ECONOMIC THEORY AND ECONOMETRIC METHODS IN SPATIAL MARKET INTEGRATION ANALYSIS

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For Rosi, René, Mónica, Móniquita, Dolores,

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Through the last six year, I have been living is a sort of self-exile driven by my own ideas about experiencing life in a foreign country. At this stage I feel alienated not only here, but at homeland as well. Somehow, as one Professor once said: “You will become a citizen of the world”, so that defining homeland is no longer straightforward in my situation. Along with the many sacrifices, i.e. spicy food, that have been done for pursuing a life abroad, there are invaluable rewards; the most important for sure is the chance of meeting wonderful people trough the journey.

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Finally, I would like to show some quote which personally I consider interesting. Honestly I not only share the views of the authors who wrote those words, but also admire them.

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Some phrases that reflect the contradictory human nature of this particular Ph.D student regarding his views about the whole experience abroad

"Espero alegre la salida y espero no volver jamás"

— Frida Kahlo

"These are days you'll remember
Never before and never since, I promise,
will the whole world be warm as this …"

— Robert Buck & Natalie Merchant, *Lyrics from "These are days"*

".. this place needs me here to start
this place is the beat of my heart…"

— Michael Stipe, Peter Buck, Mike Mills & Scott McCaughey, *Lyrics from "Oh my heart"*

"Running through a field where all my tracks will be concealed
and there is nowhere to go"

— Flea, Frusciante, Kiedis & Smith, *Lyrics from "Snow (Hey Oh)"*

Historical and contemporaneous views/critiques regarding education which I share

"Undergraduates today can select from a swathe of identity studies.... The shortcoming of all these para-academic programs is not that they concentrate on a given ethnic or geographical minority; it is that they encourage members of that minority to study themselves - thereby simultaneously negating the goals of a liberal education and reinforcing the sectarian and ghetto mentalities they purport to undermine."

— Tony Judt, *The Memory Chalet*

"The proper function of an University in national education is tolerably well understood. At least there is a tolerably general agreement about what an University is not. It is not a place for professional education. Universities are not intended to teach the knowledge required to fit men for some special mode of gaining their livelihood. Their object is not to make skilful lawyers, or physicians, or engineers, but capable and cultivated human beings."

— John Stuart Mill, *Inaugural Address Delivered to the University of St. Andrews*

"El contexto de crisis-cambio-globalización está marcado por una crisis en el terreno moral, que no se puede soslayar o evadir socialmente y por ello es creciente la demanda social que exige a las instituciones educativas y a los educadores ocuparse eficazmente de la formación moral que promueva un cambio hacia el mejoramiento de la convivencia social que requiere orientarse hacia la humanización individual y colectiva y no solamente, como parece orientarse hoy en día, hacia la maximización de las ganancias económicas"

— Martín López Calva

Views of other people regarding justice, responsibility and solidarity that I share

“If we remain grotesquely unequal, we shall lose all sense of fraternity: and fraternity, for all its fatuity as a political objective, turns out to be the necessary condition of politics itself.”

— Tony Judt, *Ill Fares the Land*

“The increasing tendency towards seeing people in terms of one dominant ‘identity’ (‘this is your duty as an American’, ‘you must commit these acts as a Muslim’, or ‘as a Chinese you should give priority to this national engagement’) is not only an imposition of an external and arbitrary priority, but also the denial of an important liberty of a person who can decide on their respective loyalties to different groups (to all of which he or she belongs).”

— Amartya Sen, *The Idea Of Justice*

"Somos la memoria que tenemos y la responsabilidad que asumimos, sin memoria no existimos y sin responsabilidad quizá no merezcamos existir"

— José Saramago, *Cuadernos de Lanzarote*.

“Podrán morir las personas, pero jamás sus ideas”

— Ernesto “Che” Guevara

“Las masas humanas más peligrosas son aquellas en cuyas venas ha sido inyectado el veneno del miedo… del miedo al cambio”

— Octavio Paz

"A nation's greatness is measured by how it treats its weakest members"

— Mahatma Ghandi

“Trabajar incansablemente por establecer la justicia y el derecho en un nuevo orden mundial, para consolidar una paz inalterable y duradera, y así conjurar definitivamente el flagelo de la guerra; continuar construyendo el nuevo modelo de unidad, con el respeto a las diferencias y a los derechos de los más pequeños, así en la sociedad, como en el seno de las diferentes confesiones religiosas; Apoyar las tareas de protección y conservación de la tierra, hogar común y herencia para las nuevas generaciones ; Participar, según el lugar que tenemos social y religiosamente, en la construcción de ese ‘otro mundo posible’; Colaborar con el Padre en esta Nueva Hora de Gracia: en su obra siempre creadora y siempre redentora, manifestada en esos brotes tiernos que prometen buenos y abundantes frutos”

—Samuel Ruiz García

What some Authors wrote and I really enjoy

"Sabed que en mis labios de granito quedaron detenidas las palabras"

— Rosario Castellanos, *Epitafio*

"– ¿Y hasta cuándo cree usted que podamos seguir en este ir y venir del carajo? – le preguntó Florentino Ariza tenía la respuesta preparada desde hacía cincuenta y tres años, siete meses y once días con sus noches
– Toda la vida – dijo."

— Gabriel García Márquez, *El amor en los tiempos del cólera*

"Dios, invención admirable,
hecha de ansiedad humana
y de esencia arcana,
que se vuelve impenetrable."

