments to trade between markets, trade will cause prices in the two markets to move on a one-for-one basis and the spatial arbitrage conditions are binding (Gopinath et al, 2011): $\left|p_{ikt} - p_{jkt}\right| = T$, where p_{ikt} and p_{jkt} are the price of product k at time t respectively in towns i and j and T are the costs associated with trade between these towns.

[5] Araujo and Brunelin (2013) and Versailles (2012) mention the potential problem of country heterogeneity effect highlighted by Gorodnichenko and Tesar (2009). However, Araujo and Brunelin (2013) do not control for this problem so the estimated border coefficients could reflect both countries' heterogeneity in the price distribution and real border effects. Versailles (2012) controls for countries' specific distribution but only provides the lower bound of the border effect.

[6] Note however, that we obtain similar results with the full sample (with a panel of 4'599 citypairs and a road distance between 5km and 4'850km). We also use in an Appendix a strategy similar to Zant (2013) to remove city pairs for which price differences are low compared to estimated transport costs (see Appendix C for the methodology and results in tables A3, A.4, A.5 and A.6 and in Figure A.1 of Appendix A).

[7] This is the same definition of market integration as used by Ravallion (1986). Note, however, that some analysts use the term market integration to refer to the frequency with which markets are linked by trade (Fackler, 1996).

(ii) When transfer costs exceed the structural difference of prices,[8] trade will not occur and the spatial arbitrage conditions will not be binding. In that case, the price difference between two locations is lower than the transaction cost ($|p_{ikt} - p_{jkt}| < T$).

Trade regimes (i) and (ii) are consistent with competitive spatial price equilibrium and market integration.

(iii) When price differences exceed transfer costs, the spatial arbitrage conditions are violated whether or not trade occurs. ($|p_{ikt} - p_{jkt}| > T$).

Violation of the spatial arbitrage conditions indicates that there are other impediments to trade between markets and provides evidence of a lack of market integration. In such circumstances, inter-market price differences may also reflect factors other than pure transfer costs such as the effect of government controls on produce flows, transportation bottlenecks or oligopolistic pricing (Baulch, 1997). Accordingly, the higher are inter-market price differences compared to transfer costs, the higher are barriers to market integration.[9]

Impediments to market integration between locations can be decomposed into (i) transport costs that are variable and positively related to distance and (ii) other fixed trade impediments between locations. We denote T_W=τ.distance+D as the trade impediments between towns within the same country (with τ >0 the transport costs associated with distance and D the fixed barriers to trade between towns in the same country such as state level policy controls, road blocks or weigh bridges). For cross-country trade, T_B=τ.distance+D+B with B the "border effect" or the transaction costs and trade barriers associated with crossing the border. It follows that the so-called border effect is the difference between transaction impediments associated to trade between countries T_B and those associated to trade within countries.

To explore market integration in the East and Central African region, we examine the effect of road distances, road quality and border impediments on price ratio between city pairs in our sample of thirteen countries and three goods over the period May 2008-Sept. 2009. Ideally, our analysis of the price ratio should take into account that the existence of trade costs implies a no-arbitrage band in relative prices and hence non-linearity. More precisely, as underlined by Atkin and Donaldson (2013) including town pairs for which trade does not take place because transfer costs exceed the structural price differences (case (ii)) is likely to lead to an understatement of the impact of factors obstructing market integration. For example, towns that are far from each other in the sample are likely to have structural price differences lower than transport costs, so that trade in staple goods does not take place even if all other trade impediments were removed. In that case, price differentials between these cities are not informative of the level of integration.

[8] Structural prices are determined according to towns' characteristics. For example, production costs may be different across locations if resource endowments and/or productivity of workers are different (see Gopinath et al., 2011). Moreover, preferences and/or market size may vary across locations and lead to differences in prices.

[9] Price differences could be the result of market power. The markup across countries can be different when the degree of market competition varies. However, it is reasonable to assume competitive markets of Rice, Sorghum and Maize and profit maximizing trade in the region (Zant, 2013).

For this reason, we remove from our sample the city pairs separated by more than 800km. Moreover, in an Appendix, we try to estimate transport costs between cities and use these estimations to remove from the sample town-pairs where the estimated price of trading is greater than the difference in prices (see Methodology in Appendix C). The estimations using the corrected sample are shown in tables A.3 and A.4 of Appendix A. The results and conclusions of this paper remain when using the corrected sample, but the coefficients on road quality and border dummies tend to be substantially higher, as predicted by Atkin and Donaldson (2013).

One alternative empirical strategy would be to estimate the dynamics of prices between each city pair in a threshold cointegration or threshold auto-regression (TAR) framework (for example Imbs et al, 2003; Trenkler and Wolf 2005). The key advantage of such a framework is that it allows distinguishing between the magnitude of transaction costs and differences in the speed of bilateral price adjustments that can both affect the price gap between cities.[10] However, one aim of our paper is to examine domestic and cross-border impediments. Yet, as argued by Schulze and Wolf (2009) who compare the empirical strategy we follow with the TAR approach, the TAR approach is not well suited to the analysis of border effects. First, it would imply to fit a TAR-model to each of the city-pairs separately (we have 4'599 city pairs in the initial sample). Second, inference on border effects between city-pairs can only be made indirectly by comparing the pair-wise results, which in turn requires structural stability over time and comparable time series dynamics in the cross-section (Trenkler and Wolf, 2005). Finally, the estimation of the threshold and of the coefficient of return to the mean needs a large time dimension so that price differences vary within and outside the no-arbitrage bounds. So, the TAR technique is not be the most appropriate for our case.

Therefore, to assess the extent of trade impediments within and between countries, we estimate the following specification:

$$\left|\ln\left(\frac{P_{ikt}}{P_{jkt}}\right)\right| = \beta_0 + \delta_{ik} + \delta_{jk} + \delta_{kt} + \beta_1 \ln Road\_Length_{ij} + \beta_2 Road\_quality_{ij} + \sum_{IJ, I \neq J} \gamma_{I-J} B_{ij} + \sum_{I} \gamma_{I-I} D_{ij} + \varepsilon_{ijkt} \quad (0.1)$$

In (0.1), P_{ikt} is the price of commodity k in town i and month t expressed in dollars. As (P_{ikt}/P_{jkt}) is the ratio of prices labeled in dollars, it is also a measure of the "real exchange rate" for commodity k between towns i and j in month t. $Road\_Length_{ij}$ is the road length between towns i and j. Its coefficient is expected to be positive as trade impediments are deemed to be bigger between more distant cities. $Road\_quality_{ij}$ is the share of paved road between city pairs. The variables δ_{ik} and δ_{jk} are town-product dummy interactions and control for town-product specific characteristics affecting price differentials such as the potential non-perfect homogeneity of products across cities (differences of quality, color, shape) or differences in

[10] Imbs et al. (2003) use this method and estimate thresholds as well as the speed of adjustment of prices for nineteen sectors over 1975-1996. Then, they estimate the effect of distance and nominal exchange rate (among others) on "market segmentation", i.e. on the estimated threshold and on the speed of adjustment of prices (outside the no-arbitrage band).

input prices or quality of services; δ_{kt} are month-product dummy interactions and control for specific month-product variations.

B_{ij} is a dummy that equals one if towns are located in different (but contiguous) countries, and zero if towns are located in the same country (20 dummies). D_{ij} is a dummy equal to one if towns are located in the same country and zero otherwise (13 dummies as we have 13 countries in our sample). However, in order to identify simultaneously coefficients on all dummies, we need to exclude one of these dummies (Gorodnichenko and Tesar, 2009). We generally exclude the dummy D_{ij} for Djibouti city pairs (and therefore, we do not estimate $\gamma_{Djibouti-Djibouti}$) since this is a small country in which market integration within the country is expected to be high. Coefficients on these variables reflect respectively the degree of market integration between and within countries, after controlling for impediments to trade due to distance and road quality. More precisely, coefficients on the dummies D_{ij} and B_{ij} measure respectively the "average market integration" within and between countries with respect to the average market integration within Djibouti.

As a first step in the empirical section, we only include a global dummy "border_{ij}" equal to one if cities are from different countries and zero otherwise and we do not include dummies for city-pairs within countries. In this case, the estimated coefficient on border_{ij} reflects the average border effect, i.e. the increase in relative prices associated with crossing a border.

It is worth noting that in equation (0.1), the error terms ε_{ijkt} may not be identically and independently distributed. Indeed, there could exist substitution effects between maize, sorghum and rice. Moreover, even if these staple goods are perishable, there may be inter-temporal substitution effects. That is why, in our estimation, we allow for possible correlations within city-pair clusters.

3.2. Evaluation of Border Effects

Measuring the degree of market integration between and within countries with respect to a common benchmark (such as the "average market integration" in Djibouti) has the advantage of providing measures of market integration that are directly comparable. Therefore, to evaluate the border effects between countries, i.e. the additional impediments associated with crossing a border, we only need to compare the relative prices of town-pairs between countries with the relative price of town-pairs within the countries on both sides of the borders (Gorodnichenko and Tesar, 2009). For example, the border effect estimated between Tanzania and Kenya is the magnitude of price differences between Tanzania and Kenya with respect to the average price differences within Tanzania and within Kenya ($\gamma_{TZA-KEN}-0.5\ \gamma_{TZA-TZA}-0.5\ \gamma_{KEN-KEN}$).

Yet, when market integration or relative price distribution in a country is different from the relative price distribution in the neighboring country, the border effect, as computed with the above formulation, may reflect what Gorodnichenko and Tesar (2009) call the country heterogeneity effect. For example, if the price differences are much higher between cities in

Kenya than between cities in Tanzania, the additional price differences at the border will reflect both a border effect and the difference in the relative price distribution between cities of these two countries. Therefore, when within-country price distributions are very different, it is only possible to estimate a lower and an upper bound for the border effect. In the example of Kenya and Tanzania, the upper bound will reflect the border effect from the Tanzania's perspective ($\gamma_{KEN\text{-}TZA}$-$\gamma_{TZA\text{-}TZA}$) and will be much bigger than the lower bound, computed from the Kenya's perspective ($\gamma_{KEN\text{-}TZA}$ –$\gamma_{KEN\text{-}KEN}$).

In addition to trade impediments, border effects can reflect different degrees of price stickiness between markets on both sides of the border. Indeed, if the price of a good in local currency does not change when the nominal exchange rate changes, cross-border relative prices would fluctuate with the nominal exchange rate and these variations will be captured by the border dummies. Yet, price stickiness may be related to border barriers, as a seller can resist cutting the price of their good when markets are imperfectly integrated. To separate this effect from the border effects, we introduce as an explanatory variable a measure of monthly nominal exchange rate variations ($\left|\Delta \ln ER_{ijt}\right|$). If prices perfectly adjust to nominal exchange rate variation, the coefficient of $\left|\Delta \ln ER_{ijt}\right|$ will not be significant.

3.3. Data and Impediments to Market Integration in the Region

Detailed consumer price data for 3 commodities (Maize, Sorghum, and Rice) was compiled from FEWSNET and FAO for 150 towns in 13 countries in East and Central Africa on a monthly basis. Because of data availability, we restrict our analysis to the common period May 2008-Oct. 2009.[11] In the raw data, prices of commodities are sometimes available in different units (e.g. kilograms, tons, etc) and for different varieties (e.g. maize or white maize). In order to keep the largest possible number of observations, we transform the price units to dollars per kilogram using the monthly average exchange rate and assimilate a variety (e.g. white maize) to the main commodity (e.g. maize) when the latter is not available. In appendix B, we compare the relative prices of our expanded sample with a more restricted sample where we exclude goods that are labeled differently than the main good (e.g. white maize) and find that the distributions of relative prices are similar, therefore our choice is unlikely to affect the results.

