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Toward a Better Understanding of the Rice Market in Madagascar: Preliminary Analysis with the Threshold Autoregression (TAR) Model*

Yutaka Arimoto [a], Hisaki Kono [b], Takeshi Sakurai [c], Kazushi Takahashi [a]

[a] *Institute of Developing Economies-Japan External Trade Organization (IDE-JETRO)*

[c] *Department of Economics, Kyoto University*

[c] *Institute of Economic Research, Hitotsubashi University*

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Abstract: Using the weekly price data from 2007 to 2013, this paper examines whether rice markets in Madagascar are well integrated spatially. It finds that the price adjustment of Ambatorazaka and Anjozorobe with Antananarivo, the capital city of the country, is not quick even though they are located near to Antananarivo. Remoteness does not explain this phenomenon and further analysis is clearly needed.

Keywords: Spatial integration, Rice market, Madagascar

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1. Introduction

Increased food production and its efficient distribution are essential for global food security. Well-functioning markets play a vital role to protect both producers' and consumers' welfare: on the one hand, well-integrated markets provide outlets for surplus of local food production, preventing food prices to fall, thereby fostering incentives for farmers to adopt new technology in order to increase food production and their income; on the other hand, well-integrated markets protect consumers from local supply shocks by facilitating trade across spaces, leading to price stability (Moser et al., 2009).

However, commodity markets in sub-Saharan African (SSA) countries are typically poorly integrated spatially due to high transaction costs associated with poor road and communication infrastructure, institutional constraints, etc.

Rice markets in Madagascar are no exception. In Madagascar, rice is a staple food and consumed widely, constituting nearly 50% of caloric intake. Rice is also produced widely across regions in the country, but trade between distant regions has been not so common. For instance, Mendoza and Randrianarisoa (1998) found that, in 1996-97, only 8.8% of wholesalers made purchases from areas more than 100 km away. Another study by Butler and Moser (2010) found that on average the probability of interprovincial market integration is only about 56%, though the degree of integration varies largely across provinces. Moser et al. (2009) concluded that rice market in Madagascar is spatially relatively well-integrated at the subregion level, but not necessarily at the provincial or national level. Remoteness, high crime rates and lack of information facility that increase unobserved transaction costs, were major factors to reduce the degree of market integration (Moser et al. 2009; Butler and Moser, 2010).

Against this background, we launched a research project on spatial market integration in rice markets in Madagascar. The overall objectives of the project are to characterize spatial market relationships and identify factors that hinder effective market integration. As an initial step for future studies, this paper attempts to understand recent, district-level, spatial rice market relationships in Madagascar, using the weekly price data with the Threshold Autoregression (TAR) Model.

2. Theory of Spatial Market Integration

Concepts of market integration have been well documented in the existing literature (e.g., Barrett and Li, 2002; Van Campenhout, 2007; Moser et al., 2009). Although several different approaches have been used, most of them start with the basic idea of the law of one price.

Suppose that there is a set of separate markets, each with their own supplies and demands for each homogeneous commodity. If there is no trade, autarkic commodity price is determined solely by local supply and demand conditions. Once free trade is introduced, there will be a process of arbitrage in such a way that markets with higher autarkic prices attract import of a commodity from outside regions, lowering the price of that commodity in the region. Meanwhile, the source market increases price of the commodity due to the reduced local supply associated with export of the commodity. In well-integrated, competitive markets, such an arbitrage process will continue until all profitable arbitrage opportunities are exhausted, at which actual price differences between two markets are equal to transaction costs between them.

More formally, let r_{it} be the price of a homogeneous commodity in market i at time *t*, and τ_{ijt} be the transaction costs to move the commodity between markets i and j, including observed transfer costs and unobserved costs associated with loading, temporary storage, information search, contract enforcement, and various risks (Moser et al., 2009) . Markets are competitive and in perfect integration if

$$|r_{it} - r_{jt}| = \tau_{ijt},$$

where price differences between two markets are exactly equal to transaction costs.

On the other hand, markets may not be perfectly integrated, even though they are still in equilibrium if

$$|r_{it} - r_{jt}| < \tau_{ijt},$$

where price differences between two markets are less than transaction costs. Under this condition, two markets are segmented and no trade will occur because it is not profitable. Yet, this is still in equilibrium.

Finally, markets are in disequilibrium if

$$|r_{it} - r_{jt}| > \tau_{ijt},$$

where price differences between two markets are greater than transaction costs. In this setting, unexploited profitable opportunities remain, suggesting that markets are imperfectly integrated or temporarily in segmented disequilibrium (Barrett and Li, 2002).