— Guadalupe "Pita" Amor, *Décimas a Dios*

"Todo lo que es hecho, todo lo humano de la Tierra es hecho por manos"

— Ernesto Cardenal

"Tierra desnuda, tierra despierta, tierra maicera con sueño…"

— Miguel Ángel Asturias, *Hombres de Maíz*

"Todo dura siempre un poco más de lo que debería"

— Julio Cortázar, *Rayuela*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
AR(p)	Autoregressive of order p
ECM	Error Correction Model
JTT	Johansen Trace Test
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
LOP	Law of One Price
LTD	Lagged Trade Disequilibrium Model
MARD	Moving Average Restriction Disequilibrium Model
MLE	Maximum Likelihood Estimator
NSP	Net Social Payoff
OLS	Ordinary Least Squares
RRD	Restrictive Recursive Disequilibrium Model
SEC	Spatial Equilibrium Condition
SMI	Spatial Market Integration
TAR	Threshold Autoregressive Model
TJM	Takayama Judge Price and Allocation Model
TVAR	Threshold Vector Autoregressive
TVECM	Threshold Vector Error Correction Model
VAR	Vector Autoregressive Model
VECM	Vector Error Correction Model
WND	White Noise Disequilibrium Model
WNE	White Noise Equilibrium Model

INTRODUCTION

The study of Spatial Market Integration (SMI) has been of great concern for agricultural economists for quite some time now, with the Takayama and Judge Price and Allocation Model (TJM) in which prices are bounded by the Spatial Equilibrium Condition (SEC) being the core economic theory (Faminow & Benson, 1990; Fackler & Goodwin, 2001; Barrett, 2001). The SEC implies that no profits are made from trading goods among spatially separated regions; mathematically it can be written as $p_j - p_i \leq \tau_{ij}$, where p_j and p_i are the prices of a homogeneous good in regions j and i respectively, and τ_{ij} is the cost of moving one unit of the good from region i to region j. Fackler & Goodwin (2001) refer to the SEC as a weak form of another important concept in market integration: the Law of One price (LOP). Indeed the LOP denotes perfect market integration by a linear relationship such that $p_j - p_i = \tau_{ij}$ and it is regarded as a perfect equilibrium. There is also the concept of market efficiency, which can be understood as markets being cleared, that is an optimum allocation of the resources which leads to the correct pricing of the goods. In theory, when trade occurs among regions the excess supply and demand signals are transferred to the prices of the goods among trading regions, in a way that prices move together among the regions. For some authors such as Fackler & Goodwin (2001) or Ravallion (1986) the price co-movement is defined as market integration, nevertheless it is important to point out that prices co-movement does not necessarily lead to a Pareto efficiency (Barrett, 2005).

Most of the research which has been done until now in the field of SMI deals with prices mainly because prices are easily accessible and they capture the shocks in supply and demand that link the markets. The early work done in the field dealt with price correlations and regressions (Goodwin & Piggott, 2001; Fackler & Goodwin, 2001) and often found weak support in favour of the LOP. Later, with the development of the concept of cointegration, new econometric techniques such as Vector Autoregressive Models (VAR's), Impulse Response Functions (IRF's) and Vector Error Correction Models (VECM's) provided support in favour of the LOP (McNew, 1996; Fackler & Goodwin, 2001); as for that such methods have become the standard tools in market integration analysis. However, such methods suffers from neglecting the role of the SEC by depicting the equilibrium as a linear relationship such as the LOP. In this regard Obstfeld & Taylor (1997) and Goodwin & Piggott (2001) proposed that prices are only linked when the price differences are found beyond the transaction costs. Indeed acknowledging the role of the transaction costs served as a justification for using non-linear methods.

The type of non-linear techniques which have been used for market integration analysis originated whit the concept of the Threshold Auto Regressive (TAR) model proposed by Tong (1978), for which Tsay (1989) propose testing and estimation methods. The idea of the threshold model is that the parameters change their value beyond certain threshold value. Taking Tong's idea of a regime dependant model, Balke & Fomby (1997) introduced the concept of Threshold Error Correction which considers a non-linear or threshold adjustment process error term, their definition of Threshold Error Correction is based on the adjustment process which is activated beyond a certain threshold value. While the adjustment process globally is stationary, locally it has unit roots. The Threshold Error Correction idea has been extended to different models, for instance Lo & Zivot (2001) used it on a Threshold Vector Autoregressive (TVAR) model in order to evaluate market integration. Nonetheless, it was the work done by Hansen & Seo (2002) the first "full statistical treatment", which allowed Threshold Error Correction to be estimated and tested for (Gonzalo & Pitarakis, 2006) in the context of a Threshold Vector Error Correction Models (TVECM's). Indeed, the fact that the TVECM includes a regime often referred to as the neutral band, which is analogous to the SEC, has served to popularize such a model within the area of Spatial Market Integration analysis.

While the TVECM has served to overcome the issue of regime dependant price behaviour, it still has some pitfalls such as considering a constant threshold on the long run which is quite restrictive. Some recent research has focused on improving the econometric techniques for estimating the TVECM, such as, for example, through the use of thresholds as smooth functions or Bayesian methods to improve the estimation. Nonetheless, economic theory still suffers from an unclear definition of market integration and little attention is given to the theoretical implications that market integration has (McNew, 1996; McNew & Fackler, 1997). Following this concern one can question to which extent the TVECM is the correct instrument for evaluating Spatial Market Integration when little attention has been paid to the theoretical models, namely to the Takayama and Judge Price and Allocation Models.

With the following thesis the author aims to compare the economic theory and the standard econometric techniques used in Spatial Market Integration in order to evaluate whether or not the TVECM is the correct specification for Spatial Market Integration analysis as it is claim or assumed in the literature.

Chapter One introduces the seminal equilibrium model: the Takayama Judge Price and Allocation Model (TJM) which serves as the ground theory for Spatial Market Integration. It also introduces the TVECM and the standard econometric techniques used in the estimation of the TVECM. Then, using the equilibrium model, artificial prices are generated (Monte Carlo simulations) under the SEC. For the simulations the true parameters are known, hence if the

TVECM is the correct specification the estimated parameters from the TVECM have to be unbiased with respect to the true parameters.

