Country and border effects in the transmission of maize prices in Eastern Africa: evidence from a semi-parametric regression model

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Abstract

There is an extensive literature on distance and border effects in trade, but little attention has been paid to the impact of distance and borders on spatial price transmission. We analyze distance and border effects in maize price transmission between Kenya, Tanzania and Uganda. Using monthly data from January 2000 to October 2008, maize price transmission is measured for 85 market pairs within and between these countries. The magnitude of price transmission between market pairs is found to vary systematically with distance and the presence or lack of a national border between a market pair. This analysis extends the border effects literature in three ways. First, price transmission rather than trade flows or price variability is analyzed. Second, the impact of distance on price transmission is shown to be nonlinear, and is modelled using a semi-parametric partially linear model. Third, strong evidence is found that border effects are heterogeneous; the Tanzanian border has a significant negative impact on price transmission, while the Ugandan border has no effect. The results suggest that Tanzania is a relatively isolated and internally fragmented island within the East African maize market. Price transmission between Nairobi and other markets is strong, which confirms the role that Nairobi plays as a hub on East African maize markets.

Keywords: **border effect, spatial market integration, cointegration, semi-parametric regression, partially linear model, Eastern Africa, maize.**

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1 Introduction

The transmission of price signals across space provides insights into the degree to which markets at different locations are integrated and into the ability of spatial arbitrage to buffer the price and welfare effects of local supply and demand shocks. A central question in this context is whether a long-run equilibrium between prices at different locations exists and, if so, how strongly prices at one or both locations react to deviations from this relationship. The magnitude of this reaction will depend on various factors such as the nature of the good in question (e.g. perishability), transport costs, and the existence of impediments to spatial arbitrage such as regional or national borders. *Ceteris paribus* one would expect that spatial price transmission (PT) between two markets becomes weaker the greater the distance between them. The presence of a border between two markets can either have no effect on PT between them (if goods can pass the border freely without any impediment whatsoever as in a functioning common market with a common currency), or varying degrees of negative effect depending on the tariff and non-tariff measures in place, the time required to complete border formalities, possible costs due to corruption, etc.

So far, the empirical literature on price transmission (PT) has paid scant attention to distance and border effects. The aim of this paper is to begin to fill this gap by studying whether PT on maize markets in Eastern Africa displays evidence of distance and border effects. We analyse whether there are long-run relationships between maize prices on 85 pairs of markets in Kenya, Tanzania and Uganda, and how rapidly prices respond to deviations from these relationships. Second, using parametric and semi-parametric techniques we analyze the factors such as distance and border effects that explain the magnitude of these responses.

Maize is the most important staple food in Eastern Africa (Awuor 2007). It accounts for more than one-third of caloric intake in Kenya and Tanzania, and one-tenth in Uganda (FAOSTAT Food Balance Sheet 2009). Tanzania and Kenya are the largest producers in the region; the former is largely self-sufficient and the latter is by far the largest importer in the region. Demand in the maize deficit regions in Kenya is largely met by maize inflows from the country's central highlands, eastern Uganda and northern Tanzania (World Bank 2008a). Uganda is the largest exporter in the region (for a more detailed account of the regional maize trade flows, see Awuor 2007, Michigan State University 2008, and FEWSNET 2009). According to the UN COMTRADE database (United Nations 2009b), approximately 60% of all Tanzanian and Ugandan maize exports are shipped to Kenya, and maize is among the five most important commodities exported by Uganda and Tanzania to other Eastern African countries.

Kenya, Tanzania and Uganda belong to the East Africa Community (EAC) and a corresponding customs union that came into force in January 2005. Nevertheless, they apply different agricultural and trade policies, which sometimes run counter to the spirit of a customs union. Kenya and Uganda are largely liberalized economies compared with Tanzania. According to the World Bank (World Bank 2008b), distortions to incentives in agriculture have been reduced in all three countries since 1980. However, while Kenya and Uganda have changed their policies from taxation to a slight support of farm-gate prices, agriculture in Tanzania remains relatively regulated and protected. Uganda's policy makers are aware of their country's potential to become the region's food basket and earn considerable export revenues. Hence no export duties, bans or other restrictions on trade in food commodities exist. Agricultural policy in Kenya aims at supporting and stabilizing prices via the National Cereals and Produce Board which, although its influence has declined considerably since the 1980s, is estimated to have increased domestic maize prices by 20% in the period from 1995 to 2004 in order to ensure a minimum price (Jayne et al. 2008). Tanzania's approach is characterized efforts to ensure nation-wide food security. This target is pursued by a variety of measures from the local to the national level, including national export bans for maize (Delgado & Minot 2000; see Temu et al. 2007 for a detailed account of Tanzania's export policy).

In view of these heterogeneous policies and the importance and complexity of regional maize trade, price transmission on Eastern African maize markets presents a rich and relevant case study for analysing distance and border effects on PT. The remainder of this paper is structured as follows: Following a review of the literature on border effects, we explore the relationship between transaction costs (TC), distance, borders and the strength of PT in section 2. Section 3 presents the methods and data used in our empirical analysis, and is followed by a discussion of results in Section 4. Section 5 closes with a summary and implications for further research.

