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Implications of conceptual and data complexities on time-series econometric applications in market integration analysis

This article demonstrates and highlights the conceptual limits of current empirical market integration (MI) time series models (threshold models) and their implications on market efficiency and competitive equilibrium conclusions. The complexities and diversities that characterise the analysis of the concept of market integration are evaluated within the framework of Enke-Samuelson-Takayama-Judge (ESTJ) spatial equilibrium theory. The efficiency and competiveness implications drawn from MI models are limited by how the data generation process (DGP) is influenced by equilibrium conditions, by the tradability restrictions of the inter-markets relationships and by the presence of unobserved transactions costs. However, empirical applications scarcely address these limitations. Two sets of synthesized data with varying levels of non-linear complexity implied by alternating equilibrium conditions are generated to demonstrate conceptual limits of current threshold models in market integration analysis. Inconsistent conclusions that linear representations imply for threshold propagated DGP will also apply for conclusions derived from threshold models if markets are characterised by switching equilibria conditions.

Keywords: market integration, switching equilibria, threshold models, transactions costs.

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Introduction

The concept of market integration (MI) has received considerable treatment in both classical and applied economics literature. The concept is fundamentally based on market equilibrium theory in its static version of market competitiveness and structural conditions on the one hand and arbitrage processes in the dynamic framework on the other. Economic efficiency and welfare issues have underpinned many market reforms and arguments for free market economic policies in many countries (Baulch, 1997; Barrett and Li, 2002; WTO, 2006). The importance of understanding the functional structure of markets for the appropriate design and assessment of market policies cannot be overstated.

In a dynamic framework time series tools of varying levels of non-linear complexity have been applied in MI analysis to infer the extent and degree to which markets are integrated (see for example Brorsen *et al*., 1985; Kinnucan and Forker, 1987; von Cramon-Taubadel, 1998; Wohlgenant, 1999; Abdulai, 2000; Goodwin and Piggott, 2001; Meyer, 2004; Fackler and Tastan, 2008; Stephens *et al*., 2008; Moser *et al*., 2009; Butler and Moser, 2010). Based on the adjustment dynamics, these models have attempted to address issues of price transmission asymmetries, structural breaks, trend, transaction costs and threshold cointegration. Under specific model assumptions the nature of these adjustment processes have been used to draw conclusions and implications for market efficiency, levels of competition and market integration.

From a structural perspective, market integration in a spatial (and temporal) equilibrium setting has been demonstrated to be complex (see Spiller and Wood, 1988; Sexton *et al*., 1991; Baulch, 1997; McNew and Fackler, 1997; Barrett and Li, 2002 among others). Here the roles various concepts, such as tradability, contestability, efficiency, transactions costs, market imperfections, time trend and data scarcity, play in inter-markets equilibrium processes and outcomes have been demonstrated. These have also studied how individual concepts or their combined effects affect market integration outcomes and associated modelling implications. In a static regime switching framework, these authors have comprehensively evaluated the MI concept within competitive equilibrium conditions following the Enke, 1951, Samuelson, 1952, and Takayama and Judge, 1971 (ESTJ) market equilibrium theory through parity bound models (PBM)[1].

Though notable improvements have been seen in the time series applications with the application of cointegration tools, error correction models and threshold extensions, the price transmission econometric models still do not provide a comprehensive framework for market integration analysis, as demonstrated through the ESTJ spatial equilibrium theory, especially the PBM. The econometric time-series models tend to be restrictive or tend to address a particular type of inter-market equilibrium condition by assuming *a priori* market integration, or by assuming threshold limits conditional on transactions costs. Where market inter-relationships are characterised by alternating equilibrium conditions over time, as one would expect in many developing markets where market imperfections and inefficiencies exist, parameter estimates and conclusions derived from these types of time-series models can be misleading.