We match the commodity price data with a detailed data set on the road network in these countries compiled from GIS. The rich road network data not only includes the length of the road minimizing the travelling time between any pair of towns in our sample, but also includes detailed information about the road quality between any two towns.

[11] The original database includes price data for several cities and countries from 2000 to 2011. Two main reasons lead to the decision of limiting the period. First, Data for Congo (D.R.) are only available over May 2008 and September 2009 and there are no observations for most countries before 2006. Second, most city prices in the original sample are available only for some periods. Therefore taking a larger period would reduce drastically the number of cities and countries. This could be appropriate to study the evolution of levels of market integration of a few cities over time but in this paper, we choose to give priority to the impediments to market integration between and within a large number of countries in the region during a recent period.

Market integration could differ within and between countries of our sample for many reasons. Language or ethnicity differences may impede trade partnership and could lead to lower market integration.[12] In Central and Eastern Africa, ethnic and language differences are high between and within countries and therefore, could explain a lack of domestic market integration as well as a lack of cross-border integration. Moreover, internal and cross-border conflicts may impede market integration. According to Lecoutere et al. (2009), risk associated with conflict leads to an increase of transaction costs between producers and consumers. For example, these authors highlight that, partly as a result of the war, the North Kivu area in DRC has experienced a substantial reduction in market opportunities.

Trade policy regulations (export and import bans, tariffs, licenses and permits, nontariff barriers, such as restrictive application of SPS measures) and customs inefficiency are important barriers to cross border market integration in the majority of countries in our sample. Many countries in the region have programs and policy regulations seeking to limit exports of theses staple goods. While the main objective is often to tackle problems of food insecurity, these policies reduce the market integration between countries although their impact is attenuated by the large volumes of informal trade that are observed. The extent of informal trade is itself a response to the restrictiveness of formal trade barriers. Table A.11 in appendix A summarizes information provided by Rashid and Minot (2010) about trade regulations affecting staple goods with a focus on the countries of our sample.

Many efforts have been made in the region to improve regional access to markets, in particular, through the implementation of regional trade agreements. The three main regional trade agreements are the Common Market for Eastern and Southern Africa (COMESA), the Southern African Development Community (SADC) and the East Africa Community (EAC).[13] The EAC can be considered as the deepest of these agreements with a Customs Union between Uganda, Kenya and Tanzania operational since 2005. Rwanda and Burundi joined the union in 2009 and have subsequently phased out tariffs on imports from other EAC members. Thus, tariffs on other EAC members were low but not zero during the period we study (see table A.8 in appendix A). Zambia, Malawi and Tanzania have been members of the SADC free trade area since 2008. Finally, Djibouti, Kenya, Malawi, Sudan, Zambia have liberalized their tariffs in the context of COMESA since 2000. However, only Kenya and Sudan are contiguous countries in this group. Due to these agreements, tariffs on maize, rice, and sorghum are positive but relatively low between members of the same regional agreement.[14]

In the next section, we estimate the extent of impediments to market integration within and between countries. Our data coverage also allows for assessing market integration between countries members and non-members to preferential trade agreements.

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[12] As an example, Aker et al (2012) found that at the border between Niger and Nigeria, price differences may vary from 8% to 24% regarding if the people are from the same ethnic group or not.

[13] Since 2008 there have been attempts to create a single Free Trade Area and merge the three regional blocs. This will address the problem that arises because some countries are party to more than one of these agreements. This Tripartite Agreement is still under discussion. Table A.7 in the appendix A summarizes countries participation to regional trade agreements.

[14] See Tables A.8 and A.9 in appendix A.

4. Econometric Analysis

The effects of transport costs and additional transaction impediments within and between countries are assessed in this section. Then, we represent in a map our estimates of barriers to market integration.

4.1. Descriptive Statistics

Table 1 provides a summary description of the number of towns and the availability of price data for each of the three commodities studied. Depending on the country, commodity prices may be available for one to three commodities. The number of cities in the data varies also greatly between countries. Most countries have price data for at least two commodities and 4 towns; the greater data availability being for Rwanda with 30 towns and 3 commodities.

Table 2 shows summary statistics for the dependent variable, the absolute value of the log of relative prices, across country-pairs and good groupings. Higher values of relative prices reflect a lower degree of market integration. In addition, column (1) reports the average road distance between towns (in kilometers) and column (2) shows the share of paved roads between towns (as a percentage of the total road length), which is our measure of road quality.

Table 1: Countries, towns and commodities in the sample

Country	Product	Number of towns	Country	Product	Number of towns
Burundi	Maize	14	Rwanda	Maize	29
	Rice	14		Rice	30
	Sorghum	14		Sorghum	30
Djibouti	Maize	0	Sudan	Maize	0
	Rice	5		Rice	0
	Sorghum	0		Sorghum	7
DRC	Maize	19	Somalia	Maize	5
	Rice	19		Rice	9
	Sorghum	0		Sorghum	8
Ethiopia	Maize	9	Tanzania	Maize	8
	Rice	0		Rice	9
	Sorghum	8		Sorghum	0
Kenya	Maize	4	Uganda	Maize	4
	Rice	0		Rice	0
	Sorghum	3		Sorghum	4
Mozambique	Maize	8	Zambia	Maize	9
	Rice	8		Rice	0
	Sorghum	0		Sorghum	0
Malawi	Maize	9			
	Rice	7			
	Sorghum	0			

Source: Authors' calculation

Table 2: Summary statistics of within-country and between-country price differentials.

	Road_km (average)	Road_quality (average)	|Ln(Pikt/Pjkt)| Obs	Mean	Std. Dev.	Max-Min
	(1)	(2)	(3)	(4)	(5)	(6)
WITHIN-COUNTRY						
BDI-BDI	136.8	77.5%	4'629	0.23	0.20	1.65
DJI-DJI	227.6	78.4%	222	0.11	0.09	0.54
DRC-DRC	465.6	31.5%	1'853	0.55	0.54	2.75
ETH-ETH	520.1	53.5%	470	0.23	0.21	1.26
KEN-KEN	421.8	96.8%	153	0.23	0.15	0.68
MOZ-MOZ	382.2	98.2%	369	0.18	0.16	1.10
MWI-MWI	368.6	90.8%	851	0.17	0.13	0.79
RWA-RWA	154.5	87.2%	19'856	0.15	0.14	1.10
SDN-SDN	604.2	79.4%	166	0.18	0.14	0.68
SOM-SOM	424.2	84.3%	653	0.40	0.38	2.00
TZA-TZA	507.9	66.0%	441	0.21	0.19	0.97
UGA-UGA	333.1	66.7%	170	0.24	0.17	0.83
ZMB-ZMB	541.1	91.2%	349	0.21	0.18	0.84
Maize			10'232	0.27	0.30	2.75
Rice			10'832	0.15	0.17	2.00
Sorghum			9'118	0.18	0.18	1.79
Average values	**206.2**	**81.5%**	**30'182**	**0.20**	**0.23**	**2.75**
BETWEEN-COUNTRY						
DRC-BDI	479.0	65.4%	3'638	0.41	0.39	2.72
MWI-MOZ	274.0	87.7%	20'785	0.28	0.21	1.40
RWA-BDI	427.6	59.3%	7'695	0.36	0.33	2.16
RWA-DRC	577.4	35.7%	49	0.39	0.28	0.95
SDN-ETH	510.8	54.7%	153	1.22	0.57	2.11
SOM-DJI	657.8	31.9%	17	0.58	0.45	1.24
SOM-ETH	334.4	57.1%	705	0.18	0.15	1.11
SOM-KEN	589.8	63.3%	266	0.42	0.43	2.24
TZA-BDI	606.0	91.8%	81	0.33	0.18	0.81
TZA-DRC	600.2	95.5%	299	0.32	0.19	0.91
TZA-KEN	500.7	76.1%	1'417	0.34	0.16	1.02
TZA-MWI	600.2	95.5%	299	0.32	0.19	0.91
TZA-RWA	500.7	76.1%	1'417	0.34	0.16	1.02
UGA-DRC	712.4	87.3%	112	0.40	0.27	1.22
UGA-KEN	451.1	91.1%	267	0.24	0.16	0.79
UGA-RWA	677.9	95.2%	1'609	0.27	0.19	0.89
ZMB-DRC	499.2	84.5%	286	0.33	0.23	1.11
ZMB-MOZ	603.5	68.0%	51	0.24	0.18	0.71
ZMB-MWI	499.2	84.5%	286	0.33	0.23	1.11
ZMB-TZA	603.5	68.0%	51	0.24	0.18	0.71
Maize			15'252	0.38	0.35	2.72
Rice			15'448	0.30	0.24	2.12
Sorghum			7'955	0.27	0.28	2.45
Average values	**370.2**	**78.3%**	**38'655**	**0.33**	**0.30**	**2.72**

Source: Authors' calculations

Some stylized facts emerge from Table 2. First, East and Central African countries have heterogeneous distributions of within-country relative prices and are different in terms of domestic infrastructure. Unsurprisingly, Kenya has one of the highest shares of domestic paved road, with 96.8% of paved roads linking the towns in our sample, and DRC has the lowest share of paved road in our sample with only 31.5% of roads paved. Domestic price differences between towns vary widely across countries. Countries with greater domestic distances and with low road quality tend to have high price differences (for example relative prices in the DRC are on average twice as high as in Kenya), but there is also heterogeneity between countries with similar road lengths and road quality. For example, the road quality and the average distance between towns in Mozambique are similar to those in Kenyan, whereas the relative price differences between Kenyan towns are much higher, of 0.23, than between Mozambique's towns, of 0.18. This may suggest that additional impediments to domestic market integration in Mozambique are lower than in Kenya.

Second, comparing the average within-country relative prices with between-country relative prices provides a first rough estimate of the average effect of crossing the border on market integration. Price differences tend to be on average higher when the towns are in different countries than when they are in the same country, which suggests positive border effects. Within-country price differences are on average of 0.20 (which corresponds to price differences of 22% = exp(0.20)-1). This figure is higher in the "between-country" sample with price differences being on average of 0.33 (which corresponds to price differences of 39%=exp(0.33)-1). For example, price differences between towns in Malawi and towns in Mozambique are on average 0.28 (32 %), a figure greater than price differences between towns in these countries, which are 0.17 (19%) in Malawi and 0.18 (20%) in Mozambique.

4.2. Borders, Distance and Price Rigidity in the Region

Table 3 reports the estimates of the effect of distance, road quality, border impediments and exchange rate variations on relative prices using model (0.1). Columns (1) and (2) show the estimated impact of distance and road quality between towns. Column (3) and (4) include a single dummy for the average border effect in the East and Central African region and column (4) also includes the absolute value of monthly depreciation of the exchange rate. All these specifications include interaction terms of town-product dummies and month-product dummies. Finally, columns (5) to (7) decompose the results of column (3) respectively for Maize, Rice and Sorghum. These last specifications also include month and town dummies. In table A.12 in the Appendix, we run similar specifications but with town-month dummies and product dummies and we find similar results.

First, road length and road quality have a substantial effect on price differences. According to estimates of specification (2), a distance of 298 km between cities (the average inter-town distance in the sample) accounts for price differences of about 42%, reflecting a low degree of market integration.[15] Moreover, a higher distance of 1% between towns increases price differences by approximately 6.4%.

[15] Computed as: exp[0.0618*ln(298)]-1.

Table 3: Border coefficients, distance and price stickiness, average effect in the region.