3. Estimation Strategy

The concepts of the three distinguished regimes of spatial market relationships discussed above lead several researchers to use Parity Bounds Model (PBM) to estimate the probability of commodity markets being in each regime, using price and transfer cost data. Among others, Moser et al. (2009) and Butler and Moser (2010) have applied (modified) PBM to rice markets in Madagascar. Their estimation models are quite sophisticated. Yet, an important limitation of their model is that PBM is static in nature. Indeed, van Compenhout (2007) argues that Threshold Autoregression (TAR) Model might be better suited to capture the dynamics of the arbitrage process in markets. Thus, as a supplement to previous studies, this paper attempts to estimate Threshold Autoregression (TAR) Model to characterize dynamic spatial market relationships in rice markets in Madagascar.

TAR considers the adjustment process of price differences between markets. Defining $m_{ijt} = r_{it} - r_{jt}$ as the price difference between two markets, we can estimate how the price difference at time *t* responds to the price difference in the previous period with AR (1) process:

$$\Delta m_{ijt} = \rho m_{ijt-1} \quad + e_{ijt},$$

where $\Delta m_{ijt} = m_{it} - m_{it-1}$ and $e_{ijt} \sim \mathrm{N}(0, \sigma^2)$ is the estimated residual. The parameter ρ captures the adjustment speed by which the price difference is "corrected" over time, and is expected to be negative.

This model, however, does not incorporate changes in adjustment behavior depending on transaction costs. As discussed in the previous section, we can reasonably assume that trade between markets occurs if the absolute value of price differences between two markets is greater than transaction costs of shipment, such that $m_{ijt} > \tau_{ijt}$ or $m_{ijt} < -\tau_{ijt}$. On the other hand, arbitrage is unprofitable and trade will never occur if $-\tau_{ijt} < m_{ijt} < \tau_{ijt}$, where the absolute value of price differences between two markets is less than transaction costs of shipment. Under the setting where trade does not occur in the previous period, the price difference in the current period will be independent from that in the previous period.[1] Thus, price adjustment behavior would be considerably different between inside and outside the price bands. Imposing unit root behavior by setting $\rho = 0$ within the band of $-\tau_{ijt} < m_{ijt} < \tau_{ijt}$, we can distinguish three regimes of spatial arbitrage opportunities as follows:

$$\Delta m_{ijt} = \begin{cases} \rho m_{ijt-1} + e_{ijt} & m_{ijt} > \tau_{ijt} \\ e_{ijt} & \text{if} \quad -\tau_{ijt} \leq m_{ijt} \leq \tau_{ijt} \\ \rho m_{ijt-1} + e_{ijt} & m_{ijt} < -\tau_{ijt} \end{cases}$$

A well-known limitation of this standard band-TAR model is that the transaction cost is assumed to be constant over time. An innovation by Van Compenhout (2007) is to relax that assumption and to include a time trend in both the threshold and adjustment parameters. Following Van Compenhout (2007), we model the threshold as a linear function of time:

$$\tau_{ijt} = \tau_{ij0} + \frac{\tau_{ijT} - \tau_{ij0}}{T} t \; .$$

Here, *t* denotes time running from 0 to T. So, at *t*=0 the threshold is τ_{ij0}, and at *t*=T, it is τ_{ijT}.

Similarly, we add a time trend to the adjustment parameter as follows:

$$\Delta m_{ijt} = \begin{cases} \rho m_{ijt-1} + \rho' t m_{ijt-1} + e_{ijt} & m_{ijt} > \tau_{ijt} \\ e_{ijt} & \text{if} \quad -\tau_{ijt} \leq m_{ijt} \leq \tau_{ijt} \\ \rho m_{ijt-1} + \rho' t m_{ijt-1} + e_{ijt} & m_{ijt} < -\tau_{ijt} \end{cases} \; .$$

ρ', which reflects time trend of adjustment parameter, is positive if speed of price adjustment becomes slower, and negative if it becomes faster over time.