Although this conceptual concern has remained in the literature for over three decades, methodological limitations and their implications on MI conclusions in the context of market structure, data complexity and equilibrium theory are scarcely discussed and addressed in empirical applications of the time series models. Inconsistent conclusions that linear representations imply for threshold autoregressive (TAR) propagated data generating processes (DGP) will also apply for conclusions derived from TAR models if markets are characterised by switching equilibria conditions. This study systematically demonstrates these limits to TAR models with synthesised data generated from two varying levels of non-linear complexity. A general non-linear modelling structure is suggested as a sensible and practical alternative.

[1] A few recent studies (e.g. Stephens *et al*., 2008 and Moser *et al*., 2009) in the dynamic frame have included some components of the basic PBM structure.

The market integration concept

From the literature and empirical work, the concept of market integration has been identified as an indicator of a process of market inter-relationships, evidenced by tradability and the resultant co-movements of market prices in particular, or by an outcome of inter-market process, gauged by arbitrage conditions and the resulting competitive equilibrium.

Market integration analysis has been carried out within the framework of the ESTJ spatial equilibrium model. In general, the model assesses markets inter-connectedness within the concepts of tradability, market equilibrium and efficiency. In its basic setting, Enke (1951) defines trade functions and transportation costs for regions that trade in homogenous goods whereby each region constitutes a single and distinct market separated but not isolated by transportation cost per unit. A state of equilibrium exists between spatially separated markets if conditions for regional producer (supply), consumer (demand) and location price equilibrium are met. Samuelson (1952) showed how this equilibrium process could be formulated into mathematical linear programming problem and illustrated how the maximisation of the objective function could be solved by iterative methods. Following Samuelson's model, Takayama and Judge (1971) reformulated the problem into a quadratic programming setting.

In MI analysis the level of tradability, as might be dictated by trade restrictions, market competition and the cost of arbitrage, determines the level of efficiency and integration of the markets under consideration. From Barrett (2005), tradability signals the transfer of excess demand from one market to another, as captured in actual or potential physical flows, while market efficiency requires the minimisation of inter-market transfer costs and quasi rents from binding quotas in addition to the attainment of competitive spatial equilibrium (Barrett, 2001).

Based on ESTJ spatial equilibrium theory in general one of three consistent long run market conditions applies based on tradability restrictions and arbitrage conditions. These are:

$$E\{P_{At}\} = P_{Bt} + \tau_{ABt} \tag{1}$$

$$E\{P_{At}\} < P_{Bt} + \tau_{ABt} \tag{2}$$

$$E\{P_{At}\} > P_{Bt} + \tau_{ABt} \tag{3}$$

where E is the expectation operator, P_{At} is the price in market A in time t, and τ_{ABt} is the transactions cost involved in trading from market B to A in time t. From the theory, if we take P_{Bt} and τ_{ABt} as given, then P_{At} is expected to be at least equal to P_{Bt} since in this setting, market A is importing from B (see Spiller and Wood, 1988; Sexton *et al*., 1991; Baulch, 1997; Barrett and Li, 2002; Negassa and Myers, 2007 for detailed model characterisation).

In equation (1) competitive equilibrium and perfect integration conditions hold (Baulch, 1997; Barrett and Li, 2002). From (2) the negative expected profit to arbitrage means no attractive opportunities exist for marketing intermediaries to trade and exploit. From Barrett and Li (2002), this is consistent with a spatial competitive equilibrium for non-trading activities (segmented competitive equilibrium) while in equation (3) there exist positive expected returns to inter-market trade, signalling foregone arbitrage opportunities or failed-arbitrage (Fackler and Goodwin, 2001; Park *et al*., 2002). Here markets are characterised by an imperfectly competitive equilibrium in which positive marginal profits to arbitrage are unexploited owing, for example, to oligopsonistic or oligopolistic behaviour or to binding quantitative restrictions on trade (Baulch, 1997; Barrett and Li, 2002). The theory implies that in the long run markets may be characterised by switching equilibria (multiple equilibria in time space) in the following form:

$$R_t^* = \begin{cases} v_t + \upsilon_t & R_t^* > 0 \quad \text{Regime 2} \\ v_t \qquad \text{if} & R_t^* = 0 \quad \text{Regime 1} \\ v_t - \upsilon_t & R_t^* < 0 \quad \text{Regime 3} \end{cases} \tag{4}$$

where R_t^* is the difference between two market prices at time t, given transactions cost, υ_t represents unexploited rent or costs which can be attributed to market imperfections, trade restrictions or segmentation. The v_t error component describes perfect integration conditions where rent levels do not significantly differ from zero and as such are represented by a normally distributed error. In short, the equilibrium theory in effect implies that switching techniques are required to capture market integration dynamics within the various equilibrium conditions if they alternate over the time period under consideration.