	All products (Maize-Rice-Sorghum)				Maize	Rice	Sorghum
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$
lnRoad_Length	0.0571***	0.0618***	0.0352***	0.0354***	0.0236***	0.0600***	0.0175***
	(0.00472)	(0.00607)	(0.00516)	(0.00518)	(0.00760)	(0.00821)	(0.00489)
Road_quality		-0.0407***	-0.0260**	-0.0264**	-0.00247	-0.0527***	-0.0147
		(0.0140)	(0.0131)	(0.0131)	(0.0255)	(0.0182)	(0.0155)
border			0.0742***	0.0723***	0.0546***	0.126***	0.0298***
			(0.00576)	(0.00534)	(0.0113)	(0.00729)	(0.00875)
$\lvert\Delta \ln ER_{ijt}\rvert$				0.114			
				(0.0696)			
Constant	0.0820	0.109	0.247**	0.248**	0.213**	-0.283***	0.350***
	(0.0877)	(0.0898)	(0.102)	(0.102)	(0.0870)	(0.0584)	(0.0452)
Town-Product dummies	Yes	Yes	Yes	Yes	No	No	No
Month-Product fixed effects	Yes	Yes	Yes	Yes	No	No	No
Town dummies	No	No	No	No	Yes	Yes	Yes
Month fixed effects	No	No	No	No	Yes	Yes	Yes
Observations	68,821	68,821	68,821	68,821	25,468	26,280	17,073
R-squared	0.473	0.474	0.483	0.483	0.496	0.444	0.452

Note: Robust standard errors in parentheses are clustered by city-pair. Significance levels are: *** p<0.01, ** p<0.05, * p<0.1. In columns (1)-(4), regressions include 314 interaction terms for town-product dummies ('Ngozi x Maize' being dropped) and 48 interaction terms for month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). In columns (5)-(7), regressions include only town and month dummies because the regression are by product. The coefficients on the border dummy in this table have to be interpreted with respect to the average price correlation within-countries in the sample (the omitted dummy).

Road quality plays also a significant role on market integration. Ceteris paribus, city pairs with 65% of road paved (the first quartile of the sample) have a higher relative price difference of 1.2% compared to city pairs where 94% (the median of the sample) of road joining them is paved. In other words, ceteris paribus, if road quality between Rwanda and DRC (35.7%) increased to the level of road quality between Tanzania and Malawi (95.5%), the relative prices would be lower by 2.5%, and therefore market integration would be slightly higher. This is in line with the intuition of Teravaninthon and Raballand (2009) who argue that poor roads increase transport costs by increasing fuel consumption, increasing maintenance costs, accelerating depreciation of vehicles and therefore increasing replacement costs and raising journey times due to lower speeds (opportunity costs).

Yet, the effect of road quality is low compared to the effect of distance. In columns (5) to (7) of this table, only the relative prices of rice are significantly impacted by the road quality but, controlling for town-month fixed effects in table A.12, price differences of all products are affected negatively and significantly by road distance. In all cases, the effect of road quality is low. For rice in column (6) of table 3, once controlling for the distance separating towns, increasing the share of road paved between two cities by 10 percentage point would have the same effect as an increase of distance of 1 additional kilometer (=exp(0.10*0.0527/0.06)).

Second, in columns (3), the coefficient on the single dummy for the existence of a border between towns is positive and highly significant. This means that impediments to trade in the region are on average higher between countries than within countries. After controlling for inter-town distance and road quality, price differentials for towns separated by a border are 7.7% (=exp(0.0742)-1) higher. This suggests that dealing with policy barriers at the border can be as important as infrastructure spending that increases the quality of roads in delivering greater market integration for food products. Our estimated coefficients on the border dummy are slightly higher in terms of magnitude than those obtained by Aker et al (2012) for Cowpea and Millet between Niger and Nigeria (of around 2%).

Comparing with the literature, the effects in terms of price differences are slightly higher than those found by Broda and Weinstein for Canada and US (of around 7%) and a bit lower than Versailles (2012) for staple food between Uganda, Burundi, Tanzania and Kenya (of around 9%). However our estimated distance coefficient is much higher than the distance coefficient reported by Broda and Weinstein (2008) for Canada and US reflecting unsurprisingly that distance plays a much bigger role in Eastern and Central Africa. The effect of distance is also slightly higher than in Versailles (2012), who finds a distance coefficient of around 0.015 for staple foods (i.e. for rice, maize potatoes and sweet potatoes). Computing a distance-equivalent as suggested by Engel and Rogers (1996), we find that crossing a border in the region impedes market integration by the same amplitude as increasing the distance between cities by 8km (computed as exp(0.0742/0.0352)) while Versailles finds a distance equivalent of 220km and Broda and Weinstein of around 328km. The low distance equivalent reveals the predominance of the effect of distance on market integration in the region. Araujo and Brunelin (2013) found similarly a small border effect in West Africa between Benin, Burkina Faso, Mali and Niger for mil, sorghum and maize, between 2km and 35km.[16]

Many factors could explain that the border effects between African countries are relatively low. First, the high number of weighbridges and policy controls along intra-national roads increase transport delays and, therefore, constitute substantial barriers to trade within African countries. Second, within-country differences of ethnicity and language could explain the low domestic market integration. Third, the lack of control at the border and the corruption of customs may facilitate trade of primary commodities between countries; which is reflected in the large amount of informal trade estimated by Stryker (2012) based on FEWSNET data. For example, according to Stryker (2012), 15’815 MT of Maize have been informally traded between Tanzania and Kenya in 2011. In this regard, it is less surprising that the estimated average border coefficients between African countries are low compared with the effect of distance.

[16] As these authors argue, the distance equivalent proposed by Engel and Rogers (1996) is unitless, i.e. it does not vary according to the measurement unit for distance. However, it is usual to express it in terms of the unit of measurement of distance in the sample, which is in kilometers in this paper.

In column (4) the estimated coefficient on exchange rate variation is positive but not significant, although, it is significant when we introduce separated border dummies in Table A.1. In each case, its inclusion reduces the estimated border coefficient slightly. In line with the literature (e.g. Crucini et al, 2010), this confirms that nominal price rigidities partially explain deviations from the Law of One Price. This is also in line with Araujo and Brunelin (2013) who found a higher border effect for countries outside of the CFA franc zone, explaining that in case of currency differences between countries, exchange rate volatility could be reflected in relative price volatility.

To sum up, market integration is weaker between towns where the distance separating them is longer and road quality lower. Moreover, on average in the region, impediments to market integration are higher between countries than within countries.

4.3. Internal Market Integration and Border Effects in Central and East Africa

In this section, we analyze the specific border effects and constraints to internal market integration for each country of our sample. To do this, we add to equation (0.1) all border dummies and domestic market dummies (except for Djibouti), and we use the estimates to measure specific border effects, providing lower bounds and upper bounds between each pair of contiguous countries.

Table 4 and 5 summarize the results of estimation of equation (0.1). First, table 4 shows the coefficients obtained on each country dummy which should reflect the level of impediment to market integration within these countries (D_{ij} in equation (0.1)). These coefficients measure the relative integration of domestic markets with respect to market integration in Djibouti and are directly comparable. The information in the table shows that, controlling for the quality of roads and distance between markets, the countries with the highest domestic impediments to market integration are Somalia and the DRC while those with the lowest barriers (after Djibouti) are Sudan and Tanzania. This is not surprising given the state of security in DRC and Somalia, which can considerably impede trade between cities.[17] Moreover, the relatively good integration of Malawi is consistent with studies of market integration of maize in Malawi at the micro level (Mutambatsere et al, 2007 and Myers, 2013) that find a high degree of market integration in the country.

In Table 5, column 1 shows the coefficient estimated on the border dummy (B_{ij} in equation (0.1)).[18] These coefficients measure the cross-border impediments to market integration with respect to market integration in Djibouti. In column 2, the computed "border effect" is presented for each country pair by taking the difference between the border coefficient (of column 1) and a linear combination of coefficients on dummies for countries on each side of the

[17] Note that we do not have any cities from south Sudan in our sample which may explain, at least partially, why we observe a relatively good level of market integration in Sudan.

[18] All results of this regression are available in Table A.1 of the appendix. Coefficients on distance and road quality estimated are almost the same as those discussed in the previous section.

border (shown in Table 4) as explained in Section 3.2. These border effects provide a measure of the average impediments to trade that are associated with crossing the border. Columns 3 and 4 show the lower bound and the upper bound obtained by computing the difference between the border coefficient (in column 1) and the coefficient on the dummy of each country located on one side of the border (reported in Table 4). These bounds qualify the accuracy of border effects reported in column 2 given the country heterogeneity effect highlighted by Gorodnichenko and Tesar (2009).[19]

Table 4: Domestic Impediments to market integration (country are ranked from the one with the lowest to the one with the highest impediments).

Country	Domestic impediments
(1)	(2)
Djibouti	0
Sudan	0.0437 [b/]
Tanzania	0.0586 [a/]
Ethiopia	0.0589 [c/]
Mozambique	0.0610 [a/]
Malawi	0.0623 [a/]
Rwanda	0.0628 [a/]
Zambia	0.0631 [c/]
Kenya	0.110 [a/]
Burundi	0.144 [a/]
Uganda	0.123 [a/]
Somalia	0.317 [a/]
DRC	0.373 [a/]

Significance levels are: [a/]$p<0.01$, [b/] $p<0.05$, [c/] $p<0.1$. Notes 1 Figures in column 2 report coefficients estimates of equation (0.1) on the dummy $D_{country\text{-}country}$ (when the dummy $D_{Djibouti\text{-}Djibouti}$ is omitted). Note 2 : The regression used to build this table has the following properties: (i) the dependent variable is the absolute value of the log of good relative prices (ii) there are 68'821 observations, (iii) the R-squared is of 0.509, (iv) standard errors are clustered by city-pair, (v) right hand side variables are the road length taken in logarithm, the roads' quality index, 12 country dummies (one for each country except Djibouti) and 20 dummies for pairs of contiguous countries, a constant, 315 interaction town-product dummies, 48 interaction month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). Coefficients on city-product dummies are constrained to sum to zero for each country in order to properly estimate the border coefficients (see Gorodnichenko and Tesar, 2009). All results of these regressions are in table A.1 of the Appendix.

There are several interesting results that emerge from column 2. First, countries that belong to a free trade agreement have relatively lower border effects than countries that do not. Countries in EAC and in SADC have an average border effect of respectively 0.060 and 0.112, i.e. price differences between these countries are higher than domestic price differences by respectively 6.2% and 11.8%. By contrast, the average border effect between other countries is 0.287, which corresponds to a price difference of 33.2%. Second, in line with the level of

[19] When within-country price differentials are similar, the lower bound is close to the upper bound, as in the case for example for Tanzania-Malawi. In contrast, large differences between lower and upper bounds reveal heterogeneity of within-country price differences. In this case, border coefficients reflect both heterogeneity in price variability between the countries and the costs associated with crossing the border.

"depth" of the agreements documented in Section 3.3, trade impediments between EAC countries are lower than between countries in SADC. In EAC, Tanzania-Kenya and Tanzania-Rwanda have among the highest estimated border effects, of respectively 15.6% and 18%. This is likely to be due both to the border impediment at the border but also to the relatively good domestic integration of Tanzania. Among SADC countries, Malawi and Mozambique are relatively better integrated while border impediments are relatively higher between Zambia and Mozambique and Zambia and Malawi. Finally, among the other countries, there is substantial heterogeneity between border effects. Not surprisingly, Somalia is the least regionally integrated country (the average border effects as well as the lower bounds with Djibouti and Ethiopia are among the highest). Sudan-Ethiopia and Zambia-Congo are the two other country-pairs with very high border effects that are accurately measured.

