Modelling Trends in Food Market Integration: Method and an Application to Tanzanian Maize Markets

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Abstract

Pushed by increasing availability of price data and extensive market liberalisation efforts in many developing countries, research on food market integration has evolved rapidly over the last two decades. Empirical methods to measure market integration diverged in two directions: on the one hand, there is the Parity Bounds Model (PBM), while on the other hand the use of Threshold Autoregressive (TAR) Models has been proposed. This article provides a discussion of the two methods and argues that TAR models are more able to capture the dynamics of the arbitrage process underlying interconnected markets. Furthermore, we extend the standard TAR model to include a time trend in both the threshold and the adjustment parameter. Using weekly maize price data on seven selected markets in Tanzania, we illustrate how both transaction cost and the speed of adjustment have changed during the nineties.

Keywords: market integration, transaction costs, thresholds, maize, Tanzania.

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Introduction

There is little disagreement on the benefits of a well-integrated market system. In general, producer marketing decisions are based on market price information, and poorly integrated markets may convey inaccurate price information, leading to inefficient product movements (Goodwin and Schroeder, 1991). For developing countries, there are some additional cases to be made for well-integrated market systems. Linkages to marketing centres have been found to contribute significantly to rural household's escape out of poverty (Krishna, 2004; Krishna et al., 2004). Furthermore, the existence, extend and persistence of famines in market economies is also closely linked to market integration. Indeed, the answer to the central question how long an initially localised scarcity can be expected to persist depends entirely on how well the region is connected by arbitrage to other regions (Ravallion, 1986). Finally, the extent of market integration also has consequences for designing successful agricultural price stabilisation policies (Fackler and Goodwin, 2001)

Apart from the importance of market integration, two additional factors have spurred research in the field over the last two decades. First of all, in the wake of extensive economic reform and market liberalisation in many developing countries, market integration studies are needed to evaluate policy (Dercon, 1995). Secondly, time series data on prices in different locations are increasingly available, and at higher frequencies than ever before[1]. However, data on other factors affecting market integration (most notably transaction costs) have not followed this trend. This is why the challenge has been to assess the degree of market integration using only price data of a particular good in different markets. Studies using only price data to assess market interconnectedness have been labelled level I methods (Barrett, 1996). Since the application in the present study relies solely on price data, we will mainly concentrate on level I methods here.

Markets are said to be integrated if they are connected by a process of arbitrage. This will be reflected in the price series of commodities in spatially separated markets. Thus, as a measure of market integration, the extent of co-movement between prices in different locations has been suggested. Initially, simple bivariate correlation coefficients have been suggested (Blyn, 1973), but the time series properties of the prices resulted in the preference of cointegration and error-correction models (Harriss, 1979; Ardeni, 1989; Goodwin and Schroeder, 1991; Palaskas and Harris-White, 1993; Alexander and Wyeth, 1994; Dercon, 1995). Later, the non-linearity introduced in the adjustment of the prices by the existence of transaction costs prompted the search for more suitable models. Here, research seems to diverge in two directions: on the one hand, there is the Parity Bounds Model (PBM) (Sexton et al., 1991; Baulch, 1997) and on the other hand, Threshold Autoregressive (TAR) models have been applied (Obstfeld and Taylor, 1997; Goodwin and Piggott, 2001).

In this paper, we argue that there are potentially serious problems with the distributional assumptions of the PBM. Furthermore, we feel that Threshold models are better suited to capture the dynamic nature of market interlinkages. This is why we revisit the TAR model here, extending it to allow for a time trend in both the threshold and adjustment parameter. Using weekly price series data on maize in seven carefully selected markets in Tanzania, we then estimate (changes over time in) the transaction cost and speed of adjustment between these markets.

The paper is organized as follows. The next section briefly explains what is understood by market integration, and the main econometric models used to measure it. Section three provides a discussion of these models. Section four presents the TAR model, and extends it to allow for a gradual change in market integration over time. In Section five, we apply this model on weekly maize price data in selected Tanzanian markets. The last section concludes.