Chapter Two starts off with an introduction to the econometric concept of cointegration and the testing procedures of linear cointegration, namely the ADF, KPSS and JTT Tests. Then the concept of Threshold Error Correction is explained followed by the standard statistical tests for Threshold Error Correction, namely the Hansen & Seo (2002) and Seo (2006) Tests. The main aim is to test whether the data which is economically integrated in equilibrium serves to econometrically test for Threshold Error Correction for which five conditions are proposed to be fulfilled.

Chapter Three addresses the incompatibilities between pure equilibrium data and the TVECM found in the previous chapters. Following such concern some modifications to the original Takayama and Judge Allocation Models are proposed in order to obtain prices beyond the SEC. The rationale of the processes which violate the SEC is based on economic theory, with the focus being random transport costs, random errors in trade, random and average moving restrictions in trade and delayed flows of trade. Following the procedure in Chapter One, the new models are used to generate prices (Monte Carlo simulations) for which the true threshold value is known. Then those prices are used to estimate the threshold parameter(s) under the TVECM.

The last Chapter is a summary of the major findings regarding the compatibility between the economic theory and the econometric methods. The purpose is to point out the importance of improving vague and ambiguous definitions in economic and econometric theory; for that plausible alternatives are reviewed. Along with the lack of sound theory is the fact that empirical applications often do not support theory; this is exemplified with two studies conducted in Mexican and US maize markets.

Nowadays, Spatial Market Integration analysis has a main role in research and policy making, thus the people conducting such analyses have to be more aware of the theoretical implications in order to address properly the conclusions of their empirical work.

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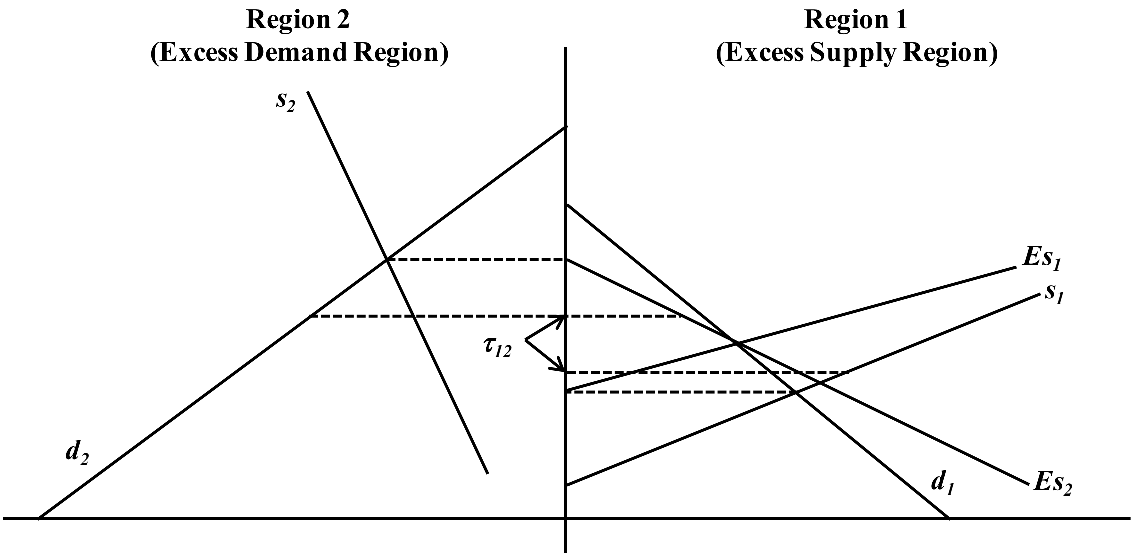
1. UNDERSTANDING THE LINKAGE BETWEEN THE ECONOMIC THEORY AND THE ECONOMETRIC METHODS

The Takayama and Judge Price and Allocation Model (TJM) serves as the theoretical foundation for Spatial Market Integration analysis and in recent years the Threshold Vector Error Correction Model (TVECM) has become the standard method for empirical estimation of the Spatial Market Integration process. Despite the large number of papers that invoke the TJM spatial equilibrium framework and estimate the TVECM, little attention has been devoted to the question of their compatibility. Such an issue is addressed by generating artificial ideal data using the Takayama and Judge Price and Allocation Models and estimating threshold models with such data. The results suggest that the TVECM is not a correct specification of the spatial equilibrium generated by the TJM as it produces biased parameters estimates.

1.1. Introduction to the Takayama and Judge Price and Allocation Models

In the literature the most common model that has been used to describe the concept of Spatial Market Integration is the so called Takayama and Judge Price and Allocation Model (TJM). The TJM denotes a partial equilibrium of which two or more regions trade one or more goods subject to linear constrains. For understanding how the TJM is related with the concept of Spatial Market Integration and its economic theory one should take a closer look at the model and start by assuming two separated regions, region 1 and region 2, which trade a single homogeneous good. One is an excess supply market and the other is an excess demand market. Then, d_1, d_2, s_1 and s_2 denote the demand and supply functions for each region; Es_1 and Es_2 the excess supply function, and τ_{12} the transport costs for moving a unit of product from region 1 to region 2. (Figure 1.1)

Figure 1-1 Equilibrium among two regions trading a single homogeneous good



Source: Own elaboration based on Takajama & Judge (1964)