2. Distance and border effects on price transmission

2.1 Literature review

In general economics a literature on the impact of borders on trade and price volatility has evolved since a seminal paper by Engel & Rogers (1996). This literature includes Helliwell (1996, 1997), Parsley & Wei (1996), Wei (1996), Evans (2003), Morshed (2003, 2007), Feenstra (2002), Anderson & van Wincoop (2004), Chen (2004) and Helble (2007). In agricultural economics, only a few publications study the effects of borders on trade or the prices of agricultural products. Gardner & Brooks (1994) assess the impact of distance and regional administrative borders on price differences between 14 cities in Russia for six food products at the beginning of the 1990s. While the influence of distance appears to be negligible, they find that regional borders between cities account almost entirely for the differences in most product prices. Berkowitz & DeJong (1999, 2000) assess the determinants of price dispersion across Russia's regions between 1993 and 1996. They find strong evidence for an internal economic border which separates the "red belt", i.e. regions which voted for the Communist Party in the early 1990s, from the rest of the country. Furtan & van Melle (2004) study border effects in agricultural trade between Canada, Mexico and the US. Olper & Raimondi (2008a) analyze the trade of 22 agricultural products in the OECD and find substantial border effects that are declining over time. Olper & Raimondi (2008b) study border effects on food trade between Canada, the EU, Japan and the US. In an analysis of the determinants of border effects they find that information costs and consumer preferences are important factors.

Since the cited papers find evidence of distance and border effects on trade and price volatility, it is reasonable to expect that distance and borders will have an impact on the dynamics of spatial PT – i.e. the degree to which and speed with which price signals are transmission between markets in space. To our knowledge this has not been studied in detail in the literature so far. In the remainder of this paper we first discuss the impacts of borders and distance on PT from a theoretical perspective before presenting the results of an empirical analysis of these impacts on maize markets in Eastern Africa.

2.2 Theoretical considerations

Spatial PT is commonly estimated using the vector error correction model (VECM) in (1):

$$\begin{pmatrix} \Delta p_t^A \\ \Delta p_t^B \end{pmatrix} = \begin{pmatrix} \alpha^A \\ \alpha^B \end{pmatrix} ect_{t-1} + \sum_{i=1}^{k} \mathbf{\Gamma}_i \begin{pmatrix} \Delta p_{t-i}^A \\ \Delta p_{t-i}^B \end{pmatrix} + \begin{pmatrix} \varepsilon_t^A \\ \varepsilon_t^B \end{pmatrix} \qquad (1)$$

where $\Delta p_{t-i}^l = p_{t-i}^l - p_{t-(i+1)}^l, i = 0,1,\ldots,k; l = \{A, B\}$ denote the (lagged) price differences for markets *A* and *B*, α^l are the adjustment parameters which measuring the magnitude of error correction, $\mathbf{\Gamma}_i, i = 1,\ldots,k$ are *(2x2)* matrices denoting the short-run price response coefficients, and ε_t^l are Gaussian errors terms. The adjustment parameters (α^l) are of particular importance; they indicate whether one or both prices adjust to correct deviations from their long-run equilibrium, and they measure the magnitude and thus speed of this adjustment.

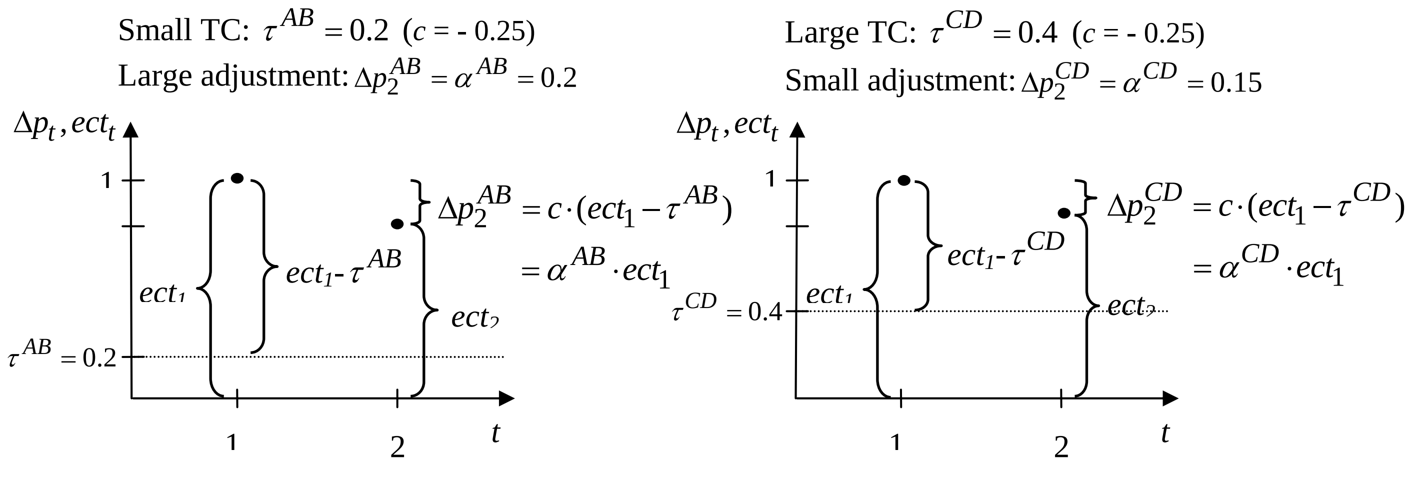
Spatial arbitrage involves costs that are incurred in the completion of physical commodity transactions[2]. Like most studies that deal with distance effects, we assume an *iceberg* form of these transaction costs (TC): "if a good is shipped from one location to another, a fraction [of its value] melts en route" (O'Connell & Wei 1997, see, e.g., also Engel & Rogers 1996 and Lo & Zivot 2001) creating a *band of no-arbitrage* within which arbitrage is not profitable. Hence, only short-run deviations which exceed the transaction costs (depicted by τ^{AB} for trade from A to B) are

[2] These costs are sometimes referred to as *market frictions*, see, e.g., O'Connell & Wei (2002).

corrected, i.e., correction only takes place until the edge of the band (Lo & Zivot 2001).