Market Integration: theory and statistical models

The starting point for discussing market integration is the existence of separate regions, each with their own supplies and demands for a range of commodities. Because each product has its own supply and demand function, it is possible to identify autarkic prices in each region at each point in time (say P_t^{1A} and P_t^{2A}) for each homogeneous commodity. When free trade across the regions is introduced, the actual prices may differ from the autarky prices. For instance, if the price difference between P_t^{1A} and P_t^{2A} exceeds the transaction costs at t (T_t) required to ship a unit of the good between the regions, profits can be made by shipping commodities from the region with the lowest price to the region with the highest price. This process will increase demand for the commodity in the region with the low price, while increasing supply in the market with the high price. The increase in demand (with unaltered supply) in the market with low autarchy price will drive up the actual price, while the increased supply (at a given level of demand) will decrease the actual price in the region with the high autarchy price. This process of arbitrage will persist until actual prices differ by exactly T_t.

Integrated markets are markets that are connected through such a process of arbitrage. However, if the price difference between two markets is lower than the transaction cost, rational traders will stop trading, otherwise they will incur a loss. In this case, actual prices are again determined by local demand and supply conditions. Prices will move independently, although it would be wrong to conclude from this that these markets are not integrated.

The first attempts to measure the extend of market integration did not consider the existence of transaction costs and took price co-movement as evidence for market integration. The first models use simple bivariate correlation coefficients (Blyn, 1973). Ravallion (1986) formulates a dynamic model of spatial price differentials, allowing differentiation between short-run market integration, long-run market integration and market segmentation. Realising that arbitrage takes time, he thus provides an alternative to the all-or-nothing approach of correlation coefficients. If evidence for long-run market integration is found, he reformulates the model as an error-correction model. This model, together with the non-stationary nature of most price series gave rise to a whole series of studies that used cointegration techniques to test for long-run market integration. When evidence of long-run market integration is found, error-correction specifications are used to investigate the short run dynamics that are consistent with this long run relationship (e.g. Ardeni, 1989; Goodwin and Schroeder, 1991; Palaskas and Harris-White, 1993; Alexander and Wyeth, 1994; Dercon, 1995, González-Rivera and Helfand, 2001; Rashid, 2004).

The first econometric model to explicitly acknowledge the existence of transaction costs was a model developed by Sexton et al. (1991). Their model, essentially a switching regressions model, returns estimates for the transaction cost and the probabilities of being in a state of too little, too much or efficient arbitrage between two markets. Owing to Baulch (1997), this model has become very popular for measuring food market integration in developing countries as the Parity Bounds Model (PBM), resulting in several studies using the underlying estimation framework (e.g. Fafchamps and Gavian, 1996; Barrett and Li, 2002; Park et al., 2002; Negassa et al., 2004).

The second model that incorporates transaction costs are threshold models, allowing for a different relationship between variables once a threshold has been surpassed. For studying food market integration, the Self-Exciting Threshold Autoregressive model (SETAR) is often used[2]. This model describes the adjustment of price differences between two markets over time. However, this adjustment process can be different according to this price difference being below or above the transaction cost (i.e. the threshold). Hence, they are conceptually closer to the dynamic models discussed above. In this study, we opt for such a model. It will be explained in detail in section four.

The acknowledgement of the existence of transaction costs alters the way market integration is viewed. It essentially breaks the process of market integration into two components: transaction costs and the speed of price adjustment. For instance, a primary factor affecting market integration is an agent's cost and risk associated with trade between markets (Buccola, 1983). This would indeed increase transaction costs between markets, but this does not automatically mean that the adjustment speed decreases. The agent's access to market information, on the other hand, is more likely to influence the speed of adjustment than the transaction cost. For example, in the context of rural food markets, the existence of a telephone line between two markets might dramatically increase the speed of adjustment, without significantly affecting the transaction cost.

Models for Measuring Market Integration: A Discussion

Although a significant improvement over the models that disregarded transaction cost, the PBM and TAR models have their shortcomings too. A first criticism on the PBM concerns its underlying distributional assumptions. The original model identifies three exhaustive regimes, based on the price difference between two markets. Either this price difference is equal to the transaction cost (regime 1), above the transaction cost (regime 2) or below the transaction cost (regime 3). In the switching regressions model, regime 1 is modelled as a constant (i.e. the transaction cost) plus a normally distributed error term. For regime 2, an additional error term is added, while for regime 3, the additional error term is subtracted. This additional error term is assumed to be half-normal distributed truncated from below at zero. After formulating the corresponding density functions for each regime, probabilities are assigned to each regime, and the likelihood function can be specified. Maximizing the log of this function returns estimates for the probabilities of being in one of the three regimes, the transaction cost, and the standard errors of both error terms (Sexton et al., 1991).