According to Samuelson (1952), the Net Social Payoff (NSP) can be defined as the sum of all the individual payoffs minus the sum of all the individual transport cost shipments. Takayama & Judge (1964) showed that maximizing the NSP solves for the so called Spatial Equilibrium Condition (SEC). Assuming that the supply and demand curves are linear and have the form

$$d_{t,i} = y_{t,i} = \alpha_i - \beta_i p_{t,i}^d \quad (1.1)$$

$$s_{t,j} = x_{t,j} = \theta_{t,j} + \gamma_j p_{t,j}^s \quad (1.2)$$

where y_i and x_j are the quantities demanded and supplied respectively, $p_{t,i}^d$ and $p_{t,j}^s$ are the demand and supply prices, α_i and $\theta_{t,j}$ are intercepts, β_i and γ_j are positive parameters, and t is the time dimension, thus the NSP can be written as:

$$NSP =$$

$$\sum_t \left(\sum_i \int_0^{\sum_j q_{t,ij}} \left(\frac{\alpha_i}{\beta_i} - \frac{1}{\beta_i} \sum_j q_{t,ij} \right) d\left(\sum_j q_{t,ij}\right) - \sum_j \int_0^{\sum_i q_{ij}} \left(-\frac{\theta_{t,j}}{\gamma_j} + \frac{1}{\gamma_j} \sum_i q_{t,ij} \right) d\left(\sum_i q_{t,ij}\right) - \sum_i a_i - \sum_i \sum_j \tau_{ij} q_{t,ij} \right) \tag{1.3}$$

where q_{ij} denotes the amount of trade between regions, and a_i is the sum of producers and consumers surplus under pre-trade equilibrium. Evaluating equation (1.3) yields equation (1.4)

$$NSP = \sum_t \left(\sum_i \frac{\alpha_i}{\beta_i} \sum_j q_{t,ij} - \frac{1}{2} \sum_j \frac{1}{\beta_i} \left(\sum_j q_{t,ij}\right)^2 - \sum_i - \frac{\theta_{t,j}}{\gamma_j} \sum_j q_{t,ij} - \frac{1}{2} \sum_j \frac{1}{\gamma_j} \left(\sum_j q_{t,ij}\right)^2 - \sum_i a_i - \sum_i \sum_j \tau_{ij} q_{t,ij} \right) \tag{1.4}$$

So far, the algebraic expression has been derived allowing for the NSP as denoted in equation (1.4) to be calculated. For a single period of time the equilibrium among the regions trading is reached when the NSP$_t$ is maximized with respect to the total trade for such a period, that is:

$$M_t = \frac{\partial NSP_t}{\partial q_t} = \frac{\alpha_i}{\beta_i} - \frac{1}{\beta_i} \sum_j q_{t,ij} + \frac{\theta_{t,j}}{\gamma_j} - \frac{1}{\gamma_j} \sum_i q_{t,ij} - \tau_{ij} \tag{1.5}$$

The Kuhn-Tucker conditions for the optimization problem are $M \leq 0$, and $M \times q_{ij} = 0$ for $q_{ij} \geq 0$. Next consider the inverse supply and demand functions such that:

$$p_{t,i}^d = \frac{\alpha_i}{\beta_i} - \frac{1}{\beta_i} \sum_j q_{t,ij} = \lambda_i - \omega_i \sum_j q_{t,ij} \tag{1.6}$$

$$p_{t,j}^s = -\frac{\theta_j}{\gamma_j} + \frac{1}{\gamma_j} \sum_i q_{t,ij} = \nu_{t,j} + \eta_j \sum_i q_{t,ij} \tag{1.7}$$

note that equations (1.6) and (1.7) can be substituted in (1.5) so as to get:

$$M_t = p_{t,i}^d - p_{t,j}^s - \tau_{ij} \leq 0 \tag{1.8}$$

Equation (1.8) is the so called Spatial Equilibrium Condition (SEC), which will be discussed later on. To solve the optimization problem in equation (1.4) the transport costs matrix $\mathbf{T}_{ij}$ contains all the transport cost τ of moving a unit of the commodity from region *j* to region *i,* such that:

$$\mathbf{T}_{ij} \equiv \begin{bmatrix} 0 & \tau_{21} & \cdots & \tau_{n1} \\ \tau_{12} & 0 & \cdots & \tau_{n2} \\ \vdots & \vdots & 0 & \vdots \\ \tau_{1n} & \tau_{2n} & \dots & 0 \end{bmatrix} \tag{1.9}$$

Furthermore, let $\mathbf{Q}_{ij}$ denote the total amount of trade among regions such that:

$$\mathbf{Q}_{t,ij} \equiv \begin{bmatrix} q_{t,11} & q_{t,21} & \cdots & q_{t,n1} \\ q_{t,12} & q_{t,22} & \cdots & q_{t,n2} \\ \vdots & \vdots & \ddots & \vdots \\ q_{t,1n} & q_{t,2n} & \cdots & q_{t,nn} \end{bmatrix} \tag{1.10}$$

Finally, equation (1.4), which is equivalent to the consumer surplus, is rewritten in matrix form so as to get

$$CS = (\lambda - \boldsymbol{\Omega} y)' y - (\nu + \mathbf{H} x)' x - \mathbf{T}'\mathbf{Q} \tag{1.11}$$

where λ is a vector containing all the parameters λ_i in equation (1.6), ν a vector containing all the parameters ν_j in equation (1.7), y a vector containing the quantity demanded for each region y_i, x a vector containing the quantity supplied in each region x_j, and $\boldsymbol{\Omega}$ and $\mathbf{H}$ are matrices containing the parameters ω_i and η_j respectively.