The parity bound model (PBM) has been applied in the above framework with varying levels of non linear restrictions while TAR models have been developed in the dynamic framework to address non-linearities imposed by transaction costs. Thus, from a price transmission stand point (threshold modelling), transaction costs constrain price transmission and the exhaustion of arbitrage opportunities to a given threshold. If transaction costs play a role in the adjustment process then integrated markets are characterised by TAR models (see Tong, 1983; Tsay, 1989; Balke and Fomby, 1997; Goodwin and Piggott, 2001 for detailed exposition). In general, TAR models can be represented as follows:

$$R_t = \beta R_{t-1} + u_t \tag{5}$$

where R_t represents the price differentials ($P_{At} - P_{Bt}$) or rent; u_t is a white noise error term; and beta is a parameter that indicates the extent to which price differentials adjust in the period that follows a price shock. Two forms of TAR effects are identified, the band-TAR and the equilibrium TAR. In the former case when arbitrage or rent levels significantly fall or exceed cost of arbitrage or a given margin, market forces lead to the correction of that deviation only to the lower or upper bound of the threshold band respectively. In the equilibrium TAR however, the adjustments or corrections move into the threshold band, towards where the equilibrium point lies. That is, unlike the usual TC-based TAR effects, a form of adjustment activities can also occur within the band (see Balcombe *et al*., 2007 for methodological perspective of the two TAR forms).

For threshold effect (b-TAR), imposed by transaction costs, the following relationship holds between changes in price differentials and previous values:

$$\Delta R_t = \begin{cases} \rho_1(R_{t-1} - \tau_1) + u_1 & \text{if } \infty > R_{t-1} \geq \tau_1 \\ \rho_0 R_{t-1} + u_2 & \text{if } \tau_1 > R_{t-1} > \tau_2 \\ \rho_1(R_{t-1} + \tau_2) + u_3 & \text{if } \tau_2 \geq R_{t-1} > -\infty \end{cases} \quad (6)$$

where R_{t-1} represents the lag of price differentials (rent), $\rho = \beta - 1$, τ_i stands for transactions costs and ρ_i depicts regime specific adjustment parameter. Compared to the complete equilibrium model defined in equation (4), the TAR models imply a particular scenario of inter-market relations where in the long run all profit to trade is zero, that is, equation (1) above or assuming threshold cointegration effects. The ESTJ theory however, postulates that three long run market equilibrium conditions are possible: whether in the long run arbitrage rent is greater, equal or less than the inter-market transactions cost, whether or not trade actually occurs.

If equilibrium conditions alternate between these regimes, TAR models that do not incorporate regime switching beyond the threshold band will underestimate parameter values for periods of market integration phase. Hence, as noted above, inconsistent conclusions that linear representations will imply for TAR propagated DGP will also apply for conclusions derived from TAR models if markets are characterised by switching equilibria conditions. For instance, asymmetries and price irreversibility/stickiness may be implied while in fact the markets might be characterised by alternating equilibrium conditions driven by policy changes, inefficient market institutions or inter-markets segmentations that result from seasonal bumper harvests of many developing markets.