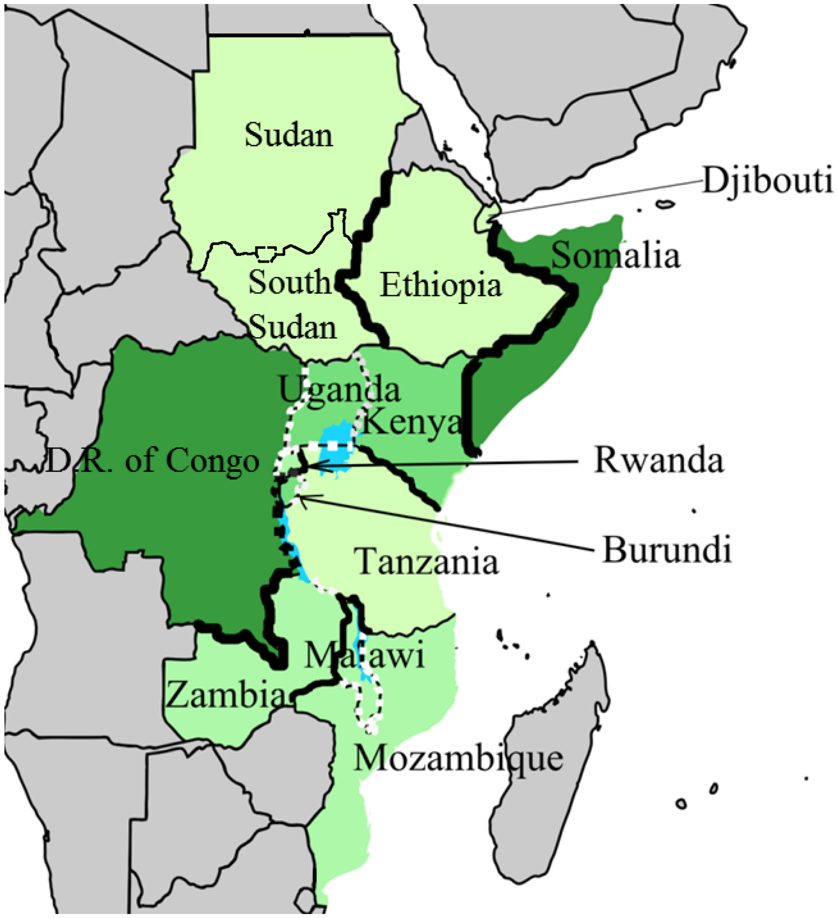
Table 5: Border effects and Regional Trade agreements.

Country pairs	**Border coeff***	**Average border effect****	**[Lower bound;*****	**Upper bound]*****
	(1)	(2)	(3)	(4)
EAC				
Tanzania-Burundi	0.0753 $^{a/}$	-0.026	-0.069 $^{b/}$	0.017
Uganda-Kenya	0.119 $^{a/}$	0.003	-0.004	0.009
Uganda-Rwanda	0.104 $^{a/}$	0.011	-0.019	0.041
Rwanda-Burundi	0.164 $^{a/}$	0.061 $^{a/}$	0.020	0.101 $^{a/}$
Tanzania-Kenya	0.229 $^{a/}$	0.145 $^{a/}$	0.119 $^{b/}$	0.170 $^{a/}$
Tanzania-Rwanda	0.226 $^{a/}$	0.165 $^{a/}$	0.163 $^{b/}$	0.167 $^{a/}$
Average EAC	**0.153**	**0.060**	**0.035**	**0.084**
SADC				
Malawi-Mozambique	0.0655 $^{a/}$	0.004	0.003	0.005
Zambia-Tanzania	0.179 $^{b/}$	0.118	0.116	0.120
Tanzania-Malawi	0.183 $^{a/}$	0.123 $^{a/}$	0.121 $^{b/}$	0.124 $^{a/}$
Zambia-Malawi	0.204 $^{a/}$	0.141 $^{a/}$	0.141 $^{b/}$	0.142 $^{a/}$
Zambia-Mozambique	0.238 $^{a/}$	0.176 $^{a/}$	0.175 $^{b/}$	0.177 $^{a/}$
Average SADC	**0.174**	**0.112**	**0.111**	**0.114**
Others				
Uganda-DRC	0.210 $^{a/}$	-0.038	-0.163 $^{b/}$	0.087
Rwanda- DRC	0.261 $^{a/}$	0.043	-0.112 $^{b/}$	0.198 $^{a/}$
DRC -Burundi	0.309 $^{a/}$	0.051 $^{c/}$	-0.064	0.165 $^{a/}$
Tanzania- DRC	0.329 $^{a/}$	0.113 $^{b/}$	-0.044	0.270 $^{a/}$
Sudan-Ethiopia	0.256 $^{a/}$	0.205 $^{a/}$	0.197 $^{b/}$	0.212 $^{a/}$
Somalia-Kenya	0.569 $^{a/}$	0.356 $^{a/}$	0.252 $^{b/}$	0.459 $^{a/}$
Somalia-Djibouti	0.611 $^{a/}$	0.453 $^{a/}$	0.294 $^{c/}$	0.611 $^{a/}$
Somalia-Ethiopia	0.699 $^{a/}$	0.511 $^{a/}$	0.382 $^{b/}$	0.640 $^{a/}$
Zambia- DRC	1.112 $^{a/}$	0.894 $^{a/}$	0.739 $^{b/}$	1.049 $^{a/}$
Average others	**0.484**	**0.287**	**0.165**	**0.410**

Significance levels are: $^{a/}$p<0.01, $^{b/}$ p<0.05, $^{c/}$ p<0.1. Notes 1 :* compared to DJI-DJI. On each row with a pair of countries, figures in column 1 report coefficients estimates of equation (0.1) on the dummy $B_{country1-country2}$ (when the dummy $D_{Djibouti-Djibouti}$ is omitted). ** compared to average market integration within countries on each side of the border reported in table 4. ***columns (3) reports the difference between the border coefficient of column (1) and the domestic coefficient in table 4 of the country of one side of the border which has the lowest coefficient. Similarly, column (4) reports the difference between the border coefficient of column (1) and the domestic coefficient in table 4 of the country of one side of the border which has the highest coefficient. Note 2 : The regression used to build this table has the following properties: (i) the dependent variable is the absolute value of the log of good relative prices (ii) there are 68'821 observations, (iii) the R-squared is of 0.509, (iv) standard errors are clustered by city-pair, (v) right hand side variables are the road length taken in logarithm, the roads' quality index, 12 country dummies (one for each country except Djibouti) and 20 dummies for pairs of contiguous countries, a constant, 315 interaction town-product dummies, 48 interaction month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). Coefficients on city-product dummies are constrained to sum to zero for each country in order to properly estimate the border coefficients (see Gorodnichenko and Tesar, 2009). All results of these regressions are shown in table A.1 of the Appendix.

Figure 1 shows on a map the extent of domestic and cross border impediments to market integration in the East and Central African region. The color of a country reflects the relative level of domestic impediments to market integration, from the lightest and best integrated (Djibouti, Sudan) to the darkest and least integrated (DRC, Somalia). The thickness of the borders illustrates the magnitude of the border effects and takes into account the accuracy of measure. The thick solid borders represent border effects with positive and significant lower bounds. The thick and dotted lines show borders where the average border effect is positive but where the lower bounds are not significant or negative (which means that we cannot distinguish between the real border effect and the country heterogeneity effect). In that case, the amplitude of the border effects is indeterminate. Finally, thin white dotted lines denote borders where the average estimated effect is insignificant, which means that we do not find substantial higher impediment to trade between than within countries for the three staple goods considered in this paper.

Figure 1: A map of market integration and border effects of the east and central Africa region.



Note: Green tones indicate the level of domestic market integration after having controlled for distance and road quality; the lightest being the most integrated and the darkest the least. The thickness of the border indicates the magnitude of estimated border effects. Thick solid black borders are high positive border effects from the perspective of countries on each side of the border, others solid black borders are positive border effects from the perspective of countries on each side of the border, dashed black borders are positive border effects but with a lowest bound not significant and the white dashed borders correspond average border effects which are not significant.

5. Food Security and Market Integration

In this section, we examine the link between the estimates of the impediments to market integration and measures of food security. We use the estimated coefficients reported in column 2 of Table 4 (the "domestic impediments") as indexes for market integration in each country. In addition, we use both the simple average of the estimated border effects reported in column 1 of Table 5 (the "Cross border impediment") as measures of constraints on cross-border integration. Table A.2 in the Appendix shows descriptive statistics of these indicators. The higher the value of the indicator, the lower is the level of market integration.

Then, we simply examine correlations between these indicators and the level of prevalence of food insufficiency defined by FAO measures for the year 2009. Unfortunately, the indicator of food insufficiency is not available for Sudan.

Table 6: Correlations between impediments to market integration and food insufficiency.

	Domestic impediment	Cross border impediment	food insufficiency.
Domestic impediment	1.0000		
Cross border impediment	0.3296	1.0000	
food insufficiency	0.5428	0.2216	1.0000

Source: Authors' calculations

Table 6 reports the correlation coefficients between the measure of prevalence of food insufficiency and the indicators of impediments to market integration. First, the indicator of domestic impediments to market integration and the indicator of cross border impediments are positively correlated. This means that countries with relatively low impediments to domestic integration are also, on average, the countries with lowest barriers to integration with neighbors.

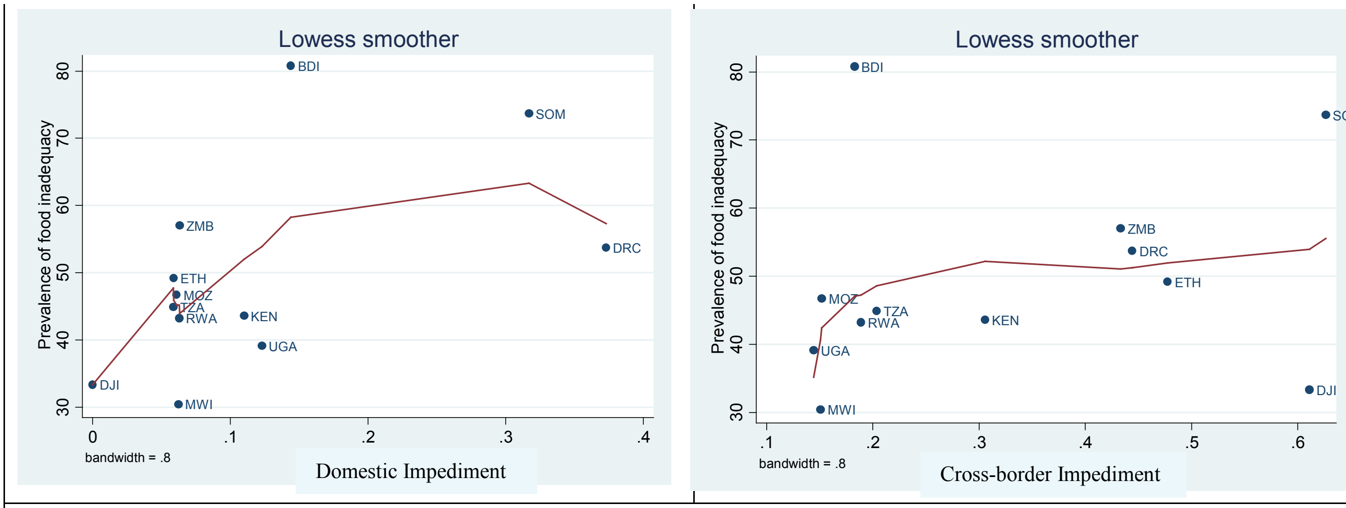
Second, the table confirms a negative association between barriers to market integration and food security. For example, the "domestic impediment" index is positively associated with the prevalence of food insufficiency. A positive but lower correlation is found between the food security variable and the impediments to market integration at the border.

Figure 2 shows the relationship between the prevalence of food insufficiency and the estimated impediments to domestic market integration (Figure 2a) and the estimated impediments to cross border market integration (Figure 2b). In both figures there is a positive correlation between prevalence of food insufficiency and levels of domestic and cross border impediments to market integration. In figure 2(a), the countries with the most integrated markets, Djibouti and Malawi, have the lowest levels of food insufficiency. Thus, this provides some evidence that countries in the region with more integrated markets both domestically and internationally have lower problems of food insecurity than less integrated countries: lack of market integration impedes the provision of sufficient amounts of food.[20]

Figure 2: Food security and domestic and cross border market integration.