Figure 1 illustrates the relationship between the observed adjustment speed α, the underlying adjustment speed *c*, and the TC (τ^{AB}). In both panels, all factors are held constant except the size of the TC. The deviation from long-run equilibrium (ect_1) at time $t=1$ takes the value 1 in both panels, and the underlying adjustment speed *c* equals -0.25 meaning that 25% of any deviation from the band of no arbitrage is corrected in any period. This *c* can be considered a measure of the reaction of arbitrageurs to a given price difference, in other words what volume of trade flows they initiate in a given period in response to a given price difference (profit incentive). In the left panel, TC for trade from market *A* to *B* are assumed to amount to 0.2 while the TC between markets *C* and *D* in the right panel amount to 0.4.

Figure 1: Transaction costs and PT



Source: Own presentation.

The following relationship can be shown to hold between the observed adjustment speed α, TC, and the underlying adjustment speed *c*:

$$\alpha^{AB} = c \cdot \frac{ect_{t-1} - \tau^{AB}}{ect_{t-1}} = c - \frac{c \cdot \tau^{AB}}{ect_{t-1}}. \qquad \textbf{(2)}$$

Consequently, the higher TC the lower the observed speed of adjustment α, and the lower the speed of PT, all other factors being equal.

Although transportation costs are often an important component of TC, various other costs can be incurred in spatial arbitrage. Barrett (2001) discusses the following components of TC:

$$\tau^{AB} = fr^{AB} + v^{AB} + d^{AB} + \theta^{AB} = transfer\,costs^{AB} + \theta^{AB} \quad (3)$$

where τ^{AB} are the TC per unit between markets *A* and *B*; *fr* denotes freight rates per unit; *v* are variable costs of insurance, financing, contracting and satisfying formal and informal barriers to trade such as quality standards; and *d* are the average unit duties on the product. These first three components together comprise the transfer costs, while the final component θ denotes immeasurable TC such as opportunity or search costs.

The components of TC in (3) are determined by a number of factors. The per unit freight rate for example will depend on distance, the quality of the transport infrastructure between the markets, and the quantity transported. The trader or hired transporter's efficiency and network can also be expected to play a role, for example by determining whether a lucrative back-haul from *B* to *A* helps defray the costs of transport from *A* to *B*. While TC will generally increase with distance, this relationship need not be linear because, for example, difference modes of transportation and thus freight rates might be relevant over different ranges of distance. However, distance is in general easy to measure, and since it is likely to determine a large part of freight rates, a significant *distance effect* on TC and thus PT can be expected.

If arbitrage crosses national borders, further costs can arise. Olper & Raimondi (2008a) classify these into costs related and unrelated to policy barriers, respectively, and the substitutability between imports and domestic produce. The costs of crossing a border include certifying quality and preparing necessary customs documentation, paying applicable import duties or export taxes, and the opportunity costs caused by delays at border crossing. In some cases bribes may be required to complete or accelerate border procedures. Language differences across a border can influence costs, as can the quantity and professionalism of customs staff, and whether or not customs procedures are transparent and automated. Where informal trade is prevalent, the cost of evading border controls can play an important role. Since most of the factors are country-specific, a significant *country-specific effect* of border crossing can be expected, so that equation (3) can be rewritten as:

$$\tau^{AB} = f(d^{AB}) + D^{AB}_{border} + D^{AB}_{country\ X} \qquad (4)$$

where
$$D^{AB}_{border} = \begin{cases} 1 & if\ trade\ between\ A\ and\ B\ crosses\ a\ border \\ 0 & otherwise \end{cases}$$
$$D^{AB}_{country\ X} = \begin{cases} 1 & if\ A\ or\ B\ are\ located\ in\ country\ X \\ 0 & otherwise \end{cases} \qquad (5)$$

and d^{AB} denotes the distance between markets *A* and *B*. Hence, TC in spatial arbitrage, and thus PT, can be thought of as a function of distance, general border effects and country-specific border effects.

3. Empirical methods

3.1 Specification

As a measure of PT we consider $S^{AB}_{\alpha} = \alpha^{AB} + \alpha^{BA}$, which is the sum of the estimated adjustment speeds taken from the VECM in equation (1) for prices at locations *A* and *B*. This is reasonable because the strength of PT depends on how quickly prices react to deviations from their long-run equilibrium. We only consider adjustment parameters that are significant at the 10% level in generation of S^{AB}_{α}, on the assumption that insignificant parameters reflect a lack of price reaction.[3]

S^{AB}_{α} is regressed on the distance between markets *A* and *B*, and on a series of dummy variables that capture border effects. These include a dummy for border crossing in general (D_B) and in alternative specifications specific dummies for the Kenyan-Tanzanian (D_{KT}) and the Kenyan-Ugandan (D_{KU}) borders. Furthermore, we consider country-specific dummies for trade between markets that are

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[3] Most of the adjustment speeds were significant at the 1% level.

both located within Tanzania (D_{Tan}) or Uganda (D_{Ug}). Finally, we also consider a dummy (D_{Nai}) for market pairs that include Nairobi in acknowledgement of the key role that Nairobi plays as a hub of maize trade in Eastern Africa.

We expect that distance will have a negative impact on S_{α}^{AB}. Borders are also expected to have a negative impact, but this might be corrected up- or downwards by country-specific border effects. Similarly, country-specific effects for market pairs within a single country can be positive or negative depending on which country is taken as the reference scenario, while the inclusion of Nairobi in a market pair is expected to have a positive impact on the speed of PT.