Synthesised market data

Price differentials are generated based on the above ESTJ theoretical framework and reflect the *process* of integration by taking into account the time series characteristics of the data. Thus, when tradability holds price transmission is implied, at least conditional on transactions costs. The base model for the TAR evolves from the perfect market integration condition as specified in equation (1), which translates into (5) in time series settings. Two data sets were used for the demonstration. One set comes from a purely transaction costs (TC) based TAR propagated data generating process while the other adds another layer of non-linear complexity imposed by inter-market segmentation as implied by equations (2 and 3) above. The first set was utilised to highlight the strengths of the TAR models when the non-linear complexity is imposed by transaction costs on the adjustment process in the inter-market relationship. The resultant series is denoted as series *A*, where $\rho_1 = -0.78$ at expectation, ($\beta_1 = 0.22$) and presented in Figure 1 as a simple non-linear series. This means that when trade occurs rent is fully and quickly exhausted and as such price differentials revert to TC (τ) bounds. To focus on real inter-market conditions beyond normal TC-created autarky conditions we specify $\tau_1 = \tau_2 = 8.3$, indicating symmetric structure; with 1.0 innovation (u) variance and ρ_0 set at 0 at expectation (thus, $\beta_0 = 1$), which defines random walk process within the threshold band. To exemplify the strengths and limits of current TAR models we have concentrated on the dynamics that associate with inter-markets equilibrium processes as dictated by various levels of market efficiency or inefficiency. In effect, the complexity that a trend component in the time series can impose on TAR modelling, especially on transaction costs (see van Campenhout, 2007) and the latter's non-constant implications, are not included in this demonstration. This was done to avoid dampening the strengths of classical TAR models in identifying transactions cost motivated threshold effects.

The second data set is characterised by relatively complex non-linear processes that reflect switches between inter-markets conditions within the equilibrium structure identified

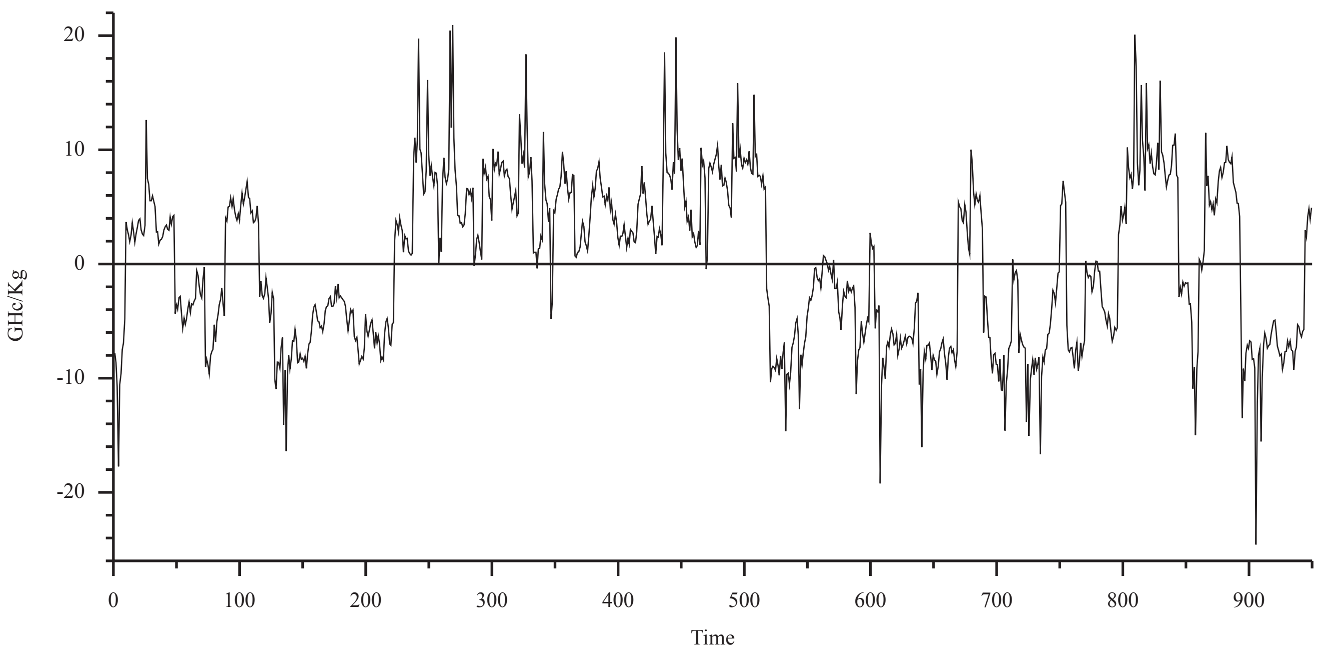

Figure 1: Simple non-linear price differentials series (Series *A*)

Source: Author's own construct (with OX).