Takajama & Judge (1964) demonstrated that equation (1.11) can be maximized subject to the constrains

$$\begin{bmatrix} \mathbf{G_y} \\ \mathbf{G_X} \end{bmatrix} \mathbf{Q_V} \geqq \begin{bmatrix} y \\ -x \end{bmatrix} \tag{1.12}$$

and

$$y \geqq 0, x \geqq 0, \mathbf{Q} \geqq 0 \tag{1.13}$$

with $\mathbf{G_Y}$ **and** $\mathbf{G_X}$ denoting the matrices which ensures a neutral or positive balance between trade-demand and trade-supply respectively such that:

$$\begin{bmatrix} \mathbf{G_y} \\ \mathbf{G_x} \end{bmatrix} \equiv \begin{bmatrix} 1 & & & & 1 & & & & & 1 & & & \\ & 1 & & & & 1 & & & & & 1 & & \\ & & \ddots & & & & \ddots & & & & & \ddots & \\ & & & 1 & & & & 1 & \cdots & & & & 1 \\ -1 & -1 & \cdots & -1 & & & & & & & & & \\ & & & & -1 & -1 & \cdots & -1 & & & & & \\ & & & & & & & & \ddots & & & & \\ & & & & & & & & & -1 & -1 & \cdots & -1 \end{bmatrix} \tag{1.14}$$

Furthermore, $\mathbf{Q_V}$ denotes a vector containing all the trade among and within the regions which can be written as:

$$\mathbf{Q_V'} \equiv [q_{t,11} \;\; q_{t,12} \;\; \cdots \;\; q_{t,1n} \;\; q_{t,21} \;\; q_{t,22} \;\; \cdots \;\; q_{t,2n} \;\; \cdots \;\; q_{t,n1} \;\; q_{t,n2} \;\; \cdots \;\; q_{t,nn}] \tag{1.15}$$

and $\begin{bmatrix} y \\ -x \end{bmatrix}$ denoting a vector containing all the supply and demand quantities for all the regions such that:

$$\begin{bmatrix} y \\ -x \end{bmatrix} \equiv \begin{bmatrix} y_{t,1} \\ y_{t,2} \\ \vdots \\ y_{t,n} \\ -x_{t,1} \\ -x_{t,2} \\ \vdots \\ -x_{t,n} \end{bmatrix} \tag{1.16}$$

Takayama & Judge (1964) showed that the quadratic maximization problem can be transformed into a linear maximization problem. However the quadratic form is preferred because it is a more straight forward representation of the consumer surplus. The problem solves for demand, supply, trade and prices in the equilibrium condition.

1.2. The Spatial Equilibrium Condition and the Threshold Vector Error Correction Model

After having introduced the TJM equilibrium, the task now concentrates on explaining the linkage between economic theory and the econometric techniques used in Spatial Market Integration Analysis.

1.2.1. Linking the Economic Theory and the Econometric Model

From the TJM, the Spatial Equilibrium Condition was derived, denoted as:

$$p_{t,i} - p_{t,j} \leq \tau_{ji} \tag{1.17}$$

This relationship bounds the prices of a homogeneous good which is traded among two or more spatially separated markets. As its name states, it implies that the prices for such a good within the regions where it is trade are in equilibrium. Under such a scenario, the traders moving the product from market i to market j do not make any profit, as the difference between the prices is less or equal to the transport costs.

The concept of the spatial equilibrium condition is closely linked to the Law of One Price (LOP), which states that prices in spatially separated markets will be equal after exchange rates and transaction costs are adjusted for (Goodwin, 1992), that is:

$$p_{t,j} = \tau_{ji} + p_{t,i}. \tag{1.18}$$

Rather than an economic phenomena, the LOP is a static concept which implies a partial equilibrium among the markets. For instance Barret (2001) and Barret & Li (2002) stress the difference between the LOP and Spatial Market Integration. Spatial Market Integration involves arbitrage force as an error correction mechanism, which in the long run brings prices to the equilibrium relationship, the LOP (McNew & Fackler, 1997), nonetheless in the short run prices might drift apart from the equilibrium. Besides, market integration can be seen as a degree of market connectedness whereby shocks in one market have an impact on another market (McNew & Fackler, 1997). Following the previous idea, market integration can be depicted as a dynamic process whereby prices in equilibrium and disequilibrium coexist together.

Within the literature there are several studies concerning the study of price relations for spatially separated markets; furthermore, many of them use the techniques of cointegration developed by Engle & Granger (1987) and can be classified as linear methodologies. These studies concentrate on the LOP as a long run relationship, and on the estimation of it with econometric techniques, such that:

$$z_t = \tau_{ji} + \beta p_{j,t} - p_{i,t} \tag{1.19}$$

where β denotes the cointegration parameter, z_t denotes the disequilibrium , and the sub-index t denotes the time dimension. Equation (1.19) is part of a system which can be written compactly as

$$\Delta P_t = \Pi P_{t-1} + \Gamma_1 \Delta \mathrm{P}_{\mathrm{t-1}} + \cdots + \Gamma_{\mathrm{p-1}} \Delta \mathrm{P}_{\mathrm{t-p+1}} + \varepsilon_t \tag{1.20}$$

where the matrix Π can be decomposed into $\alpha\beta'$, with α being the loading coefficients. It is only when the estimated parameter β is equal to one when the LOP holds. However, even though the LOP can be rejected, markets can be integrated. For a β different than one, the cointegration parameter can be read as a degree of cointegration (Fackler & Goodwin, 2001; Fackler & Tastan, 2008). The loading coefficients are analogous to the arbitrage force which is the correction error mechanism that brings prices back to its equilibrium.

Albeit its popularity and even though there is still research which follows the linear approach, there are some concerns regarding the use of such techniques. The assumption of a linear price relation has been criticized. Using a controlled experiment based on simulations McNew & Fackler (1997) demonstrated that neither the LOP nor market integration lead to linear price relations. This finding is closely related with the type of relationship that prices have in the equilibrium. While the LOP assumes that prices are equal among markets (market clearance), the spatial equilibrium condition considers the so called neutral band. The neutral band is a region in which the price differences among regions are spread. Inside the band, that is when $p_i - p_j < \tau_{ji}$, trade does not occur among the regions. As trade does not occur, prices within this band are not related and the markets are not cointegrated. It is only when prices are in the border of the neutral band that trade occurs and the LOP holds.