3.2 Functional form

While we expect PT to become weaker as the distance between two markets increases, all other things being equal, theory does not suggest an explicit functional form for this relationship. This can be critical, because misspecification of the functional form can lead to biased parameter estimates. Some authors in the border effects literature attempt to cope with this problem by estimating alternative functional specifications of the partial influence of distance, for example logarithmic and quadratic forms (see, e.g., Engel & Rogers 1996, Morshed 2003 and 2007). Engel & Rogers (1996) are aware of this problem and note that "The effect of distance may also be understated if the log-distance function is not the appropriate one".

We adopt a different approach. We conjecture that the functional relationship between distance and pair-wise adjustment speeds is likely to be complex, making any simply functional form too restrictive. As an alternative, we estimate a semi-parametric model (Härdle et al. 2004) in which the relationship between PT and distance effects is estimated using a nonparametric estimator and border, country-specific and the Nairobi effects are incorporated using the dummy variables outlined above. In summary, the following semi-parametric models are estimated:

$$S_{\alpha}^{AB} = m(d^{AB}) + \beta_1 D_B^{AB} + \beta_2 D_{Tan}^{AB} + \beta_3 D_{Ug}^{AB} + \beta_4 D_{Nai}^{AB} \qquad (6)$$

and

$$S_{\alpha}^{AB} = m(d^{AB}) + \gamma_1 D_{KT}^{AB} + \gamma_2 D_{KU}^{AB} + \gamma_3 D_{Tan}^{AB} + \gamma_4 D_{Ug}^{AB} + \gamma_5 D_{Nai}^{AB} \quad . \qquad (7)$$

where $m(\bullet)$ is some smooth function which captures the impact of distance on the speed of PT, and the dummy variables are as explained above. This semi-parametric specification combines the benefits of flexible estimation of the likely nonlinear relationship between distance and PT, and the easy interpretability of simple fixed effects estimation for the impact of borders and country-specific factors.

3.3 Data

We analyse 16 monthly maize wholesale price series from Kenya, Tanzania and Uganda that cover the period January 2000 to October 2008 (106 observations). Table 1 and the maps in the Appendix present information on the markets studied and their locations.

Table 1: The markets studied

Country	City	Category
Kenya	Nairobi	net consumer
	Mombasa	net consumer
	Eldoret	net producer
	Nakuru	net producer
Tanzania	Dar es Salaam	net consumer
	Iringa	net producer
	Mbeya	net producer
	Songea	net producer
	Arusha	net producer, export centre to Kenya
Uganda	Kampala	net consumer
	Iganga	net producer
	Kasese	net producer
	Lira	net producer
	Masaka	net producer
	Masindi	net producer
	Mbale	net producer, export centre to Kenya

Source: Own presentation.

Most of the price data were obtained from the Regional Agricultural Trade Intelligence Network of the Eastern Africa Grain council (RATIN, 2008). Some missing values could be filled using converted monthly data in Michigan State University (2008), or by monthly averages of the weekly data published by the Ministry of Industry and Trade of Tanzania (2008) and InfoTradeUganda (2008). 59 remaining missing values (3.5% of 1696 observations altogether) were imputed using the algorithm proposed by King et al. (2001). We performed 1000 imputations for each missing value and estimated the most likely value from this set using Parzen's (1962) nonparametric mode estimator. All prices have been converted into US$/t basis and logarithms.

All series but one are found to be integrated of first order at the 5% level of significance; the exception is the Songea price series which is I(1) at the 7% level.[4] We consider in total 85 market pairs which we test for cointegration according to the Johansen method and using the Akaike, Hannan-Quinn and Schwarz criteria for lag length selection. Eight pairs, mostly consisting of one of the markets in the South of Tanzania and one of the Kenyan markets were not cointegrated at the 10% level; these are Iringa-Nairobi, Iringa-Eldoret, Iringa-Nakuru, Songea-Eldoret, Mbeya-Arusha, Mbeya-Nakuru, Kampala-Iganga and Kampala-Kasese. Five pairs showed mixed evidence of cointegration in the sense that different model selection criteria pointed to different optimal lag lengths and correspondingly different cointegration test results. In the following these pairs are nevertheless considered to be cointegrated. The final regression dataset and descriptive statistics of the 77 remaining pairs are displayed in Table 2 and

We estimate the VECM formulated in (1) for each of these pairs. In three cases we obtain significant adjustment parameters with the wrong signs (i.e. the estimated adjustment increases rather than reduces deviations from the long-run equilibrium); these are considered as outliers and excluded from further analysis.

Figure 2, respectively.