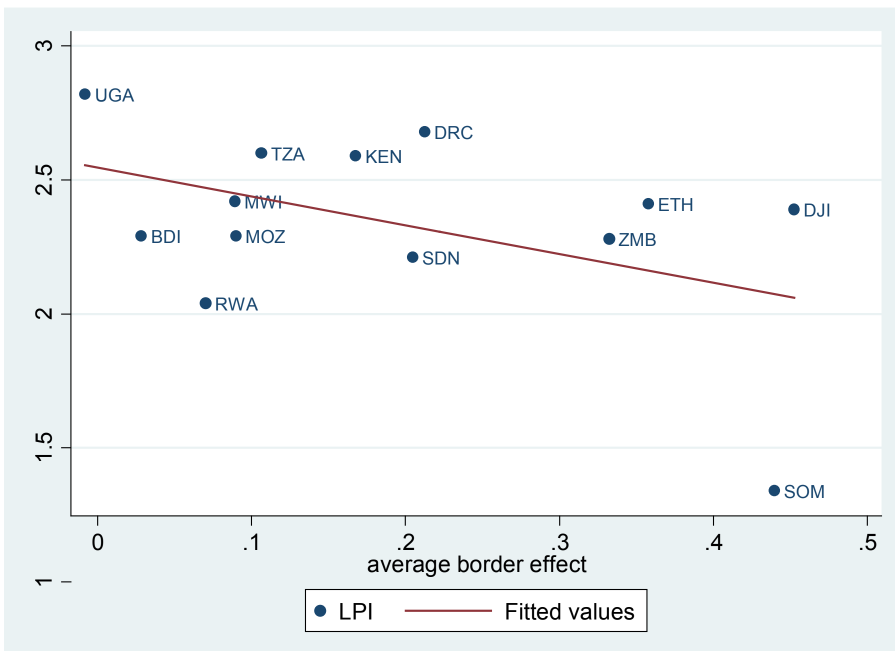
(a) Prevalence of food insufficiency and domestic integration.	(b) Prevalence of food insufficiency and cross-border integration.

[20] These simple correlations while illustrative do not reveal causal relationships. There may be omitted variables (such as conflict and the amount of government revenues) which could determine simultaneously both the level of nourishment and the level of market integration.



Note: The line is a semi-parametric estimation of the relationship between the prevalence of undernourishment (respectively the prevalence of food insufficiency) and our indicator of domestic impediments to market integration.

Figure 3: Logistic Performance Index and border effects.



Note: LPI values are for 2010 (except for Malawi and Burundi for which LPI values are from 2007 given that data for 2010 is not available).

Finally, we examine the relationship between our estimates of border effect and the Logistics Performance Index (LPI), which reflects perceptions of a country's logistics based on efficiency of customs clearance process, quality of trade- and transport-related infrastructure, ease of arranging competitively priced shipments, quality of logistics services, ability to track and trace consignments, and frequency with which shipments reach the consignee within the scheduled time. The LPI is constructed by the World Bank and ranges from 1 to 5, with a higher score representing better performance. Figure 3 confronts the LPI with our estimates of the average border effects reported in column 2 of Table 5 and shows a negative relationship as countries with poorer logistics performance also have thicker borders.

6. Conclusions

This paper seeks to contribute to the literature on the importance of policy and infrastructure constraints affecting the capacity of countries to trade food across borders in Africa. While there is enormous opportunity for trade within countries and across borders between food surplus and food deficit areas, such potential is undermined by barriers to trade along the whole value chain (World Bank, 2012).

We evaluate the relative impact of distance, road quality and domestic and cross-border impediments to market integration for 13 countries in the East and Central African region and for three key agricultural commodities, maize, rice and sorghum. To do this we assess the extent to which road infrastructure, domestic constraints and international borders explain deviations from the absolute Law of One Price (LOP) between 150 towns of the region. The results suggest that distance and road quality between towns impede market integration. Moreover, levels of domestic market integration are heterogeneous among countries and cross-border effects are substantial. On average in the region, distance increases price differences between countries by 42% and, after controlling for distance, price differences are more than 7% larger between than within countries. Countries that are members to the same regional trade agreement are relatively more integrated which suggests a positive impact from trade liberalization on food market integration. Finally, countries with high domestic and cross-border impediments to market integration tend to experience more problems with food security. In terms of policy, there is substantial heterogeneity in terms of market integration between countries of East and Central Africa.

This paper has shown that removing barriers related to distance, decreasing transport costs and implementing regional trade agreements are appropriate instruments to improve market integration and food security. The findings support policy efforts in tackling border impediments −such as reforming customs, simplifying non-tariff measures, addressing corruption− improving the quality of roads, deepening regional trade agreements, and other measures aiming at lowering international and domestic transaction costs in order to improve food security. Barriers to trade of food products are likely to hurt the poor disproportionately, as food is a larger component of the poor's consumption basket (World Bank report, 2012; Hoering, 2013). Moreover measures to reduce transactions costs at the border, particularly in fragile states could have a large payoff in terms of facilitating trade in food products across markets.

The Africa Infrastructure Country Diagnostic study (World Bank, 2010) found a deficit across all the key core infrastructure, transport, telecommunications and energy. Clearly, there is a need to scale up the levels of investment in trade related infrastructure. Though road infrastructure along the major international trade corridors is increasingly in fair to good condition, the same is not the case on the intra-regional links which require much greater attention in discussions about filling the infrastructure gap in Africa.

Attention could be also focused on removing policy constraints that impact both the movement of goods within countries and on trade across borders, such as lack of competition in the provision of transport and logistics services. In many African countries, transport cartels are still dominant and the cost of transportation is very high compared to other regions. We found that countries with poorer logistics performance, as measured with the LPI, also tend to have thicker borders. Measures that improve the availability of information on prices both within and across countries could also have an important impact on reducing differences in the relative price of food in different markets.

Finally, the approach adopted here could be useful in identifying the impact of these specific measures to reduce policy constraints to trade. For example, if procedures at the border are improved we should expect to see a decline in relative prices between markets on either side of the border.

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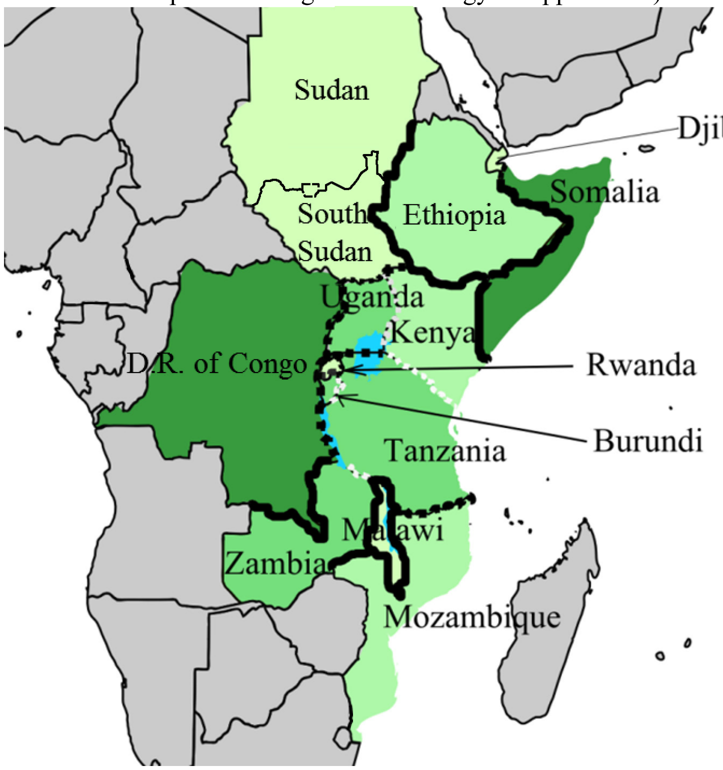
Appendix A: Other Tables and Figures

Figure A. 1: A map of market integration and border effects of the east and central Africa region (with full corrected sample according to methodology in Appendix C).



Note: Green tones indicate the level of domestic market integration after having controlled for distance and road quality; the lightest being the most integrated and the darkest the least. The thickness of the border indicates the amplitude of the border effects. Solid black border are positive border effects from the perspective of each country, dashed black borders are positive border effects but with a lowest bound not significant and the white dashed borders correspond to not significant average border effects.

Table A. 1: Relative prices, domestic and cross border market integration.
Panel regression over monthly relative prices, May 2008-September 2009.

	(1)	(2)	(3)	(4)	(5)	(6)
	All goods (Maize, Rice and Sorgum)			Maize	Rice	Sorghum
VARIABLES	$\|\ln(P_{ikt}/P_{jkt})\|$	$\|\ln(P_{ikt}/P_{jkt})\|$	$\|\ln(P_{ikt}/P_{jkt})\|$	$\|\ln(P_{ikt}/P_{jkt})\|$	$\|\ln(P_{ikt}/P_{jkt})\|$	$\|\ln(P_{ikt}/P_{jkt})\|$
lnRoad_Length	0.0330***	0.0370***	0.0370***	0.0358***	0.0483***	0.0218***
	(0.00396)	(0.00512)	(0.00512)	(0.00830)	(0.00654)	(0.00447)
Road_quality		-0.0315***	-0.0314***	-0.0501*	-0.0297**	-0.00615
		(0.0119)	(0.0119)	(0.0256)	(0.0137)	(0.0111)
$\|\Delta \ln ER_{ijt}\|$			0.0953*			
			(0.0509)			
bd_DRCBDI	0.315***	0.309***	0.304***	0.441***	0.146***	
	(0.0220)	(0.0230)	(0.0234)	(0.0340)	(0.0231)	
bd_MWIMOZ	0.0685***	0.0655***	0.0646***	0.0150	0.0757***	
	(0.0166)	(0.0178)	(0.0178)	(0.0221)	(0.0232)	
bd_RWABDI	0.162***	0.164***	0.163***	0.143***	0.202***	-0.00933
	(0.0135)	(0.0146)	(0.0146)	(0.0237)	(0.0160)	(0.0496)
bd_RWADRC	0.269***	0.261***	0.257***	0.354***	0.145***	
	(0.0205)	(0.0217)	(0.0219)	(0.0329)	(0.0211)	
bd_SDNETH	0.286***	0.256***	0.253***			0.193***
	(0.0674)	(0.0676)	(0.0676)			(0.0746)