4. Data and Setting

In this study, we use weekly sub-regional price data on the milled price of a Malagasy rice variety, Vary Gasy, to examine the adjustment speed of recent rice markets in Madagascar. We purposively selected ten geographically separated areas that represent major production and/or consumption areas in the country (Figure 1). We

[1] Stephens et al. (2011) discuss the possibility that price adjustments will take place even without physical trade flow.

match each city with the national capital, Antananarivo, and explore the dynamics of the arbitrage process between each pair. Following Van Compenhout (2007), to take into account inflation, we use the price difference in two cities as a share of the average price level of the two markets, which is:

$$m_{ijt} = \frac{2(p_{it} - p_{jt})}{p_{it} + p_{jt}}$$

The price data employed in this study are collected by Observationaire du Riz in Madagascar (OdR), which cover from July 2007 to October 2013. Yet, because of political instability caused by a coup d'état in 2009, the data collection temporality stopped from January 2010 to July 2010. We thus have two successive observation periods, from July 2007 to December 2009 and July 2010 to October 2013.

5. Estimation Results

Estimation results of the first and second periods are presented in Table 2 and 3. [2] In addition to ρ, which denotes the adjustment parameter on the lagged price difference (expressed as the percentage of mean price in the two markets), as well as the time trend ρ', we present the threshold (also expressed as a percentage of mean price), θ, and half-life, following Van Campenhout (2007) , where a half-life is defined as the time that is needed for a given shock to return to half its initial value and calculated as Half-life=ln(0.5)/(ln(1+ρ)) without time trend, and with time trend, Half-life*t=ln(0.5)/(ln(1+ ρ+ ρ'*t)). 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% of the observations were either within or outside the band formed by the thresholds.

According to Table 2, ρs of all market pairs without a time trend are negative and statistically significant, indicating that each market pair under study seems to integrated and converges to a long-term equilibrium over time in that observation period.

Among all market pairs, transaction costs, reflected in θ, are large for those with Bealana and Toliara due presumably to remoteness and poor road infrastructure between Antananarivo and those cities. Yet, transaction costs with Anjozorobe and

[2] We thank Van Campenhout for sharing his Stata code to implement TAR models.

Ambatorazaka, which are not far from Antananarivo, are equally high and the half-life is surprisingly high at 8.08 for Anjozorobe and 3.7 for Ambatorazaka, indicating that it needs 8 weeks for a given shock to return to half its initial value with Anjozorobe and 3.7 weeks with Ambatorazaka. Indeed, among all pairs, the half-life is highest in Anjozorobe, followed by Bealana.

Turning to the TAR model with time trend, it is also observed that ρs become even statistically insignificant for several markets, such as Bealana, Anjozorobe, and Toliana. The results indicate that those areas are relatively unconnected with Antananarivo. We also observe that, among many market pairs, θt tends to become greater than θo, suggesting that transaction costs have increased over time, even though road and communication infrastructure has developed during the period.

Similar trends are also observed in the later survey period, as reflected in Table 3. Again, transaction costs with Bealana, Ambatorazaka, and Anjozorobe are higher than other cities and adjustment speed, represented by the half-life, is considerably slower.

These results together suggest that rice markets in Madagasar remain not to be well integrated even cities near to the national capital, and there is much room for efficient market integration.

6. Discussion

To our surprise, these overviews of spatial market relationships are less consistent with Butler and Moser (2010) who carried out the modified PBM using information on markets and transaction costs. Their results show that the TOAMASINA, where Ambatorazaka is located, and ANTANANARIVO, where Antananarivo and Anjozorobe, are located are relatively well integrated with other cities, with the mean predicted probability of integration to be 55.6% and 60.4%, respectively. There is no denying that the observed periods of us are different from Butler and Moser (2010), and that market trend has changed during the period. Yet, we need to know in detail why Ambatorazaka and Anjozorobe are not well connected with Antananarivo throughout the observation periods. Our original survey on inter-regional traders indicates that inter-regional traders in Antananarivo frequently go those two areas for rice trade. Thus, we clearly need to extend our analyses by using not only price data, but also data on trade flow, transfer costs, and other market and trader's characteristics. Our future studies will shed light on trader's behavior as well to improve our knowledge of spatial market integration.