Table 2: Descriptive statistics of the regression data

	Distance in	S_{α}^{AB} in %	D_B	D_{KT}	D_{KU}	D_{Tan}	D_{Ug}	D_{Nai}

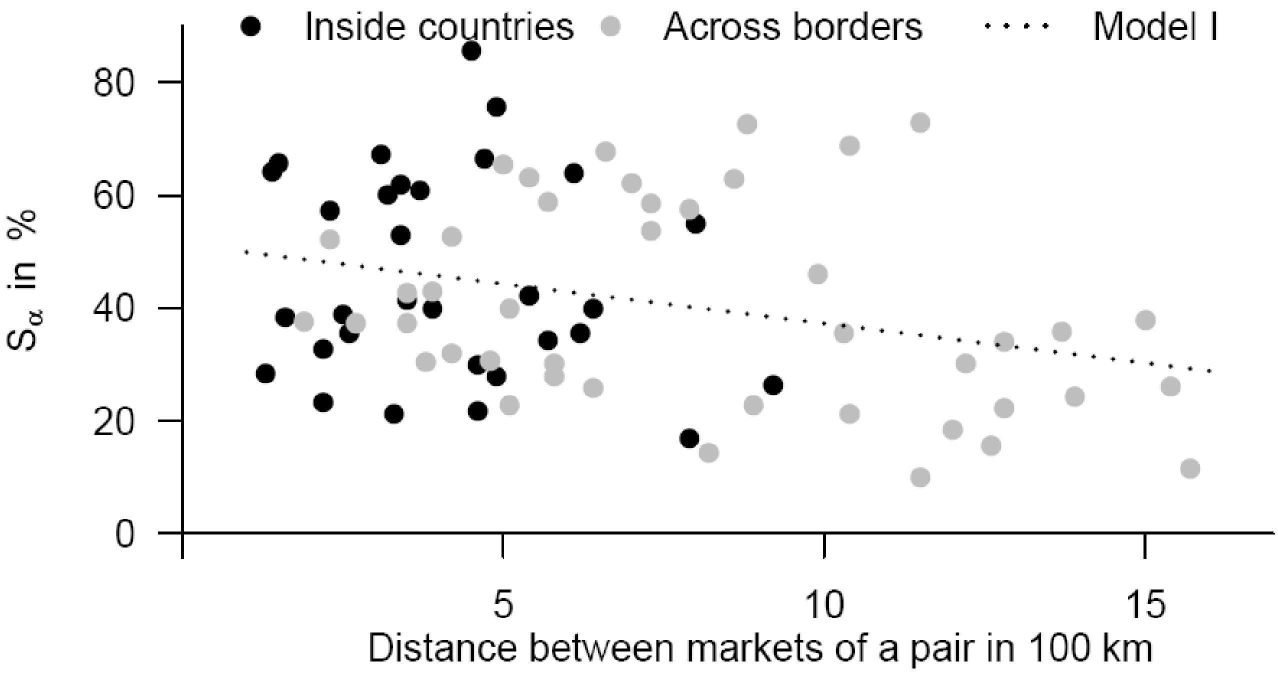
[4] Detailed results of the unit root tests can be obtained from the authors upon request.

	100 km							
Minimum	1.3	10.1	0	0	0	0	0	0
Median	5.4	38.1	1	0	0	0	0	0
Mean	6.5	42.2	0.58	0.20	0.38	0.08	0.26	0.19
Maximum	15.7	85.7	1	1	1	1	1	1

Source: Own calculations.

We estimate the VECM formulated in (1) for each of these pairs. In three cases we obtain significant adjustment parameters with the wrong signs (i.e. the estimated adjustment increases rather than reduces deviations from the long-run equilibrium); these are considered as outliers and excluded from further analysis.

Figure 2: Pair-wise adjustment speed S_α and the distance between pairs of markets



Source: Own calculations.

4. Results

4.1 Parametric specifications

Table 3 displays the estimation results for versions of the models (6) and (7) in which the $m(\bullet)$ function of distance is assumed to be linear, quadratic or logarithmic. Altogether, 43 different fully parametric model specifications characterized by different functional forms for the distance function and different combinations of the border and country effect dummies were estimated, of which only a representative selection is presented in detail here.

Overall, the evidence in Table 3 suggests that there is a robust positive Nairobi effect on the strength of PT, that there is a robust negative within-Tanzania effect, and that there is no general border effect but rather that crossing from Tanzania to Kenya has a significant negative impact on PT while crossing from Uganda to Kenya has none. Regarding distance effects, the linear models I and II reveal a strong negative relationship between distance and S_{α}^{AB}. This is depicted as the dotted line in

We estimate the VECM formulated in (1) for each of these pairs. In three cases we obtain significant adjustment parameters with the wrong signs (i.e. the estimated adjustment increases rather than reduces deviations from the long-run equilibrium); these are considered as outliers and excluded from further analysis.

Figure 2. However, as border and country effect dummies are added, the linear effect becomes weaker and ultimately, in model IV, insignificant. Quadratic distance terms are found to be insignificant in Models III and V, as is a logarithmic distance term in Model VI.

Table 3: Parameter estimates and p-values (in brackets) for selected parametric model specifications

		Model						
		I	II	III	IV	V	VI	VII
Explanatory variables	Intercept	51.3 (<0.001)	49.4 (<0.001)	43.3 (<0.001)	48.1 (<0.001)	42.2 (<0.001)	48.1 (<0.001)	46.9 (<0.001)
	Distance d	-1.4 (0.001)	-1.3 (0.028)	0.5 (0.779)	-0.4 (0.446)	2.0 (0.225)		
	d^2			-0.1 (0.543)		-0.2 (0.131)		
	$\ln(d)$						-0.9 (0.720)	
	D_B		-3.1 (0.505)					
	D_{KT}			-22.5 (<0.001)	-26.6 (<0.001)	-26.0 (<0.001)	-28.0 (<0.001)	
	D_{KU}			2.5				

	I	II	III	IV	V	VI	VII
			(0.535)				
D_{Tan}				-20.7 (<0.001)	-22.7 (<0.001)	-21.3 (<0.001)	
D_{Ug}				1.5 (0.711)			
D_{Nai}		16.9 (0.001)	17.2 (<0.001)	16.5 (<0.001)	15.2 (<0.001)	16.0 (<0.001)	15.2 (<0.001)
$D_{TanGen} = D_{Tan} + D_{KT}$							-26.5 (<0.001)
AIC	637.0	629.6	604.7	590.2	587.9	589.3	586.9

Source: Own calculations.