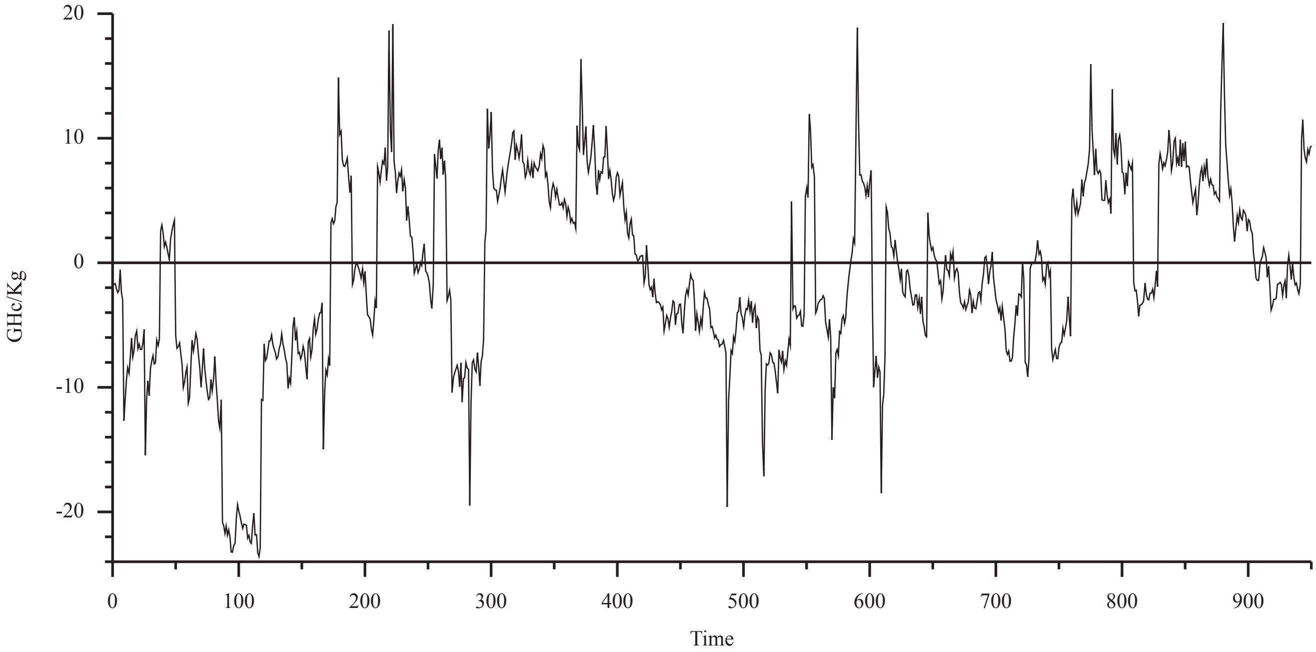

Figure 2: relatively complex non-linear price differentials series (Series *B*)
Source: Author's own construct (with OX).

in equations (1) to (4). Unlike series *A,* regime changes that follow the theoretical implications of arbitrage behaviour under imperfect or segmented market equilibrium conditions were imposed. This series is denoted as series *B* (Figure 2). Here, ρ_1 was set to negative 0.78 (beta = 0.22) for tradability periods beyond the threshold point of 8.3 with normally distributed errors with variance one as in the perfect integration case considered above. In addition, two periods of 'stylised' imperfect/segmented market conditions were fixed around time points (71:115 and 621:675). In these periods $\rho_1 = 0$ was implied to reflect inter-market segmentation periods. Again, trend and non-constant TC were not included in the series for reasons noted above.