Now, suppose the price difference between two markets falls in regime 2, where it is larger than the transaction cost. Indeed, in this case there are profitable arbitrage opportunities that remain unexploited. It seems logical here to assume a half-normal distribution, because the probability of observing large deviations from the transaction cost is lower than the probability of observing smaller deviations. Obviously, economic reasoning suggests that in this regime, there are limits as to how big the discrepancy between the price margin and the transaction cost can become. However, this is not necessarily true for regime 3. If there is no trade between two markets because the price margin is lower than the transaction cost, there is no reason why a smaller deviation from the parity bounds should occur at a higher probability than a large deviation, as suggested by the half-normal distribution underlying the model. One would expect that in this regime, any price difference has the same probability of occurrence. The story is somehow different if there is trade occurring in this regime. In that case, it might be that temporarily, too much trade is going on. These 'errors' will be corrected sooner or later; hence here a half-normal distribution seems to come closer to what economic theory predicts[3].

The point made above is related to Fackler and Goodwin (2001), who argue that "[Switching regressions models] can be viewed as nothing more than flexible models of the price spread distribution. The believability of the regime interpretation rests very strongly on the believability of the distributional assumptions (p. 1012)".[4] As explained above, in a setting where markets are not logically linked by continuous trade, there is no reason to assume any adjustment in regime 3. Even if the markets are logically connected by trade as in the original model, the assumption that the adjustment in both regime 2 and 3 is the same is weak, due to the so-called leverage effect (Deaton and Laroque, 1992)[5].

The parity bounds model is also static in nature[6]. It informs the researcher of the probabilities of being for instance off the parity bounds, but does not tell us anything about how persistent these deviations from the equilibrium are. As already pointed out by Ravallion (1986), "in many settings it will be implausible that trade adjusts instantaneously to spatial price differentials… But, given enough time, the short-run adjustments might exhibit a pattern which converges to such an equilibrium (p. 103)". Sluggishness in price adjustment, delays in transportation and expectations formation under price uncertainty are mentioned as the prime causes for these delays in price adjustment. Indeed, one can imagine markets that are prone to frequent supply and demand shocks. Using a static model like the parity bounds model, one would observe a high frequency of inefficient arbitrage (i.e. too little or too much trade), and hence conclude that these markets are poorly integrated. If one would use a dynamic specification instead, one can assess the time it takes for prices to adjust to one another. If the price differences tend to be corrected quickly, one would come to a different conclusion than the one obtained by the PBM.

The TAR model has two main shortcomings. First of all, there is the assumption that the transaction cost is constant over time[7]. Another issue concerns inference on the threshold parameters. Chan (1993) has shown that the asymptotic distribution of the threshold parameter is neither normal nor nuisance parameter free, hence it is not possible to obtain standard errors and confidence intervals. Recourse to simulation based methods to obtain standard errors is not feasible in practice, as the grid search involved in the estimation takes too much time.

A Threshold Auto Regression Model with a Time Trend

Defining $m_t = p_t - p_{r,t}$ as the price difference between the market under investigation and the price in a reference market at time *t*, we set out by estimating how the price in the previous period responds to a given price difference:

$$\Delta m_t = \rho . m_{t-1} + \varepsilon_t \tag{1}$$

where $\Delta m_t = m_t - m_{t-1}$ and $\varepsilon_t \sim N\left(0,\sigma^2\right)$ is the estimated residual. The only parameter we estimate at this stage is ρ , which is the adjustment speed. It indicates the extent to which price differences in the previous period are 'corrected', and is the basis to calculate half-lives[8].

This model does not incorporate the non-linear effects introduced by the existence of transaction costs between two markets. To account for the existence of transaction costs, we will estimate TAR models instead. One of the simplest TAR models is the following symmetric SETAR model:

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \varepsilon_t & & m_{t-1} > \theta \\ \rho_{in} m_{t-1} + \varepsilon_t & \text{if} & -\theta \le m_{t-1} \le \theta \\ \rho_{out} m_{t-1} + \varepsilon_t & & m_{t-1} < -\theta \end{cases} \tag{2}$$

where we now estimate two adjustment parameters, one for the adjustment inside the band formed by the threshold (ρ_{in}) and one for the adjustment outside this band (ρ_{out}), together with the transaction cost (θ). This model (or variants thereof) has been applied in numerous studies on market integration (e.g. Balke and Fomby, 1997; Obstfelt and Taylor, 1997; Goodwin and Piggot, 2001; Mancuso et al., 2003).