bd_SOMDJI	0.628***	0.611***	0.610***		0.615***	
	(0.155)	(0.154)	(0.154)		(0.127)	
bd_SOMETH	0.709***	0.699***	0.697***	0.465***		0.720***
	(0.0679)	(0.0676)	(0.0676)	(0.0374)		(0.0981)
bd_SOMKEN	0.574***	0.569***	0.567***	0.404***		
	(0.0474)	(0.0470)	(0.0471)	(0.0378)		
bd_TZABDI	0.0812***	0.0753***	0.0740***	-0.0358	0.0283	
	(0.0214)	(0.0220)	(0.0221)	(0.0387)	(0.0220)	
bd_TZADRC	0.338***	0.329***	0.324***	0.397***	0.0925**	
	(0.0444)	(0.0453)	(0.0454)	(0.0669)	(0.0444)	
bd_TZAKEN	0.228***	0.229***	0.227***	0.275***		
	(0.0314)	(0.0321)	(0.0322)	(0.0329)		
bd_TZAMWI	0.186***	0.183***	0.182***	0.243***	0.0981***	
	(0.0245)	(0.0252)	(0.0253)	(0.0268)	(0.0379)	
bd_TZARWA	0.228***	0.226***	0.224***	0.0800**	0.190***	
	(0.0196)	(0.0203)	(0.0204)	(0.0369)	(0.0201)	
bd_UGADRC	0.221***	0.210***	0.205***	0.257***		
	(0.0655)	(0.0659)	(0.0659)	(0.0682)		
bd_UGAKEN	0.120***	0.119***	0.116***	0.0887***		0.0142
	(0.0235)	(0.0246)	(0.0247)	(0.0263)		(0.0533)
bd_UGARWA	0.106***	0.104***	0.101***	0.0641**		0.0527
	(0.0213)	(0.0223)	(0.0224)	(0.0249)		(0.0523)
bd_ZMBDRC	1.117***	1.112***	1.107***	1.177***		
	(0.164)	(0.164)	(0.164)	(0.155)		
bd_ZMBMOZ	0.244***	0.238***	0.234***	0.197***		
	(0.0383)	(0.0392)	(0.0393)	(0.0403)		
bd_ZMBMWI	0.206***	0.204***	0.200***	0.175***		
	(0.0395)	(0.0399)	(0.0400)	(0.0416)		
bd_ZMBTZA	0.184**	0.179**	0.175**	0.224***		
	(0.0828)	(0.0844)	(0.0844)	(0.0834)		
D_BDIBDI	0.142***	0.144***	0.144***	0.129***	0.0899***	0.0642
	(0.0140)	(0.0151)	(0.0151)	(0.0268)	(0.0169)	(0.0505)
D_DJIDJI	**(omitted)**	**(omitted)**	**(omitted)**		**(omitted)**	
D_DRCDRC	0.391***	0.373***	0.373***	0.522***	0.173***	
	(0.0315)	(0.0332)	(0.0332)	(0.0559)	(0.0285)	
D_ETHETH	0.0743**	0.0589*	0.0586*	**(omitted)**		**(omitted)**
	(0.0307)	(0.0324)	(0.0324)			
D_KENKEN	0.107***	0.110***	0.110***	0.0771***		0.00791
	(0.0243)	(0.0256)	(0.0256)	(0.0283)		(0.0550)
D_MOZMOZ	0.0599***	0.0610***	0.0612***	0.0479**	0.0321	
	(0.0169)	(0.0182)	(0.0182)	(0.0243)	(0.0237)	
D_MWIMWI	0.0601***	0.0623***	0.0624***	0.0363	0.0462**	
	(0.0148)	(0.0158)	(0.0158)	(0.0237)	(0.0195)	
D_RWARWA	0.0588***	0.0628***	0.0626***	0.119***	0.0126	-0.0911*
	(0.0133)	(0.0146)	(0.0146)	(0.0271)	(0.0163)	(0.0504)
D_SDNSDN	0.0514***	0.0437**	0.0428**			-0.0501
	(0.0156)	(0.0172)	(0.0172)			(0.0487)
D_SOMSOM	0.318***	0.317***	0.316***	0.0335	0.311***	0.373***
	(0.0492)	(0.0490)	(0.0490)	(0.0329)	(0.0755)	(0.0832)
D_TZATZA	0.0688***	0.0586***	0.0587***	0.164***	-0.0403**	
	(0.0154)	(0.0172)	(0.0172)	(0.0194)	(0.0195)	
D_UGAUGA	0.128***	0.123***	0.123***	0.124***		-0.0347
	(0.0362)	(0.0372)	(0.0372)	(0.0468)		(0.0541)
D_ZMBZMB	0.0654*	0.0631*	0.0633*	0.0304		
	(0.0361)	(0.0366)	(0.0366)	(0.0379)		
Constant	-0.0406*	-0.0368	-0.0359	0.0199	-0.0957***	0.136**
	(0.0243)	(0.0257)	(0.0257)	(0.0477)	(0.0335)	(0.0572)
Observations	68,821	68,821	68,821	25,468	26,280	17,073

Robust standard errors in parentheses are clustered by city-pair. Significance levels are: *** p<0.01, ** p<0.05, * p<0.1. In columns (1)-(3), regressions include 315 interaction terms for town-product dummies and 48 interaction terms for month-product dummies (‘May2008 x Maize’, ‘May2008 x Rice’ and ‘May2008 x Sorghum’ are dropped). In columns (4)-(6), regressions include town dummies and month dummies ('May2008' being omitted). In columns (1)-(3) and (5), coefficients on country and border dummies are estimated with respect to Djibouti which is the omitted country. In column (4) and (6) the omitted country-dummy is Ethiopia (as there are no observation for Djibouti for Maize and Sorghum). Coefficients on city-product dummies in column (1)-(3) and on city dummies in columns (4) to (6) are constrained to sum to zero for each country in order to avoid multi-colinearities (see Gorodnichenko and Tesar, 2009). The results in column (2) have been used to build tables 4 and 5 in the main text.

Table A.2.: Summary statistics of integration indexes.

Variable	Obs	Mean	Std. Dev.	Min	Max
Domestic impediment	13	0.11	0.11	0	0.373
Cross border impediment	13	0.32	0.18	0.14	0.63

Table A. 2: Border coefficients, distance and price stickiness, average effect in the region (uncorrected sample). (Corrected full sample with methodology detailed in Appendix C)

	All products (Maize-Rice-Sorghum)				Maize	Rice	Sorghum
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$
lnRoad_Length	0.0850***	0.0829***	0.0480***	0.0477***	0.0604***	0.0440***	0.0396***
	(0.00473)	(0.00454)	(0.00472)	(0.00468)	(0.00911)	(0.00386)	(0.00845)
Road_quality		-0.0714***	-0.0580***	-0.0559***	-0.0745***	0.00794	-0.132***
		(0.00891)	(0.00867)	(0.00859)	(0.0172)	(0.00747)	(0.0220)
border			0.0964***	0.0870***	0.125***	0.0881***	0.0594***
			(0.00533)	(0.00506)	(0.0109)	(0.00462)	(0.00942)
$\lvert\Delta \ln ER_{ijt}\rvert$				0.362***			
				(0.0453)			
Constant	-0.0192	0.0560	0.233**	0.244**	0.287***	-0.0443	0.197**
	(0.104)	(0.0986)	(0.0967)	(0.0977)	(0.0987)	(0.0534)	(0.0796)
Town-Product dummies	Yes	Yes	Yes	Yes	No	No	No
Month-Product fixed effects	Yes	Yes	Yes	Yes	No	No	No
Town dummies	No	No	No	No	Yes	Yes	Yes
Month fixed effects	No	No	No	No	Yes	Yes	Yes
Observations	106,963	106,963	106,963	106,963	43,981	42,779	20,203
R-squared	0.649	0.650	0.658	0.658	0.648	0.506	0.554

Note: Robust standard errors in parentheses are clustered by city-pair. Significance levels are: *** p<0.01, ** p<0.05, * p<0.1. In columns (1)-(4), regressions include 314 interaction terms for town-product dummies ('Ngozi x Maize' being dropped) and 48 interaction terms for month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). In columns (5)-(7), regressions include only town and month dummies because the regression are by product. The coefficients on the border dummy in this table have to be interpreted with respect to the average price correlation within-countries in the sample (the omitted dummy).

Table A. 3: Relative prices, domestic and cross border market integration. Panel regression over monthly relative prices, May 2008-September 2009. (Corrected full sample with methodology detailed in Appendix C)

VARIABLES	(1) $\|\ln(P_{ikt}/P_{jkt})\|$	(2) $\|\ln(P_{ikt}/P_{jkt})\|$	(3) $\|\ln(P_{ikt}/P_{jkt})\|$
lnRoad_Length	0.0476***	0.0478***	0.0478***
	(0.00468)	(0.00460)	(0.00460)
Road_quality		-0.0624***	-0.0623***
		(0.00883)	(0.00883)
$\left\|\Delta \ln ER_{ijt}\right\|$			0.200***
			(0.0334)
B_DRCBDI	0.407***	0.384***	0.374***
	(0.0146)	(0.0163)	(0.0164)
B_KENETH	0.310***	0.300***	0.292***
	(0.0200)	(0.0207)	(0.0206)
B_MWIMOZ	0.125***	0.133***	0.131***
	(0.0151)	(0.0156)	(0.0155)
B_RWABDI	0.145***	0.150***	0.148***
	(0.0107)	(0.0117)	(0.0117)
B_RWADRC	0.323***	0.297***	0.287***
	(0.0133)	(0.0154)	(0.0154)
B_SDNETH	0.190***	0.180***	0.175***
	(0.0200)	(0.0206)	(0.0206)
B_SDNKEN	0.174***	0.154***	0.148***
	(0.0282)	(0.0285)	(0.0285)
B_SOMDJI	0.280***	0.272***	0.271***
	(0.0265)	(0.0265)	(0.0265)
B_SOMETH	0.621***	0.601***	0.597***
	(0.0253)	(0.0259)	(0.0259)
B_SOMKEN	0.536***	0.528***	0.523***
	(0.0250)	(0.0256)	(0.0256)
B_TZABDI	0.132***	0.111***	0.108***
	(0.0149)	(0.0163)	(0.0163)
B_TZADRC	0.402***	0.389***	0.379***
	(0.0170)	(0.0183)	(0.0183)
B_TZAKEN	0.136***	0.143***	0.138***
	(0.0196)	(0.0200)	(0.0200)
B_TZAMOZ	0.125***	0.131***	0.128***
	(0.0171)	(0.0174)	(0.0174)
B_TZAMWI	0.167***	0.171***	0.168***
	(0.0148)	(0.0154)	(0.0154)
B_TZARWA	0.163***	0.151***	0.148***
	(0.0140)	(0.0153)	(0.0153)
B_UGADRC	0.415***	0.404***	0.394***
	(0.0222)	(0.0231)	(0.0232)
B_UGAKEN	0.131***	0.138***	0.131***
	(0.0171)	(0.0180)	(0.0180)
B_UGARWA	0.147***	0.156***	0.149***
	(0.0146)	(0.0151)	(0.0151)
B_UGASDN	0.219***	0.183***	0.176***
	(0.0211)	(0.0230)	(0.0229)
B_UGATZA	0.185***	0.192***	0.186***

	(0.0287)	(0.0290)	(0.0290)
B_ZMBDRC	0.627***	0.614***	0.604***
	(0.0186)	(0.0201)	(0.0202)
B_ZMBMOZ	0.223***	0.231***	0.223***
	(0.0167)	(0.0171)	(0.0171)
B_ZMBMWI	0.212***	0.220***	0.210***
	(0.0148)	(0.0153)	(0.0154)
B_ZMBTZA	0.167***	0.173***	0.166***
	(0.0234)	(0.0237)	(0.0237)
D_BDIBDI	0.130***	0.129***	0.128***
	(0.0111)	(0.0121)	(0.0121)
D_DJIDJI	**(omitted)**	**(omitted)**	**(omitted)**
D_DRCDRC	0.406***	0.370***	0.370***
	(0.0217)	(0.0238)	(0.0238)
D_ETHETH	0.102***	0.0893***	0.0880***
	(0.0192)	(0.0199)	(0.0198)
D_KENKEN	0.0921***	0.103***	0.102***
	(0.0230)	(0.0236)	(0.0236)
D_MOZMOZ	0.0626***	0.0711***	0.0714***
	(0.0148)	(0.0154)	(0.0154)
D_MWIMWI	0.0497***	0.0566***	0.0569***
	(0.0145)	(0.0155)	(0.0155)
D_RWARWA	0.0401***	0.0447***	0.0439***
	(0.0102)	(0.0114)	(0.0114)
D_SDNSDN	0.0225	0.0240	0.0213
	(0.0168)	(0.0171)	(0.0171)
D_SOMSOM	0.371***	0.376***	0.375***
	(0.0347)	(0.0341)	(0.0341)
D_TZATZA	0.119***	0.113***	0.113***
	(0.0201)	(0.0207)	(0.0207)
D_UGAUGA	0.142***	0.136***	0.135***
	(0.0501)	(0.0524)	(0.0523)
D_ZMBZMB	0.147***	0.157***	0.157***
	(0.0220)	(0.0225)	(0.0224)
Constant	-0.0947***	-0.0461*	-0.0427*
	(0.0254)	(0.0239)	(0.0239)
Observations	106,963	106,963	106,963

Robust standard errors in parentheses are clustered by city-pair. Significance levels are: *** p<0.01, ** p<0.05, * p<0.1. These regressions include 304 interaction terms for town-product dummies and 48 interaction terms for month-product dummies (‘May2008 x Maize’, ‘May2008 x Rice’ and ‘May2008 x Sorghum’ are dropped). Coefficients on city-product dummies are constrained to sum to zero for each country in order to avoid multi-colinearities (see Gorodnichenko and Tesar, 2009). The results in column (2) have been used to build tables A.5 and A.6.