Obstfeld & Taylor (1997) and Goodwin & Piggott (2001) acknowledge the importance of the transaction costs and criticize the fact that linear models neglect the role of transaction costs. For them, only when the price differential between the regions is beyond the threshold value is the linkage between the prices activated and plays a role in restoring the equilibrium. As trade does not occur within the neutral band, there is no mechanism bringing prices to its equilibrium relation; indeed prices are in equilibrium but not cointegrated. Market clearance occurs by means of trade which causes prices to go back to the long run equilibrium, Equation (1.19). Thus, transaction costs are the threshold value which leads to a regime dependent price transmission of which the error correction mechanism is not linear as it changes according to the regime.

Throughout the most recent literature, the so called threshold models have become the workhorse within price transmission analysis. The original Threshold Autoregressive Model (TAR) proposed by Tong (1978) was extended to the concept of Threshold Error Correction by Balke & Fomby (1997). Their work is based on considering a general threshold model with a long run equilibrium denoted as:

$$z_t = \beta p_{j,t} - p_{i,t} \tag{1.21}$$

such that z_t is an autoregressive process

$$z_t = \rho^{(i)} z_{t-1} + \varepsilon_t \tag{1.22}$$

where the parameter $\rho^{(i)}$ has a threshold value θ such that

$$\rho^{(i)} = \begin{Bmatrix} \rho^{(1)}\ if\ |z_{t-1}| \leq \theta \\ \rho^{(2)}\ if\ |z_{t-1}| > \theta \end{Bmatrix} \tag{1.23}$$

The threshold value θ delimits the two regimes and it is equal to the transaction costs such that $\theta = \tau$. According to Balke & Fomby (1997), in the lower regime or regime one, the autoregressive process might have a unit root, and the variables (prices) may either be, or not be, cointegrated. In the upper or second regime, the autoregressive process is stationary, which is a process which is reverting back to its mean (mean reverting process). Although locally the autoregressive process might have a unit root, generally it is stationary.

The general idea of the Threshold Models introduced by Balke & Fomby (1997) fits very well with the spatial equilibrium condition in an intuitive way. Consider a long run relationship such that

$$z_t = p_{j,t} - p_{i,t} \tag{1.24}$$

Following the threshold idea, if $z_t \leq \tau_{ji}$ holds, then $\rho^{(1)} \to 0$ and the error correction mechanism is not activated, prices are not cointegrated, prices are in regime one or the neutral band and z_t has a unit root. If $z_t > \tau_{ji}$, then $0 \leq \rho^{(2)} \leq 1$ and the error correction mechanism is activated, prices are cointegrated, prices are in the upper regime and z_t is a stationary process.

The fact that a part of the threshold model is an accurate representation of the economic theory behind spatial price transmission analysis has lead to its popularization in Price Transmission Analysis.

1.2.2. Threshold Vector Error Correction Model Estimation

The original Threshold Autoregressive Model (TAR) proposed by Tong (1978) has served as the basis for several threshold models. The estimation method and statistical tests for the TAR were developed by Tsay (1989). Balke & Fomby (1997) developed the concept of Threshold Error Correction, which later has been extended to different types of threshold models. Concerning the univariate methods, TAR models were implemented by Martens, Kofman & Vorst (1998) and Goodwin (2001) to address the question of non-linear adjustments. In addition Lo & Zivot (2001) extended the concept to the Threshold Vector Autoregressive Models (TVAR) to multivariate methods. In the literature TAR and TVAR have been used indistinctively in the study of Spatial Market Integration, nevertheless Hansen & Seo (2003) were the first to offer a formal specification for a Vector Error Correction Model (VECM) which allows for testing and estimating such a representation of a threshold model (Gonzalo & Pitarakis, 2006). It is worth, mentioning that the linear versions of such models have been implemented in cointegration analysis, but it is the Vector Error Correction Model (VECM) which is the most popular among the linear models in Spatial Market Integration analysis; hence the interest is the procedure offered by Hansen & Seo (2002) which allows for estimating the non-linear version of the VECM, namely the Threshold Vector Error Correction Models (TVECM).

The method proposed by Hansen & Seo (2002) is as follows. First they consider a variable, for instance p_t to be a I(1) time series with a cointegration vector denoted as β; the I(0) error correction term is denoted as $z_t(\beta) = \beta p_t$. The linear Vector Error Correction Model can be written as follows:

$$\Delta p_t = A^{'} P_{t-1}(\beta) + u_t \tag{1.25}$$

with

$$P_{t-1}(\beta) = \begin{pmatrix} 1 \\ z_{t-1}(\beta) \\ \Delta p_{t-1} \\ \Delta p_{t-2} \\ \vdots \\ \Delta p_{t-l} \end{pmatrix}. \tag{1.26}$$

Now, instead of a linear cointegration, consider a threshold effect as in equation (1.23) such that:

$$\Delta p_t = \begin{cases} A_1^{'} P_{t-1}(\beta) + u_t & if \quad z_{t-1}(\beta) \le \theta \\ A_2^{'} P_{t-1}(\beta) + u_t & if \quad z_{t-1}(\beta) > \theta \end{cases}. \tag{1.27}$$

Alternatively the threshold effect can be written as:

$$\Delta p_t = A_1^{'} P_{t-1}(\beta) 1(z_{t-1}(\beta) \leq \theta) + A_2^{'} P_{t-1}(\beta) 1(z_{t-1}(\beta) > \theta) + u_t \quad (1.28)$$