As said above, theory predicts that within the band formed by the transaction cost (θ) there is no adjustment. In this region, our best guess of the price difference in the next period is therefore the price difference in the current period. We can exploit this theoretical property to increase identification of the parameters and impose unit root behaviour inside the band by setting ρ_{in} =0:

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \varepsilon_t & & m_{t-1} > \theta \\ \varepsilon_t & \text{if} & -\theta \le m_{t-1} \le \theta \\ \rho_{out} m_{t-1} + \varepsilon_t & & m_{t-1} < -\theta \end{cases} \tag{3}$$

As mentioned in the previous section, one of the main objections to the TAR model is that the transaction cost is constant over time. Therefore, we will extend (3) to include a time trend in both the threshold and the adjustment parameter in the model. We model the threshold as a simple linear function of time:

$$\theta_t = \theta_1 + \frac{(\theta_T - \theta_1)}{T}.t \tag{4}$$

Here, t denotes time running from *1* to *T*. So, at $t=1$, the threshold is θ_1 while for $t=T$ the threshold is θ_T. Like for the standard TAR model, θ_1 and θ_T is identified through a grid search over possible candidates for these thresholds. The pair that minimizes de sum of squared residuals is then used to estimate the final model.

We can also add a time trend to the adjustment parameter. The complete model can then be written as:

$$\Delta m_t = \begin{cases} \rho_{out} m_{t-1} + \rho'_{out}.t.m_{t-1} + \varepsilon_t & \qquad m_{t-1} > \theta_t \\ \varepsilon_t & \text{if} \quad -\theta_t \leq m_{t-1} \leq \theta_t \\ \rho_{out} m_{t-1} + \rho'_{out}.t.m_{t-1} + \varepsilon_t & \qquad m_{t-1} < -\theta_t \end{cases} \tag{5}$$

Note that, instead of making the transaction cost and adjustment process a function of time, it would also be possible to include a dummy variable to capture sudden changes in these parameters. This is especially useful to capture the effects of structural breaks. For instance, if it is known that restrictions on trade have been removed at a particular point in time, the effect of such a sudden and dramatic shift in food marketing policy could be measured by adding a dummy from that moment onward. For less dramatic but continuous factors affecting market integrations, including a time trend is more appropriate (Negassa et al., 2004). Examples of such factors are the increase in the number of vehicles in the economy, improvements to the transportation infrastructure, gradual improvements in information dissemination (telecommunications, newspaper availability,…), etc.

An Application to Tanzanian Maize Markets

The Data and Context

We will now use price data from seven geographically separated markets to illustrate the model discussed above. The data come from the Africa Data Dissemination Service, which is part of the Famine Early Warning Systems Network and is available on the internet. We decided to use data on white maize wholesale prices, as this is the main staple food in the region under investigation. Prices were deflated by the consumer price index for Tanzania. Since this is a monthly index, we recalculate it to a weekly basis using linear interpolation.

The central market in our analysis is taken to be Iringa. Iringa is the regional capital of the region with the same name. The region is mainly inhabited by the Hehe tribe, which is known for their preference to white maize as a staple food. Climatic conditions in the region are also well suited for maize cultivation and Iringa serves as an important supply market for the rest of the country.

Iringa lies along the Tanzania-Zambian highway, about halfway between Morogoro to the east and Mbeya to the west. To the north, Iringa is connected by road to Dodoma, the administrative capital. Although the distance to Dodoma is relatively short, the road linking the two markets is in disrepair. We also included Songea, which lies at a considerable distance south of the TANZAM highway, but is connected by a fairly good road. Further east of Morogoro at the starting point of the

TANZAM highway is Dar es Salaam, the commercial capital of Tanzania. And finally, we also included Sumbawanga, which is northwest of Mbeya, also a considerable distance off the TANZAM highway. Distances (in kilometers) between these different markets are reported in the table with the results (Table 1).

The data cover a period from 1989 to 2000. During this period, there is no significant structural change to maize marketing policy in Tanzania. According to Jayne and Jones (1997) food marketing and pricing policies in Tanzania have always been fairly market oriented. Furthermore, most structural reforms that affect maize market integration, most notably the relaxation and subsequent abolition of restrictions on grain movement, have happened in the eighties (1984 and 1987 respectively). Hence a gradual linear trend in both the threshold and adjustment parameters seems to be more suitable for this period than including dummies to capture structural breaks. Evidence of decreasing transaction cost or increased adjustment speed signals that there are small but continuous factors that contribute to the integration of markets.