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Figure 1. Map of Madagascar

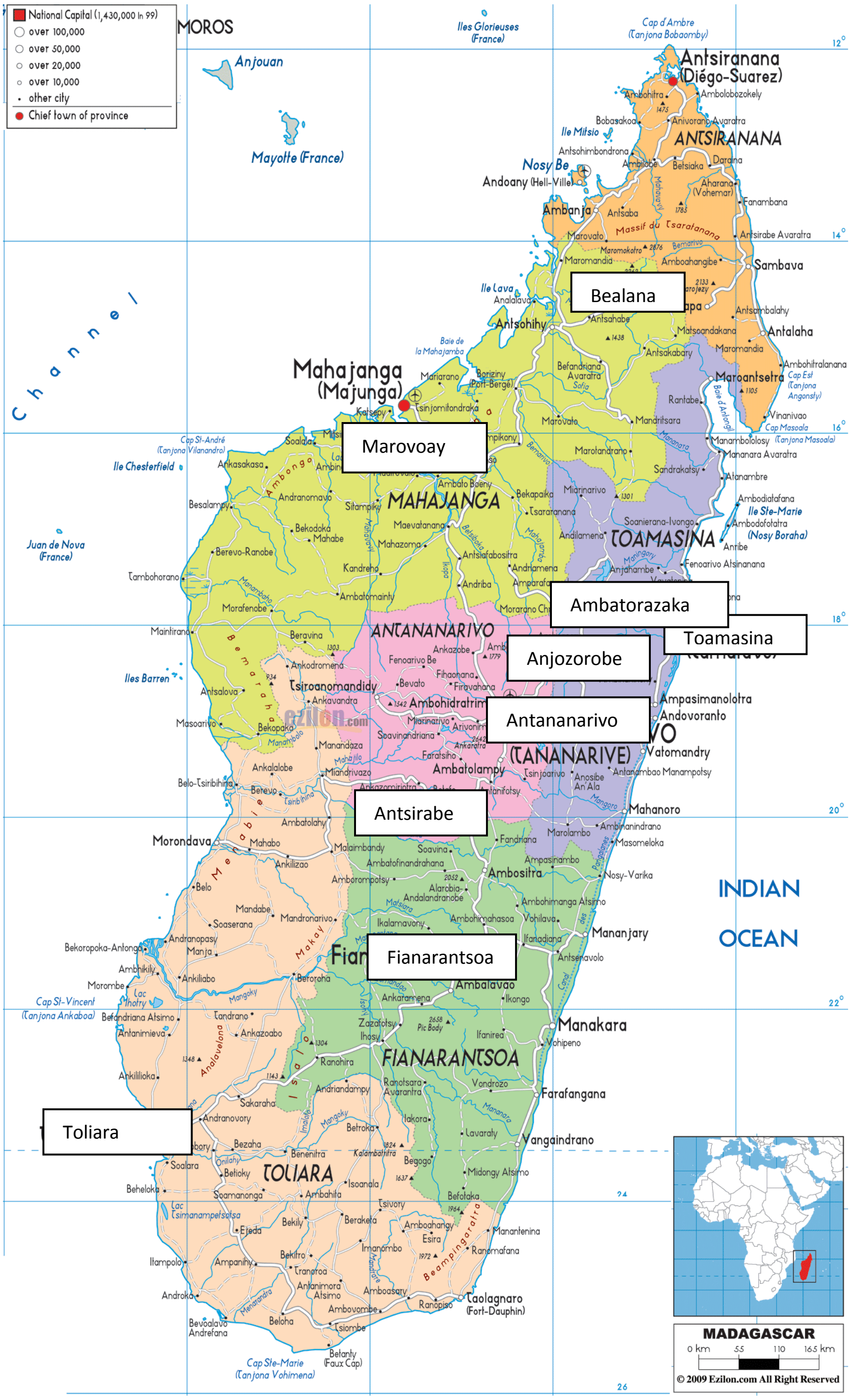

Table 1. Results of the TAR model, from July 2007 to December 2009

			without time trend				with time trend				
			TAR （ρ）	half-life	θ		TAR	trend （ρ'）	half-life	θ at t=0	θ at t=T
Bealana	MAHAJANGA	SOFIA	-0.092**	7.178	0.202		-0.089	-0.000	7.473	0.299	0.171
			(0.031)				(0.063)	(0.001)			
Marovoay	MAHAJANGA	BOEY	-0.242***	2.500	0.086		-0.254*	-0.000	2.368	0.117	0.074
			(0.058)				(0.107)	(0.001)			
Toamasina I (CL)	TOAMASINA	ATSINANANA	-0.263***	2.272	0.020		-0.400*	0.002	1.358	0.020	0.020
			(0.059)				(0.153)	(0.002)			
Aambatorazaka	TOAMASINA	ALAOTRA MANGORO	-0.171***	3.707	0.196		-0.345**	0.002	1.640	0.194	0.228
			(0.044)				(0.111)	(0.001)			
Anjozorobe	ANTANANARIVO	ANALAMANGA	-0.082*	8.080	0.209		-0.218	0.001	2.822	0.088	0.268
			(0.035)				(0.124)	(0.001)			
Tsiroanomandidy (CL)	ANTANANARIVO	BONGOLAVA	-0.195***	3.201	0.174		-0.166	-0.000	3.807	0.174	0.174
			(0.056)				(0.099)	(0.001)			
Antsirabe I (CL)	ANTANANARIVO	VAKINAKARATRA	-0.393***	1.390	0.054		-0.491**	0.001	1.027	0.049	0.091
			(0.068)				(0.167)	(0.002)			
Fianarantsoa I (CL)	FIANARANTSOA	HAUTE MATSIATRA	-0.156**	4.090	0.133		-0.137	-0.001	4.689	0.100	0.178
			(0.048)				(0.116)	(0.002)			
Toliara I (CL)	TOLIARA	ATSIMO-ANDREFANA	-0.270***	2.201	0.202		-0.009	-0.005*	75.664	0.202	0.202
			(0.064)				(0.127)	(0.002)			

Note: All models are estimated without a constant. Rho (ρ) denotes the adjustment parameter on the lagged price difference (expressed as the percentage of mean price in the two markets), and theta (θ) is the threshold (also expressed as a percentage of mean price). A half-life is the time that is needed for a given shock to return to half its initial value and calculated as Half-life=ln(0.5)/(ln(1+ρ)), and with time trend, Half-life*t=ln(0.5)/(ln(1+ ρ+ ρ'*t)). Following Van Campenhout (2007), 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% of the observations were either within or outside the band formed by the thresholds. Standard errors are in parentheses. *, **, and ** denote parameter estimates significantly different from zero at the 10%, 5% and 1% significance, respectively.