Table A. 4: Domestic Impediments to market integration (country are ranked from the one with the lowest to the one with the highest impediments). (Corrected full sample with methodology detailed in Appendix C)

Country	**Domestic impediments**
(1)	(2)
Djibouti	0
Sudan	0.021
Rwanda	0.044 [a/]
Malawi	0.057 [a/]
Mozambique	0.071 [a/]
Ethiopia	0.088 [a/]
Kenya	0.102 [a/]
Tanzania	0.113 [a/]
Burundi	0.128 [a/]
Uganda	0.135 [a/]
Zambia	0.157 [a/]
DRC	0.370 [a/]
Somalia	0.375 [a/]

Significance levels are: [a/]$p<0.01$, [b/] $p<0.05$, [c/] $p<0.1$. Notes 1 Figures in column 2 report coefficients estimates of equation (0.1) on the dummy $D_{country\text{-}country}$ (when the dummy $D_{Djibouti\text{-}Djibouti}$ is omitted). Note 2 : The regression used to build this table has the following properties: (i) the dependent variable is the absolute value of the log of good relative prices (ii) there are 106,963 observations, the R-squared is of 0.669, (iv) standard errors are clustered by city-pair, (v) right hand side variables are the road length taken in logarithm, the roads' quality index, 12 country dummies (one for each country except Djibouti) and 25 dummies for pairs of contiguous countries, a constant, 304 interaction town-product dummies ('Ngozi x Maize' being dropped), 48 interaction month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). Coefficients on city-product dummies are constrained to sum to zero for each country in order to properly estimate the border coefficients (see Gorodnichenko and Tesar, 2009). All results of these regressions are in table A.4.

Table A. 5: Border effects and Regional Trade agreements. (Corrected full sample with methodology detailed in Appendix C)

Country pairs	**Border coeff***	**Average border effect****	**[Lower bound***;**	**Upper bound***]**
	(1)	(2)	(3)	(4)
EAC				
Uganda-Kenya	0.131 a/	0.013	-0.004	0.029
Tanzania-Kenya	0.138 a/	0.031	0.025	0.036
Uganda-Tanzania	0.186 a/	0.062 c/	0.051	0.073 b/
Tanzania-Burundi	0.108 a/	-0.013	-0.02	-0.005
Uganda-Rwanda	0.149 a/	0.060 a/	0.014	0.105 a/
Rwanda-Burundi	0.148 a/	0.062 a/	0.02	0.104 a/
Tanzania-Rwanda	0.148 a/	0.070 a/	0.035	0.104 a/
Average EAC5=EAC3+EAC+	**0.144**	**0.041**	**0.017**	**0.064**
SADC				
Zambia-Tanzania	0.166 a/	0.031	0.009	0.053 c/
Tanzania-Mozambique	0.128 a/	0.036 c/	0.015	0.057 b/
Malawi-Mozambique	0.131 a/	0.067 a/	0.060 a/	0.074 a/
Tanzania-Malawi	0.168 a/	0.083 a/	0.055 b/	0.111 a/
Zambia-Malawi	0.210 a/	0.103 a/	0.053 c/	0.153 a/
Zambia-Mozambique	0.223 a/	0.109 a/	0.066 b/	0.152 a/
Average SADC	**0.171**	**0.071**	**0.043**	**0.100**
Others				
Rwanda-Congo DRC	0.287 a/	0.080 a/	-0.083 a/	0.243 a/
Somalia-Djibouti	0.271 a/	0.084 a/	-0.104 b/	0.271 a/
Sudan-Kenya	0.148 a/	0.086 a/	0.046	0.127 a/
Uganda-Sudan	0.176 a/	0.098 a/	0.041	0.155 a/
Sudan-Ethiopia	0.175 a/	0.120 a/	0.087 a/	0.154 a/
DRC-Burundi	0.374 a/	0.125 a/	0.004	0.246 a/
Kenya-Ethiopia	0.292 a/	0.197 a/	0.19 a/	0.204 a/
Tanzania-DRC	0.379 a/	0.138 a/	0.009	0.266 a/
Uganda-DRC	0.394 a/	0.142 a/	0.024	0.259 a/
Somalia-Kenya	0.523 a/	0.285 a/	0.148 a/	0.421 a/
Zambia-DRC	0.604 a/	0.341 a/	0.234 a/	0.447 a/
Somalia-Ethiopia	0.597 a/	0.366 a/	0.222 a/	0.509 a/
Average others	**0.352**	**0.172**	**0.068**	**0.275**

Significance levels are: a/ $p<0.01$, b/ $p<0.05$, c/ $p<0.1$. Notes 1 :* compared to DJI. On each row with a pair of countries, figures in column 1 report coefficients estimates of equation (0.1) on the dummy $B_{country1\text{-}country2}$ (when the dummy $D_{Djibouti\text{-}Djibouti}$ is omitted). ** compared to average market integration within countries on each side of the border reported in table A.5, *** columns (3) reports the difference between the border coefficient of column (1) and the domestic coefficient in table A.5 of the country of one side of the border which has the lowest coefficient. Similarly, column (4) reports the difference between the border coefficient of column (1) and the domestic coefficient in table A.5 of the country of one side of the border which has the highest coefficient. Note 2 : The regression used to build this table has the following properties: (i) the dependent variable is the absolute value of the log of good relative prices (ii) there are 106,963 observations, (iii) the R-squared is of 0.669, (iv) standard errors are clustered by city-pair, (v) right hand side variables are the road length taken in logarithm, the roads' quality index, 12 country dummies (one for each country except Djibouti) and 25 dummies for pairs of contiguous countries, a constant, 304 interaction town-product dummies, 48 interaction month-product dummies ('May2008 x Maize', 'May2008 x Rice' and 'May2008 x Sorghum' are dropped). Coefficients on city-product dummies are constrained to sum to zero for each country in order to properly estimate the border coefficients (see Gorodnichenko and Tesar, 2009). All results of these regressions are in Table A.4.

Table A. 6: Countries' membership to Regional Trade Agreements

	EAC(CU)	SADC (FTA)	COMESA
Burundi	July 2009		2004
Rwanda	July 2009		2004
Tanzania	2005	2008	
Djibouti			2000
Somalia			
Kenya	2005		2000
Uganda	2005		
DRC		member-not FTA	member-not FTA
Ethiopia			member-not FTA
Malawi		2008	2000
Mozambique		2008	
Zambia		2008	2000
Sudan			2000

Table A. 7: Average tariff between country-pairs (simple average) over Rice, Sorghum and Maize and the period 2008-2009.

RTA	**Country-pairs**	**Average Tariff (2008-2009) (in %)**
Others	Congo-Burundi	
	Kenya-Ethiopia	4.5
	Rwanda-Congo	10
	Sudan-Ethiopia	4.5
	Somalia-Djibouti	
	Somalia- Ethiopia	
	Somalia-Kenya	
	Tanzania-Congo	
	Uganda-Congo	43.75
	Uganda-Sudan	
	Zambia-Congo	7.5
	Sudan-Kenya (COMESA)	0
EAC	Tanzania-Burundi	5
	Rwanda-Burundi	0
	Tanzania-Kenya	0
	Tanzania-Rwanda	2
	Uganda-Kenya	0
	Uganda-Rwanda	0.4
	Uganda-Tanzania	0
SADC	Malawi-Mozambique	0

	Tanzania-Mozambique	
	Tanzania-Malawi	12.5
	Zambia-Mozambique	15
	Zambia-Malawi	0
	Zambia-Tanzania	30

Source: Author calculations based on data from TRAINS.

Table A. 8: Average tariff in the sample (simple average) over Rice, Sorghum and Maize and the period 2008-2009.

RTA	**Product**	**Average Tariff (2008-2009)**
None	Maize	7.38
	Rice	80
	Sorghum	4.5
COMESA	Maize	0
	Rice	0
	Sorghum	
EAC	Maize	0.65
	Rice	0.42
	Sorghum	0.6
SADC	Maize	12.5
	Rice	7.5

Source: Author calculations based on data from TRAINS.

Table A. 9: Net bilateral trade by product, average value over 2008-2009 (000USD)

Maize			Rice			Sorghum		
Exporter	Importer	Net trade	Exporter	Importer	Net trade	Exporter	Importer	Net trade
Congo	Rwanda	96.07	Burundi	Rwanda	53.18	Burundi	Rwanda	1.94
Kenya	Ethiopia	112.89	Djibouti	Somalia	161.76	Djibouti	Somalia	2153.73
Kenya	Somalia	2039.41	Malawi	Mozambique	43.19	Congo	Rwanda	581.66
Mozambique	Malawi	2782.95	Rwanda	Congo	2.16	Ethiopia	Djibouti	66.43
Mozambique	Tanzania	1225.73	Tanzania	Burundi	60.81	Kenya	Ethiopia	479.79
Malawi	Zambia	106.84	Tanzania	Congo	1.27	Kenya	Sudan	312.13
Rwanda	Burundi	5.74	Tanzania	Rwanda	1370.25	Kenya	Somalia	169.31
Tanzania	Burundi	159.41				Mozambique	Malawi	1.72
Tanzania	Kenya	425.03				Sudan	Ethiopia	898.59
Tanzania	Malawi	9.22				Tanzania	Kenya	1829.48
Tanzania	Rwanda	429.31				Tanzania	Malawi	1.04
Uganda	Congo	31.80				Tanzania	Rwanda	172.34
Uganda	Kenya	174.38				Tanzania	Uganda	8.76
Uganda	Rwanda	226.01				Uganda	Kenya	326.67
Uganda	Tanzania	208.15				Uganda	Rwanda	216.42
Zambia	Congo	1739.10				Uganda	Sudan	2841.81
Zambia	Tanzania	2111.81				Zambia	Tanzania	109.19

Source: author computation using baci database for hs6 product (100590 (Maize); 100610, 100620, 100630, 100640 (Rice); and 100700 (Sorghum)).

Table A. 10: Summary of government interventions in staple food markets for some countries.

	Summary of interventions in food markets
Ethiopia	Level of interventions has increased in recent years. Maintained a strategic reserves of 430 thousand tons; large emergency operation, large food aid inflow.
Kenya	Food logistic agency (NCPB) is a dominant player in maize markets, capturing 10-20% of marketed maize. Price setting is unpredictable—sometimes NCPB prices are above import parity and sometimes they're lower than domestic market and government has to force farmers to sell.
Malawi	Has active food logistic agency (ADMARC), a strategic grain reserve programs, and discussion underway to intensify interventions (more details later). Maize export bans and periodic waivers of the import tariff are common. Malawi banned private trade in August of 2008 and then imposed fixed buying and selling prices on the private sector in September 2008.
Mozambique	Low level of government intervention in staple food markets. No active market participation in buying or selling; no price mandates; trade (imports and exports) encouraged usually (some exceptions). WFP Purchase for Progress is active in maize and beans, in addition to other WFP local purchase activities. Import tariff of 17-20% on imported maize, which can be rebated if the buyer mills the grain directly but doesn't resell the grain.
Uganda	Government intervention is low. However, WFP purchase under LRP is high—some years exceeding more than 15 percent of total maize production in the country.
Tanzania	Relatively little intervention in domestic staple food markets. Strategic Grain Reserve has capacity for 150 thousand tons, but usually buys and sells much smaller quantities. Maize can be exported, particularly to the south, but maize exports are banned when there is food insecurity in the country, which is often.
Zambia	Zambia's Food Reserve Agency (FRA) is the single largest players in the country's domestic maize market, purchasing 25% of national production and over 90% of smallholder marketed volumes since 2006. The Zambian government controls trade in maize and wheat through a system of quantitative restrictions regulated under the Control of Goods Act. Both imports and exports require government permits stipulating the allowable quantities traded. In recent years, the Food Reserve Agency has received the bulk of the trading permits for both the import and export of maize. Export bans and periodic waivers of the import tariff are common. Inter-district taxes on grain movement were officially abolished earlier in 2009.