Estimation Results

We estimated three different models for price differences between the six markets and the reference market (Iringa). We first estimate the simple AR1 model of equation (1) where the change in the price difference is explained by the price difference in the previous period. Next, we estimate the standard TAR model without a time trend of equation (3). Finally, we estimate the TAR model with a trend in the threshold and the adjustment parameter as in equation (5). The results are reported in Table 1.

For the simple AR1 model, fastest adjustment has been found between Mbeya and Iringa. Mbeya is the third largest city in Tanzania, and it is also a centre for the cross border trade with Malawi and Zambia. The adjustment speed of -0.15 implies a half-life of just over 4 weeks. The markets of Songea and Sumbawanga, although relatively far from the reference market, also seem to adjust fairly well to the prices in Iringa, with half-lives of about six and a half weeks. These relatively fast adjustments given their distance can be explained by the fact that the trade routes are partly the same as the Mbeya-Iringa connection. For instance, the trade route Sumbawanga-Iringa passes through Mbeya. The goods from and to Songea use 176 kilometres from the Mbeya-Iringa route. Adjustment seems to be more sluggish to the east: it takes on average 10.5 weeks for a given price difference between Morogoro and Iringa to return to half its value, while the half-life between Dar es Salaam and Iringa is as long as 24 weeks. The adjustment speed for the Dodoma-Iringa route lies somewhere in between.

Next, we turn to the TAR estimates. There are now two different dimensions to market integration. On the one hand, there is the transaction cost and on the other hand, there is the speed of adjustment. As expected, the estimated transaction costs are generally proportional to the distance between the two markets. For instance, Dodoma-Iringa has the lowest estimate transaction cost of just over 1000 shillings. Mbeya-Iringa has an estimated transaction cost of about 1500 shillings. Sumbawanga has the highest estimated transaction cost of all the markets west of Iringa. Given the distance, transaction costs on the eastern trade route are significantly higher than for the other trade routes. There are two possible explanations for the high transaction costs between Iringa and markets to the east. The first is the fact that, at Mikumi, somewhere halfway between Iringa and Morogoro, traffic has to get up the escarpment dividing the southern highlands and the low-lying coast region. This is a steep pass and the road is in bad condition due to the heavy traffic. A second factor increasing transaction costs is the presence of a multitude of police check posts between Iringa and Dar es Salaam, who stop every single truck. Often, bribes have to be paid to be able to carry on[9].

Table 1. Estimation Results

Market Pair	Distance	AR1 Model	TAR Model		TAR Model with Trend				N
		?	*?*	*?*	*?(t=1)*	*?(t=502)*	*?*	*? *t*	
Dodoma-Iringa	272	-0.097 **	1004	-0.098 **	3584	1638	0.097 +	-0.001084 **	295
		(-3.96)		(-4.01)			(1.74)	(-4.04)	
Morogoro-Iringa	309	-0.063 **	4984	-0.093 **	5549	3060	-0.115 *	0.000071	281
		(-2.90)		(-3.71)			(-2.11)	(0.42)	
Mbeya-Iringa	355	-0.150 **	1439	-0.156 **	2720	1347	-0.055	-0.000470 *	363
		(-5.67)		(-5.79)			(-0.96)	(-2.23)	
Songea-Iringa	475	-0.092 **	2618	-0.116 **	1441	3803	0.006	-0.000626 **	328
		(-4.15)		(-4.90)			(0.15)	(-3.53)	
Dar es Salaam-Iringa	503	-0.028 **	8619	-0.068 **	8619	6736	-0.005	-0.000249 *	371
		(-2.64)		(-4.20)			(-0.16)	(-2.02)	
Sumbawanga-Iringa	677	-0.101 **	3857	-0.141 **	3826	2790	-0.144 +	0.000035	247
		(-3.45)		(-4.19)			(-1.74)	(0.14)	

Notes: Dependent variable is the change in the price difference of maize between the two markets. All models are estimated without a constant. Rho (*?*) denotes the adjustment parameter on the lagged price difference, theta (*?*) is the threshold and *t* is a time trend. The TAR models are three regime symmetric models with unit root behaviour imposed within the band formed by the thresholds. The thresholds are identified through a grid search over candidate thresholds with as model selection criterion the minimal sum of squared residuals. As starting values for the thresholds, at least 20 percent of the observations were either within or outside the band formed by the thresholds. t-ratio's are in brackets. +, * and ** denote parameter estimates significantly different from zero at the 10, 5 and 1 percent significance respectively. N is the number of observations used in the estimation.