The model that performs best in terms of the Akaike Information Criterion (AIC) is model VII which includes no distance terms whatsoever but rather only the dummy variable for Nairobi and a general Tanzania dummy that equals 1 for all market pairs that include at least one location in that country, i.e. for trade either within Tanzania or between Tanzania and Kenya. This suggests that distance effects are redundant if border and country effects are accounted for appropriately. Of course, there may be other functional forms for distance that we have not considered and that produce significant results.

4.2 Semi-parametric specifications

Although distance effects appear to be insignificant in the parametric models presented above, we include distance in semi-parametric specifications in order to evaluate whether it has a potentially nonlinear impact on PT. Based on the results in Table 3, we omit all insignificant dummy variables and estimate the following partially linear model using the Speckman estimator (Speckman 1988, Härdle et al. 2004):

Model VIII $S_{\alpha}^{AB} = m(d^{AB}) + \beta_1 D_{Tan}^{AB} + \beta_2 D_{KT}^{AB} + \beta_3 D_{Nai}^{AB}$

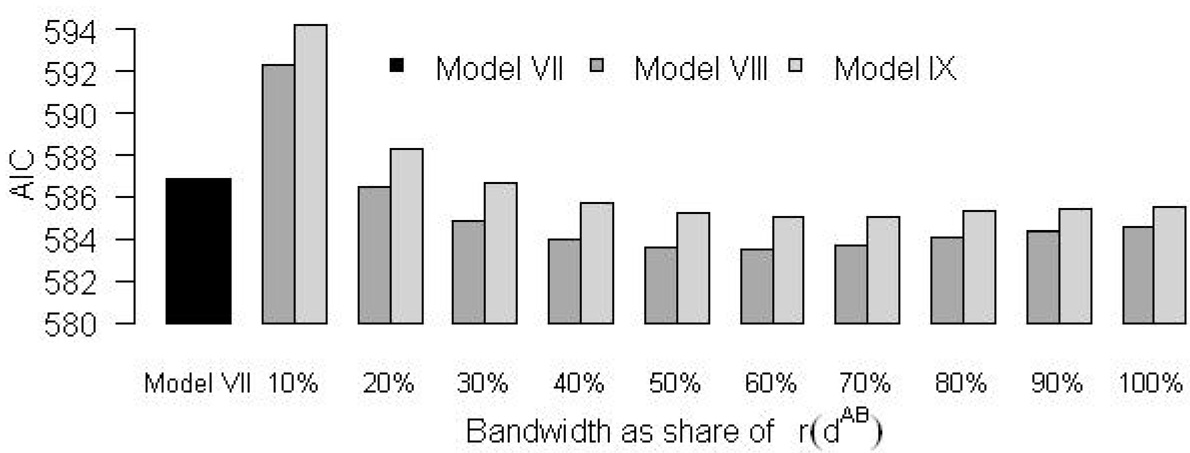
and

Model IX $S_{\alpha}^{AB} = m(d^{AB}) + \gamma_1 D_{TanGen}^{AB} + \gamma_2 D_{Nai}^{AB}$.

These models both include the Nairobi dummy variable; Model VIII also includes both the Tanzania border dummy and the within-Tanzania dummy, while Model IX combines these into an overall Tanzania effect dummy, analogous to Model VII above. The semi-parametric results depend on the bandwidth *h* which governs the degree of smoothing of the nonparametric component $m(d^{AB})$. We use ten bandwidths for each model. These are calculated as the deciles of the range of the distances between market pairs in our data ($r(d^{AB}) = \max(d^{AB}) - \min(d^{AB}) = 14.4$), and the higher the bandwidth the smoother the resulting nonparametric estimate.

According to the AIC results presented in Figure 3, both Models VIII and IX represent better models than the best parametric model (VII, in Table 3) for most bandwidths. The AIC of both models appears to be fairly stable for bandwidths greater than one third of the range of the distances. Furthermore, Model IX has a lower AIC for each bandwidth than Model VIII. For a bandwidth of 60% of the range of distances (corresponding to a optimal bandwidth of 8.6), Model IX has the lowest AIC of all considered models (583.5), which is more than 3 points less than the AIC of the best parametric model (586.9).

Figure 3: AIC for various bandwidths of the semi-parametric specifications vs. model VII



Source: Own calculations.

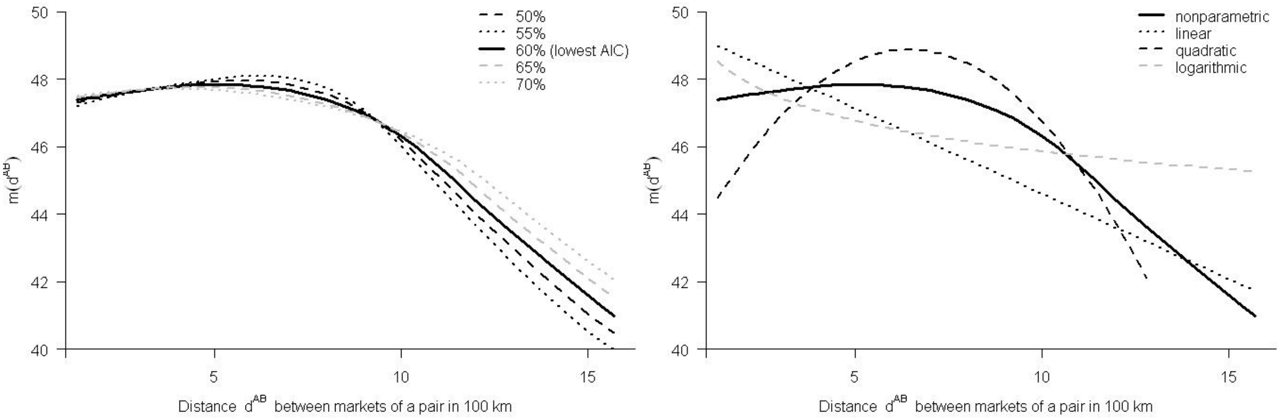
The semi-parametric Model IX with a bandwidth of 8.6 produces the following estimates (p-values in parentheses):

$$S_{\alpha}^{AB} = m(d^{AB}) - \underset{(<0.001)}{24.9} \cdot D_{TanGen}^{AB} + \underset{(<0.001)}{15.2} \cdot D_{Nai}^{AB} + \varepsilon^{AB} \quad . \tag{8}$$