Source: Rahid and Minot (2010).

Table A.12: Border coefficients, distance and price stickiness, average effect in the region.

	All products (Maize-Rice-Sorghum)				Maize	Rice	Sorghum
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	$\lvert\ln(P_{ikt}/P_{jkt})\rvert$
lnRoad_Length	0.0597***	0.0670***	0.0404***	0.0407***	0.0393***	0.0550***	0.0246***
	(0.00473)	(0.00595)	(0.00513)	(0.00516)	(0.00757)	(0.00714)	(0.00520)
Road_quality		-0.0733***	-0.0611***	-0.0619***	-0.0779***	-0.0367**	-0.0581***
		(0.0128)	(0.0119)	(0.0119)	(0.0227)	(0.0154)	(0.0167)
border			0.0768***	0.0733***	0.0528***	0.129***	0.0330***
			(0.00585)	(0.00502)	(0.0113)	(0.00713)	(0.00855)
$\lvert\Delta \ln ER_{ijt}\rvert$				0.210			
				(0.160)			
Constant	0.0290	0.0471*	0.139***	0.139***	0.188***	-0.0905***	0.136***
	(0.0264)	(0.0282)	(0.0232)	(0.0234)	(0.0314)	(0.0321)	(0.0233)
Town-Month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product fixed effects	Yes	Yes	Yes	Yes	No	No	No
Observations	68,821	68,821	68,821	68,821	25,468	26,280	17,073
R-squared	0.462	0.464	0.475	0.475	0.683	0.667	0.670

Note: Robust standard errors in parentheses are clustered by city-pair. Significance levels are: *** p<0.01, ** p<0.05, * p<0.1. The coefficients on the border dummy in this table have to be interpreted with respect to the average price correlation within-countries in the sample (the omitted dummy).

Appendix B: Cleaning of the Database on prices

In our original database, monthly price data for towns are in different units (retail/wholesale, by kg, by tons…). Moreover, price data is sometimes only available for some varieties of a product (e.g. white Maize). We use this data to obtain three variables of monthly towns' products prices:

- "original price": this price variable includes only observations for which the unit of measure is "retail price by kg".
- "new_price": this price variable adds to "original price" the observations for which units have been converted (from tons…) to kg or which correspond to wholesale prices.
- "new2_price": this variable adds to "new_price" the observations for prices of close varieties of the good when the price of the good was not available (for example, we took the price of "White Maize" when the price for "Maize" was not observed).

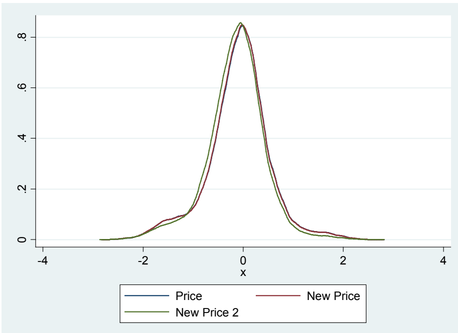
Table B.1: Summary statistics of the price variables.

Variable		Obs	Mean	Std. Dev.	Min	Max
"Original Price" lratio	(1)	115'626	-0.011	0.52	-2.82	2.81
"New_Price" lratio	(2)	134'652	-0.02	0.49	-2.82	2.81
"New2_Price" lratio	(3)	269'369	-0.09	0.52	-2.86	2.81

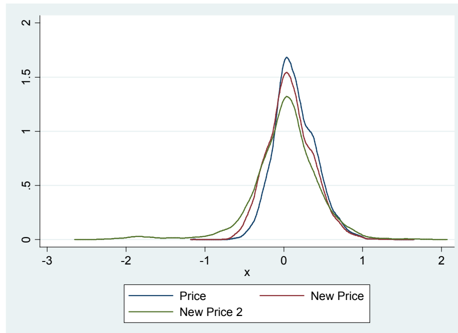
Note: "Price lratio" refer to $\ln\left(\frac{P_{ikt}}{P_{jkt}}\right)$ where P_{ikt} and P_{jkt} are alternatively the "original price" (row (1)), the "new price" (row (2)) and the "new2 price" (row (3)) of good k in city i and j at time t.

Table B. 2: Distribution of price ratios, by good.

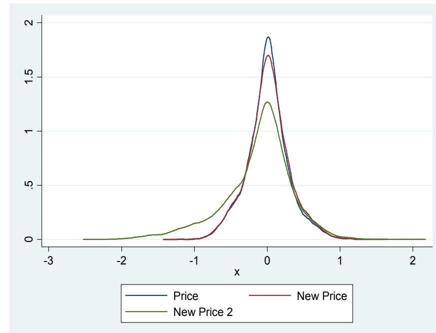
Maize, Kernel by price ratio



Rice, Kernel by price ratio



Sorghum, Kernel by price ratio



In table B.2, the distributions of price ratio are very similar, giving credibility to the conversion and assumptions made to maximize the number of observations. Same figures by countries give similar conclusions. Therefore, we use the variable with the maximum of observations for our measure of relative prices in the paper.

Appendix C: Methodology to remove city pairs with no arbitrage.

Price differences reflect the degree of market integration between cities when there are motivations to trade, i.e. when structural price differences are high enough compared to transport costs (Atkin and Donaldson, 2013). As explained in Section 3, the inclusion in the sample of city-pairs for which the structural price differences are lower than transport costs may lead to an underestimation of impediments to market integration. The majority of papers which study market integration by using price differences do not take into account this problem. In this appendix we try to mitigate this potential bias.

The optimal and easier way to correct for this problem is to identify cities which trade so that there is arbitrage between the prices of their products. Atkin and Donaldson (2013) recently collect novel data on the location of production/importation of products in Ethiopia and Nigeria in order to identify trading city-pairs. However, such data are not available for our thirteen countries. Another way is to compare transport costs of products between cities to price differences and to remove city-pairs where price differences are lower than transport costs. Unfortunately, data on transport costs of products between cities are very scarce.

Zant (2013) face this problem when he studies the market integration between cities in Malawi. As he does not have data on transport costs and trade between cities, he elaborates a strategy to estimate transport costs. First, he identifies cities which have a production surplus and those with a production deficit by comparing the local production with the nutrition requirement of the population. Moreover, he limits the sample to city-pairs relatively close in terms of distance so to increase the likelihood that there is trade between these cities. He then obtains a sub-sample of city pairs between which he can reasonably assume that there is trade. Therefore for these cities price differences should reflect transport costs. Then, he regresses the price differences between cities on potential components of transport costs (e.g. distance). He uses coefficients of this regression to estimate transport costs for all country-pairs of its sample. He then compared price differences with estimated transport costs to determine which towns pairs are in each case (i), (ii) and (iii) of the model presented in Section 3.

We follow the methodology of Zant (2013) and take a sub-sample of city-pairs separated by less than 300km. However, unfortunately, we don't have data on cities' production for Maize, Rice and Sorghum and therefore are not able to identify deficit and surplus areas. We simply assume that city pairs separated by less than 300km have motivations for trade. Regressing price differences of this sub-sample of city-pairs on road length, road quality and product-time fixed effects provided the coefficients needed to estimate transport costs between all city pairs of our initial sample. We then remove from our sample city pairs for which the difference between price gaps and transport costs is negative and sufficiently far from zero (more than a standard deviation of estimated transport costs).

More precisely, we proceed in two steps:

1) Estimation of transport costs:

We keep only city pairs separated by less than 300km (982 city pairs) and estimate the following regression :

$$\ln \tau_{ijkt} = \beta_0 + \delta_{ik} + \delta_{jk} + \delta_{kt} + \beta_1 \ln Road\_Length_{ij} + \beta_2 Road\_quality_{ij} + \varepsilon_{ijkt}$$

with $\ln \tau_{ijkt} = \ln |P_{ikt} - P_{ikt}|$. Table C.1 shows the results.

Table C. 1: Estimation of transport costs

VARIABLES	(1) $\ln\|P_{ikt} - P_{ikt}\|$
ln_road_Length	0.322***
	(0.0365)
Road_quality	-0.477***
	(0.0785)
Constant	-3.936***
	(0.162)
Product-time FE (δ_{kt})	Yes
City-product FE (δ_{ik} and δ_{jk})	Yes
Observations	41,488

Robust standard errors in parentheses are clustered by city-pair.
Significance levels are: *** p<0.01, ** p<0.05, * p<0.1.

2) Identification of city pairs where price differences are lower than transport costs:

We use coefficients of the regression to compute for all city pairs of the full initial sample (4'575 city-pairs) the estimated transport costs:

$$\hat{\tau}_{ijkt} = \exp\left(\hat{\beta}_0 + \hat{\delta}_{kt} + \hat{\beta}_1 \ln Road\_Length_{ij} + \hat{\beta}_2 Road\_quality_{ij}\right)$$
$$= \exp\left(-3.936 + \hat{\delta}_{kt} + 0.322 \ln Road\_Length_{ij} - 0.477 Road\_quality_{ij}\right)$$

We then examine the difference between the price gap and the estimated transport costs for each city pair and drop from the sample city pairs where price differences are sufficiently low compared to the estimated transport costs, i.e. we drop city pairs for which:

- $$\left|P_{ikt} - P_{ikt}\right| - \hat{\tau}_{ijkt} < -sd(\hat{\tau}_{ijkt}) \quad (0.1)$$

where $sd(\hat{\tau}_{ijkt})$ is the standard deviation of the estimated transport costs (equal to 0.066).

In the original sample, (0.1) holds for 27’277 observations. Therefore, we remove these observations from the sample.

Table C.2 below shows descriptive statistics of the main variables used in the paper before and after the correction (i.e. before and after we remove city pairs with no motivation for trade). In line with the logic behind the correction, in the new sample, price differences between cities are slightly higher on average and distance separating towns (road length) are slightly lower (as we removed city pairs where transport costs are higher than price differences).

Finally, differences between the original and the final sample are small and we find similar results using both samples. The method presented in this appendix is far from perfect to remove city pairs where price differences do not reflect market integration. However, we find that, given that data on transport costs and trade between cities are not available for our thirteen countries, it is a first attempt to correct for the under-estimates of impediments to market integration. Evaluations of impediments to integration with the corrected sample are shown in tables A.3, A.4, A.5, A.6 and in Figure A.1.

Table C. 2: Descriptive statistics before and after the sample correction.

a. Uncorrected full sample

Variable	Obs	Mean	Std. Dev.	Min	Max
$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	134'240	0.36	0.37	0.00	2.82
ln_road_length	134'240	6.40	1.15	-0.42	8.49
Road_quality	134'240	0.65	0.33	0	1
$\lvert\Delta \ln ER_{ijt}\rvert$	134'240	0.02	0.04	0	0.21

b. Corrected sample

Variable	Obs	Mean	Std. Dev.	Min	Max
$\lvert\ln(P_{ikt}/P_{jkt})\rvert$	106'963	0.42	0.39	0.00	2.82
ln_road_length	106'963	6.21	1.16	-0.42	8.49
Road_quality	106'963	0.68	0.32	0	1
$\lvert\Delta \ln ER_{ijt}\rvert$	106'963	0.02	0.04	0	0.21