Table 2. Results of the TAR model, from July 2010 to October 2013

			without time trend				with time trend				
			TAR (ρ)	half-life	θ		TAR	trend (ρ')	half-life	θ at t=0	θ at t=T
Bealana	MAHAJANGA	SOFIA	-0.091***	7.255	0.373		-0.062	-0.000	10.767	0.372	0.381
			(0.025)				(0.061)	(0.001)			
Marovoay	MAHAJANGA	BOEY	-0.247***	2.449	0.150		-0.396***	0.002	1.376	0.096	0.167
			(0.052)				(0.109)	(0.001)			
Toamasina I (CL)	TOAMASINA	ATSINANANA	-0.135***	4.769	0.051		-0.178*	0.001	3.532	0.113	0.034
			(0.039)				(0.069)	(0.001)			
Aambatorazaka	TOAMASINA	ALAOTRA MANGORO	-0.071**	9.394	0.209		-0.109*	0.000	6.006	0.210	0.182
			(0.024)				(0.052)	(0.001)			
Anjozorobe	ANTANANARIVO	ANALAMANGA	-0.083**	7.976	0.338		-0.174*	0.001	3.630	0.305	0.345
			(0.028)				(0.074)	(0.001)			
Tsiroanomandidy (CL)	ANTANANARIVO	BONGOLAVA	-0.161***	3.937	0.151		-0.295**	0.002	1.981	0.146	0.157
			(0.037)				(0.098)	(0.001)			
Antsirabe I (CL)	ANTANANARIVO	VAKINAKARATRA	-0.165***	3.847	0.113		-0.136	-0.001	4.738	0.113	0.068
			(0.044)				(0.084)	(0.001)			
Fianarantsoa I (CL)	FIANARANTSOA	HAUTE MATSIATRA	-0.093**	7.065	0.039		-0.087	-0.000	7.616	0.082	0.039
			(0.032)				(0.067)	(0.001)			
Toliara I (CL)	TOLIARA	ATSIMO-ANDREFANA	-0.171***	3.699	0.033		-0.224***	0.001	2.726	0.040	0.026
			(0.041)				(0.066)	(0.001)			

Note: All models are estimated without a constant. Rho (ρ) denotes the adjustment parameter on the lagged price difference (expressed as the percentage of mean price in the two markets), and theta (θ) is the threshold (also expressed as a percentage of mean price). A half-life is the time that is needed for a given shock to return to half its initial value and calculated as Half-life=ln(0.5)/(ln(1+ ρ)), and with time trend, Half-life*t=ln(0.5)/(ln(1+ ρ+ ρ'*t)). Standard errors are in parentheses. *, **, and ** denote parameter estimates significantly different from zero at the 10%, 5% and 1% significance, respectively.