It is also interesting to compare the estimates of the adjustment parameters in the TAR model to the estimates with the simple AR1 model. The adjustment parameters for the eastern trade routes have increased dramatically (in absolute values). Price adjustment between Morogoro and Iringa becomes similar to adjustment between Dodoma and Iringa, once transaction costs have been taken into account. Also between Dar es Salaam and Iringa, arbitrage seems to adjust prices much quicker if the nonlinearity in the adjustment process due to the existence of high transaction costs is appropriately modelled. The implied half life between Dar es Salaam and Iringa is now just under 10 weeks. The changes in the adjustment speed are much smaller for the other trade routes. The only exception is the increase in the adjustment speed in the Sumbawanga-Iringa route. Judged by the speed at which prices in different markets adjust to one another, Mbeya is best integrated with Iringa, followed by Sumbawanga. Price transmission between Dar es Salaam and Iringa is slowest.

Let us now turn to the model with a time trend included. We start by comparing the estimates of the transaction cost at the beginning of our sample to the estimates at the end of our sample[10]. For all but one trade route, transaction costs have decreased over time. Over the entire period of 502 weeks, transaction costs have been cut in half for Dodoma-Iringa and Mbeya-Iringa. For Morogoro-Iringa, Sumbawanga-Iringa and Dar es Salaam-Iringa, the decrease in transaction costs is 45, 27 and 22 percent, respectively. Between Songea and Iringa, transaction costs seem to have doubled over this 10 year period.

Turning to the adjustment process, we see that there is evidence of an increase in the speed of transaction in 4 out of 6 market pairs. For the Dodoma-Iringa trade route the adjustment parameter is estimated significantly at a 10 percent level, but the adjustment seems to go in the wrong direction. However, this is countered by a strong negative time trend in the adjustment parameter. Taking this additional effect into account, we see that the adjustment is 0.096 at the beginning of the period, but reduces to -0.447, thus ranging from virtually no adjustment in 1989 to an adjustment process with an associated half-life of just over 1 week by 2000. The second highest (absolute) increase of the adjustment speed over time is in the trade route between Songea and Iringa. Here, the estimate of the adjustment speed is not significant, but becomes significantly different from zero when it is interacted with time. While at the beginning of the period, the adjustment speed is also virtually zero, it has increased (in absolute value) to -0.31 by 2000, which means a half-life of just under two weeks. The other two market pairs that have a significant interaction between the adjustment parameter and the time trend, but no significant adjustment parameter are Mbeya-Iringa and Dar es Salaam-Iringa. For Mbeya-Iringa, the implied half-life came down from slightly more than 12 weeks at the beginning of the sample to about 2 weeks at the end. For Dar es Salaam-Iringa, the half-life at the end of the sample is about 5 weeks, while there is virtually no adjustment in 1989. For the market pair Morogoro-Iringa, there is no evidence of a significant time trend. The half-life for this pair is five and a half weeks, but increases to about 9 near the end of the sample. Also for the market pair Sumbawanga-Iringa, adjustment speed appears to have been constant over time, with a half-life ranging from four and a half weeks at around 1989 to slightly more than five weeks in 2000.

Overall, we see that the Iringa market is best integrated with the administrative capital, showing evidence of impressive reductions in both transaction costs and the time needed for prices to adjust to one another. We come to the same conclusion for the Mbeya-Iringa, although the reductions are less dramatic. Furthermore, it seems that the increase in the transaction cost between Iringa and Songea is offset by an increase in the speed of price adjustment between these markets. Both Morogoro-Iringa and Sumbawanga-Iringa have seen modest declines in transaction costs, but the speed of adjustment did not alter significantly over time.

Conclusions

In this paper, we argue that the threshold autoregressive model is a better tool to assess the degree of market integration than its rival, the Parity Bounds Model. It allows the researcher to differentiate between two components critical to inter-market arbitrage: transaction costs on the one hand and the speed of adjustment of market prices in spatially separated food markets on the other hand. Moreover, adding a simple time trend to both the threshold and the adjustment parameter allows us to break down changes in market integration in changes in these two components. We illustrate this using high frequency price data for seven maize markets in Tanzania.