The estimates of the parametric dummy variable coefficients in (8) are similar to those of Model VII, however they are free from potential misspecification bias due to the unknown functional relationship between distance and PT. A significant and negative general Tanzania effect of almost 25 percentage points and a significant positive Nairobi effect of approximately 15 percentage points are detected.

The estimated non-parametric impact of distance on PT, $m(d^{AB})$, is depicted in the left panel of Figure 4 for the model with the preferred bandwidth of 8.6 and a number of other bandwidths. The results suggest that the fundamental nature of the relationship between distance and PT is robust with respect to bandwidth choice. *Ceteris paribus*, 47-48% of any deviation from the long-run relationship between prices is corrected per period for markets that are between 0 and roughly 700 km apart. Beyond 700 km, S_{α}^{AB} falls with increasing distance, and beyond roughly 1000 km this relationship is almost linear, with each additional 100 km of distance reducing the summed adjustment by approximately 1 percentage point. Figure 6 in the Appendix depicts the estimated non-parametric relationship together with the data, and identifies which observations correspond to which border and country-specific dummy variables.

Figure 4: Parametric and semi-parametric estimates of the relationship between distance and pair-wise adjustment speeds



Source: Own calculations.

The right panel of Figure 4 plots the best semi-parametric and several parametric specifications of $m(d^{AB})$. Visual inspection suggests that the parametric and semi-parametric estimates differ considerably. Buja et al. (1989), Härdle et al. (1998) and Müller (2001) propose a bootstrapped modified likelihood ratio test with which the null hypothesis that the function $m(\bullet)$ is a specified parametric function can be tested against the alternative hypothesis that it is an arbitrary smooth function. We test three parametric functional forms (linear, quadratic and logarithmic) against the estimated semi-parametric relationship with a bandwidth of 8.6 using 1000 bootstrap replications for each test. The test results in

Table 4 show that the null hypothesis can be rejected for each of the proposed parametric specifications. This is strong econometric evidence in favour of a semi-parametric approach to modelling the relationship between distance and PT.

Table 4: Tests of various parametric specifications of the relationship between distance and price transmission against the best semi-parametric specification

Null hypothesis		Test statistic	p-value
Linear:	$m(d^{AB}) = \beta_0 + \beta_1 d^{AB}$	29.3	<0.001
Quadratic:	$m(d^{AB}) = \beta_0 + \beta_1 d^{AB} + \beta_2 \left(d^{AB}\right)^2$	5.4	<0.001
Logarithmic:	$m(d^{AB}) = \beta_0 + \beta_1 \log\left(d^{AB}\right)$	76.5	<0.001

Source: Own calculations.

5. Discussion and conclusions

Both the parametric and the semi-parametric results indicate that PT between markets within Tanzania and between markets in Tanzania and Kenya is significantly weaker than PT that does not involve markets in Tanzania. This finding is consistent with expectations based on Tanzania's comparatively interventionist agricultural trade policy. This general Tanzania effect lowers, all other things being equal, the expected speed of adjustment to deviations from the long-run price equilibrium by approximately 25 percentage points, which is more than half of the 'base' adjustment speed of 47-48%. When estimated separately, the isolated effect of crossing Tanzania's border with Kenya is somewhat larger than the isolated within-Tanzania effect, but statistically these effects do not differ significantly from one another. The finding of a significant within-Tanzania effect suggests that grain market regulation in Tanzania creates the equivalent of internal borders which impede flows of grain. This is reminiscent of Gardner & Brooks (1993) and Berkowitz & DeJong (1999, 2000) who find evidence of internal border effects in the context of market integration in Russia. Overall, Tanzania's maize markets are comparatively poorly integrated with each other and with other markets in the region. The welfare costs of this lower market integration, and whether Tanzania's grain market policies also delivers benefits which compensate for these costs, are beyond the scope of this study but certainly an interesting topic for further research.

A general border effect could not be found. While PT across the Tanzanian-Kenyan border is significantly slower, no such effect could be found for PT across the border between Kenya and Uganda. This supports the idea that border effects are likely to be heterogeneous, depending on what countries and products are involved (Chen, 2004).

Besides the strong negative Tanzania effect, a strongly positive Nairobi effect is found. The speed of adjustment between market pairs which involve Nairobi is on average roughly 15 percentage points higher than between pairs that do not involve Nairobi, *ceteris paribus*, increasing the 'base' rate of adjustment from 47-48% to over 60%. Interestingly, it does not matter whether Nairobi's partner market is located in Kenya or abroad. This highlights Nairobi's central role on Eastern African grain markets, the purchasing power of its large population, the quality of the infrastructure linking it with other markets in the region, and the relatively liberal nature of Kenya's grain policy. Comparatively large volumes of grain will flow toward Nairobi from other markets, and it is reasonable to expect that it will be easier for transporters to arrange backhauls, thus reducing transport costs and increasing PT.