Results

In this section we analyse these two series using the b-TAR as time series MI measurement tool. In typical TAR applications the transactions cost levels are not known but estimated from the model. Given these data sets, we imposed the usual economic assumptions that drive MI assessment models on the DGP and employed the b-TAR tools. The TAR model as defined in equation (6) is applied to the above data sets. We utilised general SETAR set up with the Markov-switching package (MSVAR) of Krolzig (1998) on OX 3.2 platform.

The analysis from b-TAR models for series *A* is presented in Table 1. The results from the null (linear AR) model are presented in the second column, while estimates from the b-TAR model are shown in the third column.

The test for the presence of threshold effects against the null of linear representation strongly favours the former as indicated by the likelihood ratio (LR) statistic and highly significant p-value for Davies statistic. The estimated threshold points of (-7.84 and 7.73) for series *A* under estimate the true threshold points of 8.3 in absolute terms, but when the innovations variance is taken into account the differences are not significant. The mean values and their associated standard errors for the series also point to same direction. The estimated values for rho (ρ_1 and ρ_0) strongly point to rapid adjustment process that characterises the series when the threshold point is exceeded (ρ_1 = -0.8647 (0.078) and -0.8087 (0.086) for regimes 1 and 3 respectively); and near random walk process within the threshold band as rho for this regime (ρ_0 = -0.0367 (0.020)) does not differ significantly from zero. From the second column, however, the TAR effect has blurred the rapid adjustment phases in the linear representation with indication of strong persistence in the inter-markets relationship (ρ = -0.086 (0.013)). Thus the strength of TAR models in this respect is clear.

The results from series *B* are presented in Table 2. Here, critical issues with general TAR models are highlighted,

Table 1: TAR analysis for simple non-linear relations (Series *A*)

Variable	Linear Model	B-TAR Model		
		Regime 1	Regime 2	Regime 3
Treshold point		R_1 ≤ -7.84	-7.84 ≤ R_1 ≤ 7.73	R_1 ≥ 7.73
Constant	0.0110 (0.092)	-7.8179 (0.796)	0.0009 (0.099)	7.4794 (0.884)
R(t-1)	-0.0860 (0.013)	-0.8647 (0.078)	-0.0367 (0.020)	-0.8087 (0.086)
Reg Probabilities	1.0000	0.1423	0.6986	0.1591
LR (Davies)		173.583 (0.000)***		

***,**,* represent significance levels under 1, 5 and 10%
Source: Own Analysis with MSVAR 3.1

Table 2: TAR Estimates of Complex Non-linear Series (Series *B*)

Variable	Linear Model	B-TAR Model		
		Regime 1	Regime 2	Regime 3
Treshold point		R_1 ≥ 7.68	7.68 > R_1 > -5.67	R_1 ≤ -5.67
Constant	0.0769 (0.043)	5.6156 (0.901)	-0.0647 (0.090)	-0.0726 (0.432)
R(t-1)	-0.1860 (0.018)	-0.6390 (0.091)	-0.0168 (0.022)	-0.0583 (0.038)
Reg Probabilities	1.0000	0.1380	0.6080	0.2540
LR (Davies)		79.30(0.000)***		

***,**,* represent significance levels under 1, 5 and 10%
Source: Own Analysis with MSVAR 3.1

when there are relatively complex inter-market processes and the data are generated by a mixture of threshold and switching market equilibrium conditions.

Like series *A*, the null of linear representation is again rejected as indicated by the LR and the Davies statistics. To evaluate the presence of TAR, it is expected that the adjustment process in some periods is governed by threshold effects as a result of TC constraints where rho (ρ_1) should not differ significantly from zero to reflect random walk nature of the price differentials within the threshold band. The intermediate regime, regime 2, is clearly characterised by strong persistence implied by TAR representation.