Models (1.27) and (1.28) assume two regimes separated or delimited by the threshold parameter θ, furthermore all the coefficients except for the cointegration vector β switch values between the regimes. It is important to stress that there are observations beyond the threshold only if $0 < Prob(z_{t-1} \leq \theta) < 1$; otherwise there are no observations within one of the regimes and the model is simplified to the linear case. In order to ensure a certain number of observations in both regimes, the constraint $\pi_0 \leq Prob(z_{t-1} \leq \theta) \leq 1 - \pi_0$ is imposed. Hansen & Seo (2003) proposed the estimation of equation (1.27) by profile likelihood with the assumption that the errors u_t are i.i.d. Gaussian. The Gaussian estimation is denoted as

$$\mathcal{L}_n(A_1, A_2, \Sigma, \beta, \theta) = -\frac{n}{2} log|\Sigma|$$

$$- \frac{1}{2} \sum_{t=1}^{n} u_t(A_1, A_2, \beta, \theta)' \Sigma^{-1} u_t(A_1, A_2, \beta, \theta) \quad (1.29)$$

with

$$u_t(A_1, A_2, \beta, \theta) = \Delta \mathrm{p_t} - A_1^{'} P_{t-1}(\beta) 1(z_{t-1}(\beta) \leq \theta)$$

$$+ A_2^{'} P_{t-1}(\beta) 1(z_{t-1}(\beta) > \theta) \quad (1.30)$$

The MLE $(\hat{A}_1, \hat{A}_2, \hat{\Sigma}, \hat{\beta}, \hat{\theta})$ are the values that maximizes $\mathcal{L}_n(A_1, A_2, \Sigma, \beta, \theta)$. The estimation is done holding β and θ constant, hence one only has to concentrate on the MLE(A_1, A_2, Σ), that is the OLS regression such that:

$$\hat{A}_1(\beta, \theta) = \left(\sum_{t=1}^{n} P_{t-1}(\beta) P_{t-1}(\beta)' 1(z_{t-1}(\beta) \leq \theta)\right)^{-1} \times$$

$$\left(\sum_{t=1}^{n} P_{t-1}(\beta) \Delta p_{\mathrm{t}}' 1(z_{t-1}(\beta) \leq \theta)\right) \quad (1.31)$$

$$\hat{A}_2(\beta, \theta) = \left(\sum_{t=1}^{n} P_{t-1}(\beta) P_{t-1}(\beta)' 1(z_{t-1}(\beta) > \theta)\right)^{-1} \times$$

$$\left(\sum_{t=1}^{n} P_{t-1}(\beta) \Delta p_{\mathrm{t}}' 1(z_{t-1}(\beta) > \theta)\right) \quad (1.32)$$

$$\hat{u}_t(\beta, \theta) = u_t\left(\hat{A}_1(\beta, \theta), \hat{A}_2(\beta, \theta), \beta, \theta\right) \quad (1.33)$$

and

$$\hat{\Sigma}(\beta, \theta) = \frac{1}{n} \sum_{t=1}^{n} \hat{u}_t(\beta, \theta) \hat{u}_t(\beta, \theta)'. \quad (1.34)$$

Note that equations (1.31), (1.32), (1.33) and (1.34) are the OLS regression for a specific combination of the fixed parameters β and θ. The concentrated likelihood function can be denoted as:

$$\mathcal{L}_n(\beta, \theta) = \mathcal{L}_n\left(\hat{A}_1(\beta, \theta), \hat{A}_2(\beta, \theta), \hat{\Sigma}(\beta, \theta), \beta, \theta\right) = -\frac{n}{2} log\left|\hat{\Sigma}(\beta, \theta)\right| - \frac{np}{2} \quad (1.35)$$

Equation (1.32) implies that the MLE$(\hat{\beta},\hat{\theta})$ are the minimisers of $log\left|\widehat{\Sigma}(\beta,\theta)\right|$ under the constraint $\pi_0 \leq n^{-1}\sum_{t=1}^{n} 1(p_t^{'}\beta \leq \theta) \leq 1-\pi_0$.

Indeed the estimation procedure to find the values of $\hat{\beta}$ and $\hat{\theta}$ is a profile likelihood for which Hansen & Seo (2002) proposed the following four steps:

1. Establish a grid on a certain region delimited by upper and lower values either for the threshold ($[\theta_L,\theta_U]$) and for the cointegration vector ($[\beta_L,\beta_U]$). The calibration should be based on the estimated value of $\tilde{\beta}$ as in $z_t(\beta)=\tilde{\beta}p_t$
2. For each combination of (β,θ) within the grid estimate $\hat{A}_1(\beta,\theta)$, $\hat{A}_2(\beta,\theta)$, and $\widehat{\Sigma}(\beta,\theta)$
3. Find the estimated parameters $(\hat{\beta},\hat{\theta})$ in the grid for the minimum value of $log\left|\widehat{\Sigma}(\beta,\theta)\right|$
4. Set $\hat{A}_1=\hat{A}_1(\hat{\beta},\hat{\theta}),\hat{A}_2=\hat{A}_2(\hat{\beta},\hat{\theta}),\widehat{\Sigma}=\widehat{\Sigma}(\hat{\beta},\hat{\theta})$ and $\hat{u}_t=\hat{u}_t(\hat{\beta},\hat{\theta})$.

1.3. Confronting Economic Theory and the Econometric Model

So far it has been shown that the economic theory considers an equilibrium environment in which no arbitrage opportunities can take place. In this regard the prices are bound in a region, which is interpreted as the neutral band. Furthermore, as it has been discussed, a simple linear cointegration model is not the best representation as it neglects the regime dependent adjustments. Nevertheless the linkage between the economic theory and the econometric model deserves more attention.

In the literature it is often of interest to demonstrate that the econometric techniques lead to an accurate estimation. Moreover, it is of interest to demonstrate that the econometric models truly serve for estimating or measuring the economic phenomena. For example authors such as Ardeni (1989), Officer (1989), Goodwin, et al. (1990) and Goodwin (1992) discussed the problems when testing for cointegration and the LOP in agricultural markets. Another example is the research developed by McNew & Fackler (1997) who address some issues regarding the compatibility of market equilibrium and cointegration. Baulch (1997) estimated the bias from the so called Parity Bounds Model by using data with parameters conceived beforehand (data generated artificially). Another example is the research carried our by Greb, et al. (2011) which showed that the threshold estimation using the likelihood profile developed by Hansen & Seo (2002) resulted in biased estimations. While the research carried out by McNew & Fackler (1997) and Baulch (1997) addressed whether or not the econometric models fit economic theory, research undertaken by Greb, et al. (2011) is focused on developing a better TVECM estimation based on Bayesian methods.