We find that transaction costs are markedly higher between our reference market (Iringa) and the markets to its east. Dodoma seems to be best integrated with Iringa. Interestingly, this is due to a gradual increase of the speed of price adjustment and a gradual reduction of the transaction cost over time. If time trends are not accounted for, the Mbeya-Iringa trade route overtakes Iringa-Dodoma in the speed of price adjustment. For all but one of the six market pairs, we conclude that the transaction costs have decreased over time. Only for the Songea-Iringa trade route, transaction costs seemed to have doubled, but this is offset by a significant (absolute) increase in the adjustment speed between the two markets.

The results for a simple model that disregards transaction costs and does not include a time trend generates estimated half-lives ranging form 4.2 to more than 24 months. After appropriately modelling the non-linear adjustment caused by transaction costs, half-lives are down to 4 to 10 weeks. Subsequently adding a time trend, half-lives range from just over 1 week to about 9 weeks. Studies that do not include a time trend frequently find values for half-lives that are unreasonably high given the market settings. Half-lives from the order of 1 to 5 weeks seem much more reasonable than the ones we find without allowing the transaction costs and adjustment speed to change over time.

Subsequent research is needed to explain why transaction costs between Iringa and Morogoro, and Dar es Salaam further east are higher than the transaction costs between Iringa and the other markets. Given the condition of the road between Iringa and Dodoma and the high degree of market integration between these two markets, our results seem to suggest that the labour cost is less important to traders than costs related to distance like fuel and informal trade taxes.

References:

Alexander, C. and Wyeth, J. (1994). Cointegration and Market Integration: An Application to the Indonesian Rice Market. Journal of Development Studies 30: 303-328.

Ardeni, P. G. (1989). Does the Law of One Price Really Hold for Commodity Prices? American Journal of Agricultural Economics 71: 661-669.

Balke, N.S. and Fomby, T.B. (1997). Threshold Cointegration. International economic Review 38: 627-645.

Barrett, C.B. (1996). Market Analysis Methods: Are Our Enriched Toolkits Well Suited to Enlivened Markets? American Journal of Agricultural Economics 78: 825-829.

Barrett, C.B. and Li, J.R. (2002). Distinguishing Between Equilibrium and Integration in Spatial Price Analysis. American Journal of Agricultural Economics 84: 292-307.

Baulch, B. (1997). Transfer Costs, Spatial Arbitrage, and Testing for Food Market Integration. American Journal of Agricultural Economics 79: 477-487.

Blyn, G. (1973). Price Series Correlation as a Measure of Market Integration. Indian Journal of Agricultural Economics 28: 56-59.

Buccola, S.T. (1983). Risk Preferences and Short-Run Pricing Efficiency. American Journal of Agricultural Economics 65: 587-591.

Chan, K.S. (1993). Consistency and the Limiting Distribution of the Least Squares Estimator of a Threshold Autoregressive Model. The Annals of Statistics 21: 520-533.

Deaton, A. and Laroque, G. (1992). On the Behaviour of Commodity Prices. Review of Economic Studies 59: 1-23.

Dercon, S. (1995). On Market Integration and Liberalisation: Method and Application to Ethiopia. Journal of Development Studies 32: 112-143.

Fackler, P.L. and Goodwin, B.K. (2001). Spatial Price Analysis. In Gardner, B.L and Rausser, G.C. (Eds.), Handbook of Agricultural Economics. Vol 1B Marketing, Distribution and Consumption, Elsevier North-Holland, 971-1024.

Fafchamps, M. and Gavian, S. (1996). The Spatial Integration of Livestock Markets in Niger. Journal of African Economies 5: 366-405.

González-Rivera, G. and Helfand, S.M. (2001). The Extend, Pattern, and Degree of Market Integration: A Multivariate Approach for the Brazilian Rice Market. American Journal of Agricultural Economics 83: 576-592.

Goodwin, B.K. and Piggott, N.E. (2001). Spatial Market Integration in the Presence of Threshold Effects. Journal of Agricultural Economics 83: 302-317.

Goodwin, B.K. and Schroeder, T.C. (1991). Cointegration Tests and Spatial Price Linkages in Regional Cattle Markets. American Journal of Agricultural Economics 73: 452-464.

Harriss, B. (1979). There is Method in My Madness: Or Is It Vice Versa? Measuring Agricultural Market Performance. Food Research Institute Studies 17: 197-218.

Jayne, T.S. and Jones, S. (1997). Food Marketing and Pricing Policy in Eastern and Southern Africa: A Survey. World Development 25: 1505-1527.

Krishna, A. (2004). Escaping Poverty and Becoming Poor: Who Gains, Who Loses, and Why?. World Development 32: 121-136.