From regime 3, however, unlike the simple non-linear data set considered in Table 1, the impact of the complex data set has significantly understated the threshold point (-5.73). More importantly, in contrast to the *perfect* integration system considered above, the strong rent correction implied by periods of perfect integration (-0.8647 (0.078) and -0.8087 (0.086) for regimes 1 and 3 respectively for series *A*) is blurred by the strong persistence that characterises segmented inter-markets phases that do not follow any threshold process in series *B* within regimes 1 and 3 (-0.6390 (0.091) and -0.0583 (0.038)) respectively. This is more pronounced for regime 3 where the majority of the observations under segmentation periods fell beyond the threshold point. Again, from Table 2, both estimated threshold and adjustment parameters indicate that the system is characterised by strong asymmetries even though no asymmetric constraints were imposed.

Discussion

In general these results from the SETAR models with respect to series *B* do not point to strong conclusion for TC-based threshold effects where rent correction parameter (ρ_1) values for regimes 1 and 3 are expected to be high in absolute terms. As explained under the theoretical concepts above, complete market integration conceptualisation alters the threshold space with an additional layer of non-linear complication. In this respect the three state b-TAR model would not produce estimates that a pure TC-based threshold DGP will suggest.

These complications suggest that when a mixture of TAR and switching inter-market conditions ensue, threshold models may miss the true inter-markets dynamics that govern the system. The results presented above show that asymmetric conclusions reached by many MI studies that do conduct other institutional assessment for their causes may have merely come from complex inter-market DGP *vis-à-vis* inherent weakness of current time series models. Meyer and Cramon-Taubadel (2004) have raised mis-specification issues in explaining asymmetric adjustments. Moreover, depending on the nature of non-linear complexity that governs the DGP the estimated adjustment parameters and levels of threshold constraints derived from TAR specifications can be misrepresentations of the true equilibrating structure if switching inter-markets equilibrium conditions hold. Recent survey and meta-analysis of price transmission coefficients from studies that have been conducted in the sub-Sahara African markets by Amikuzuno and Ogundari (2012) point to same conclusion demonstrated above. It was shown that price transmission coefficients in the primary studies that applied the PBM tended to be more likely to have higher (about 0.20 units) estimated coefficients than those that do not use this method. That is, higher rates of rent correction in our TAR formulation. Their study also found that studies that tested for units roots were more likely to obtain lower estimates of price transmission coefficients (about 0.13 units lower) than studies which did not test for unit roots. Clearly, time series data that generate rent series which are characterised by switching inter-markets segmentation and integration have a higher probability of testing for units roots.

The above analyses of the simple and complex non-linear sets in the context of ESTJ equilibrium conditions point to the fact that the TAR assessment tools for MI analysis have their particular strengths. However, the nature of the true underlying data generation process, resulting from inter-market rent dynamics may not follow the threshold effects as the model assumes. Additional non-linear attributes and dynamics can lead to different results and conclusions if they are not taken into account.

Conclusions

Time series econometric tools have dominated market integration and price transmission analysis in the applied economics and commodity markets literature. However, while market inter-relationships in time space can be characterised by switching equilibria conditions (implied by the market integration concept) and are taken into account in PBM applications, studies that utilise time series econometric models scarcely discuss and accommodate these. As a reminder, this study has demonstrated through market equilibrium theory and synthesised data the non-linear complications that are imposed on MI tools and their implications for MI conclusions. The consequences of representing the true data generation process with different model specification assumptions on market integration processes are illustrated by the application of two different data sets with various levels of non-linear complications. Methodologically, shortfalls and strengths of the SETAR models as the main current frontier of time series applications in MI analysis have been demonstrated under specific inter-markets equilibrium conditions.

It is suggested that hierarchical models or sample splitting methods (see Abunyuwah, 2008; van Campenhout, 2009) that are applicable in other complex non-linear modelling fields should be explored to accommodate the complete equilibrium structure along the PBM. In sample splitting procedure for instance, the complications imposed by threshold effects and the threshold band in particular, can be addressed by concentrating out the transaction costs component of the data/series so that the alternating adjustment processes imposed by switching equilibrium conditions can be assessed by regime switching methods for dynamic models. The broadness of the concept demands that each market analysis with respect to methods and data must be supported by institutional analysis as a guide to attaching socio-economic significance to significant econometric results.

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