Both the parametric and semi-parametric model produce similar estimates of the border and country-specific effects discussed above. Nevertheless, the evidence obtained concerning the role of distance differs strongly between the approaches. While distance is not significant either in linear, quadratic or logarithmic form, it does, when incorporated non-parametrically, improve the quality of the model markedly. The non-parametric estimate of the relationship between distance and PT is characterised by an initial roughly flat section from 0 to roughly 700 km of distance, over which distance does not have a marked impact on PT. At distances above 700 km, a negative relationship between distance and PT becomes apparent, and above roughly 1000 km this relationship is approximately linear, with each additional 100 km of distance reducing the aggregate adjustment speed by roughly 1%.

The results presented above suggest that non-parametric methods can make an important contribution to our understanding of the impact of distance and borders on price transmission and market integration. Further research could focus on extending this analysis to other regions and products. The welfare impacts of different degrees of PT in difference countries and over increasing distances, and the resulting policy implications of our results also deserve attention. Finally, more detailed analysis of the residuals in models such as the ones estimated here could identify particular pairs of markets that are especially well or especially poorly integrated all other things being equal, and thus represent a first step towards designing policies (e.g. infrastructure development, trade facilitation) aimed at improving price transmission and market integration.

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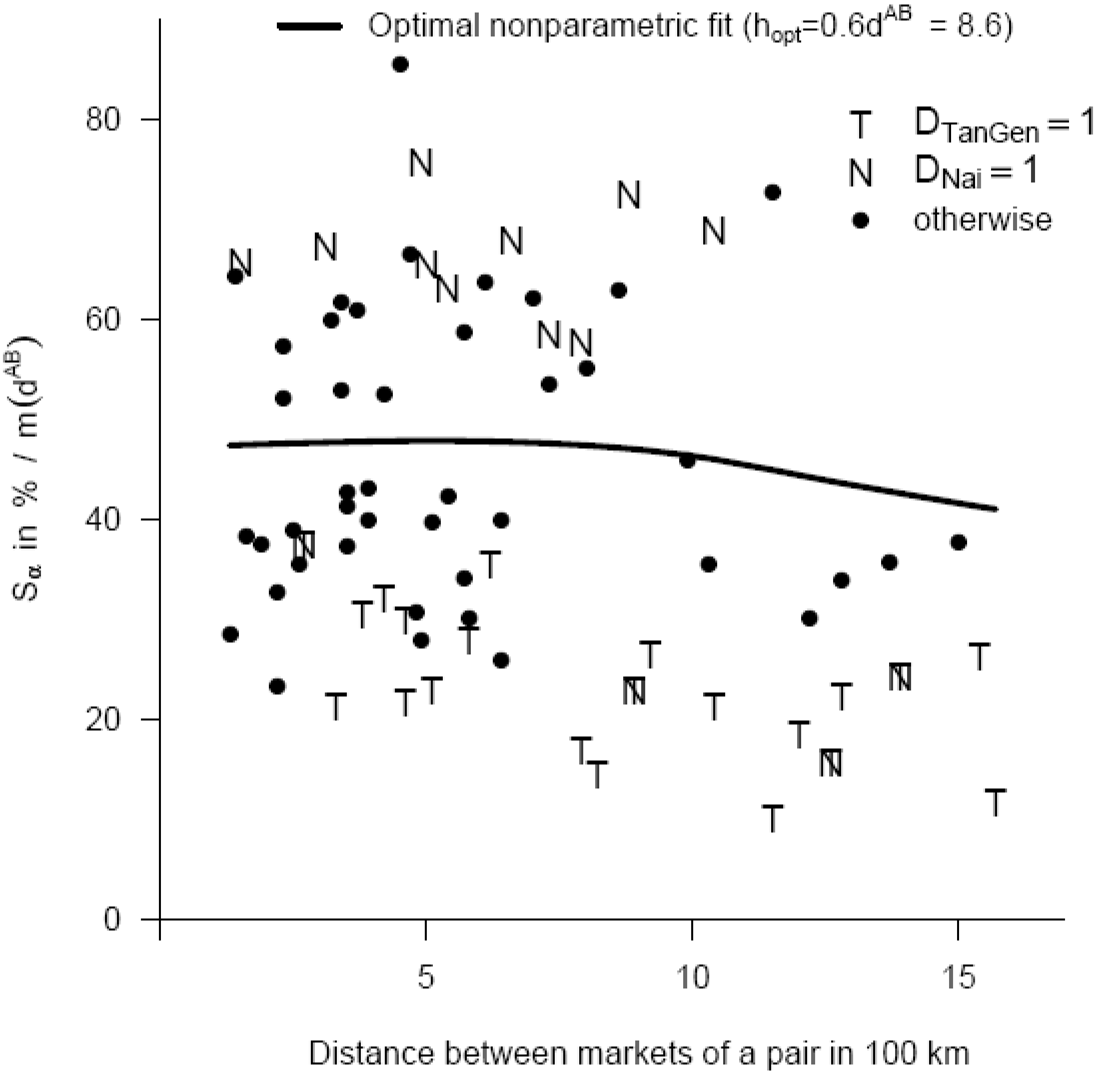
Appendix

Figure 5: The estimated nonlinear partial impact of distance on S_{α}^{AB} and the data



Source: Own presentation.

Figure 6: Map of Kenya

Source: United Nations (2009a) and own elaboration.

Figure 7: Map of Tanzania

Source: United Nations (2009a) and own elaboration

Figure 8: Map of Uganda

Source: University of Texas (2009) and own elaboration.