Krishna, A., Janson, P.K., Radeny, M. and Nindo, W. (2004). Escaping Poverty and Becoming Poor in 20 Kenyan Villages. Journal of Human Development 5: 211-226.

Mancuso, A.J., Goodwin, B.K. and Grennes, T.J. (2003). Nonlinear Aspects of Capital Market Integration and Real Interest Rate Equalization. International Review of Economics and Finance 12: 283-303.

Negassa, A., Myers, R. and Gabre-Madhin, E., 2004. Grain Marketing Policy Changes and Spatial Efficiency of Maize and Wheat Markets in Ethiopia. International Food Policy Research Institute, MTDI Discussion Paper No. 66.

Obstfeld, M. and Taylor, A.M. (1997). Nonlinear Aspects of Goods-Market Arbitrage and Adjustment; Heckscher's Commodity Points Revisited. Journal of Japanese International Economics 11: 441-479.

Palaskas, T.B. and Harriss-White, B. (1993). Testing Market Integration: New Approaches with Case Material from the West Bengal Food Economy. Journal of Development studies 30: 1-57.

Park, A., Jin, H., Rozelle, S. and Huan, J. (2002). Market Emergence and Transition: Arbitrage, Transaction Costs, and Autarky in China's Grain Markets. American Journal of Agricultural Economics 84: 67-82.

Rashid, S. (2004). Spatial Integration of Maize Markets in Post-liberalised Uganda. Journal of African Economies 13:102-133.

Ravallion, M. (1986). Testing Market Integration. American Journal of Agricultural Economics 68: 102-109.

Sexton, R.J., Kling, C.L., and Carman, H.F. (1991). Market Integration, Efficiency of Arbitrage and Imperfect Competition: Methodology and Application to U.S. Celery. American Journal of Agricultural Economics 73: 568-80.

Taylor, A.M. (2001). Potential Pitfalls for the Purchasing-Power-Parity Puzzle? Sampling and Specification Biases in Mean-Reversion Tests of the Law of One Price. Econometrica 69: 473-98.

[1] Two noteworthy African sources of market information, clearly linked to famine relief, are the Africa Data Dissemination Service, which is part of the Famine Early Warning Systems Network and the

IGAD Marketing Information System for the Greater Horn of Africa. A Latin American example is the Sistema de Información Agraria in Peru.

[2] Self-Exciting Threshold Autoregressive (SETAR) models are TAR models where the transition depends on a lag of the process itself.

[3] It is important to note that the original model was developed with such a market structure in mind. Sexton et all. (1991) were looking at two markets where one was indisputably the exporter and the other the importer (Sexton et al. p. 571). They were looking at a situation of two markets that were linked by continuous trade, and their interpretation was that regime 3 reflects a situation where there is simply too much trade (glut). Most other studies using the PBM have analyses quite different market settings, including situations where reversal of trade is likely.

[4] Although they argue that the distributional assumptions are arbitrary because economic theory generally has little to say about the distribution, we feel that theory does say something about the type of adjustment that can be expected.

[5] This effect is created by the ability of traders to hold stocks. In times when the price difference is higher than transaction cost, traders will buy in the market with the low price and sell in the market with the high price. But when the price difference subsequently falls below the transaction cost, traders will, when possible, prefer to stock up instead of selling the goods and incurring a loss. This process obviously has consequences for distributional assumptions. Note that the TAR model would be better suited to model this effect. In this case, a version of the model that allows for adjustment inside the band formed by the transaction costs like equation (2) can be used.

[6] This problem has been acknowledged from the beginning. For instance, Sexton et al. (1991) introduce some dynamics to their model by comparing the price of the exporting market to the lagged price of the importing market. However, this still not informs us on how persistent deviations from efficient arbitrage are.

[7] Strictly speaking, this is also a shortcoming in the switching regression models that only rely on price data. The subsequent PBM of Baulch (1997) relies on exogenous transaction cost data, and hence is a level II study.

[8] A half-life is the time that is needed for a given shock to return to half its initial value: it is the solution for T in $m_{t+T} = \frac{m_t}{2}$. It is calculated as $T = \frac{\ln(0.5)}{\ln(1+\rho)}$.

[9] A lot of trucks actually prefer to drive at night. Although this is much more dangerous, they prefer this to the hassle and cost of driving during daytime.

[10] Our sample runs from the 37[th] week of 1989 to the 18[th] week of 1999.