The aim of the researcher with the present work is similar to the one carried out by McNew & Fackler (1997), and Baulch (1997). This research compares and contrasts economic theory with the econometric techniques to evaluate whether they really fit as it is presumed or assumed. Following the examples of McNew & Fackler (1997) and Baulch (1997) this research does not attempt to replicate the complexity of time series properties that are assumed in prices; rather the attention is concentrated on a more parsimonious simulation process. A key component of cointegration is that prices follow the same random walk or unit root process; therefore, it is appealing to generate artificial prices which have a unit root component. In this regard it is expected that ideal artificial data will fulfil with the SEC.

Based on economic theory, the simulations are carried out using the TJM. The random walk process is introduced with a slight modification to equation (1.8), for that the parameter ν is drawn as a random walk process such that

$$\nu_t = \nu_{t-1} + \varepsilon_t = \nu_0 + \sum_{s=1}^{t} \varepsilon_t. \tag{1.36}$$

By substituting equation (1.36) in equation (1.8) yields to:

$$p_{n,t}^{s} = v_{n,t} + \eta_n x_{n,t} = v_0 + \sum_{s=1}^{t} \varepsilon_t + \eta_n x_{n,t}. \qquad (1.37)$$

After introducing the unit root component, the following step is used to set up the parameters for the simulations. For this research a two regions model based on the example provided by Takayama and Judge (1964) is considered, where the inverse supply functions are denoted as:

$$p_{1,t}^{s} = 5 + \sum_{s=1}^{t} \varepsilon_t + 0.1x_{1,t} \qquad (1.38) \qquad\qquad p_{1,t}^{d} = 20 - 0.1y_{1,t} \qquad (1.39)$$

$$p_{2,t}^{s} = 2.5 + \sum_{s=1}^{t} \varepsilon_t + 0.05x_{2,t} \qquad (1.40) \qquad\qquad p_{2,t}^{d} = 20 - 0.2y_{2,t} \qquad (1.41)$$

with $\varepsilon \backsim N(0,1)$ and a matrix of transport costs

$$T_{12} = \begin{bmatrix} 0 & 2 \\ 2 & 0 \end{bmatrix} \qquad (1.42)$$

Note that the previous model assumes a dynamic equilibrium whereby prices are bounded by the Spatial Equilibrium Condition (SEC) for all the observations. The following step is to set up the length of the time dimension: for this research two experiments are performed, one with 250 periods of time and another with 500. For each a total of 1000 repetitions were performed. The previous models can easily be implemented and solved using GAMS software.

Figure 1-2 Example of a single simulation for prices in equilibrium with a random walk

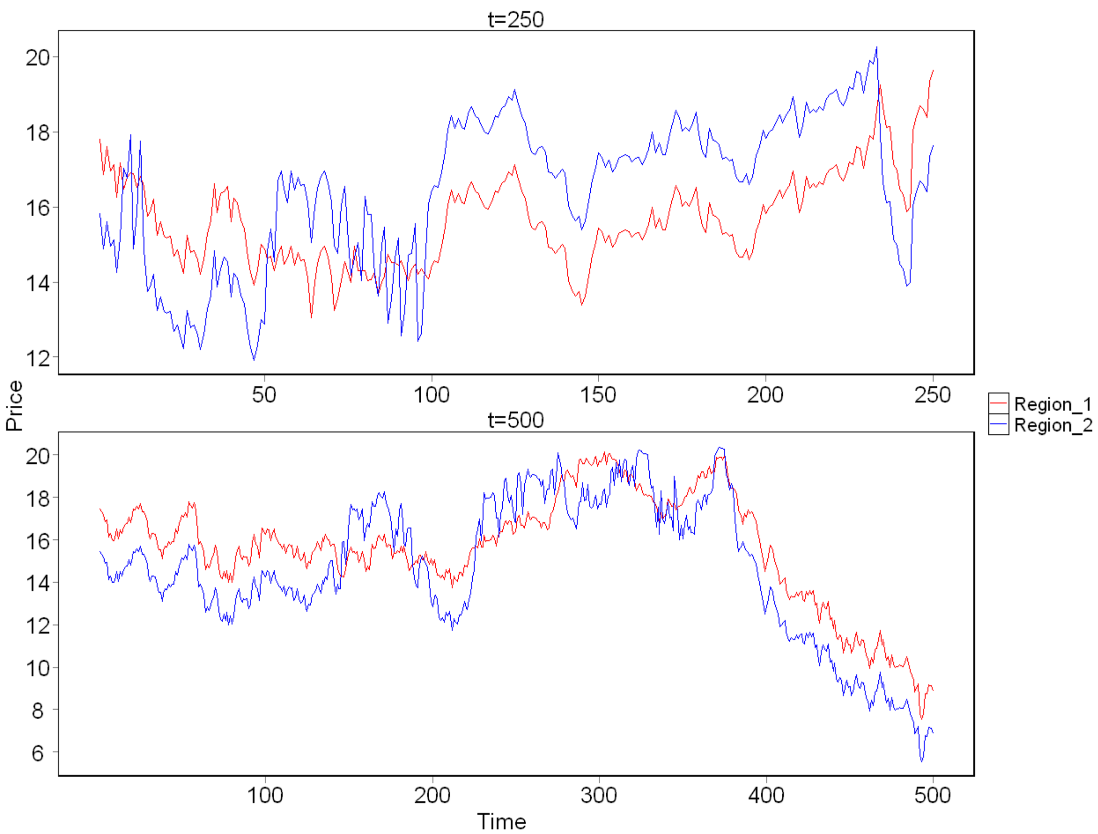
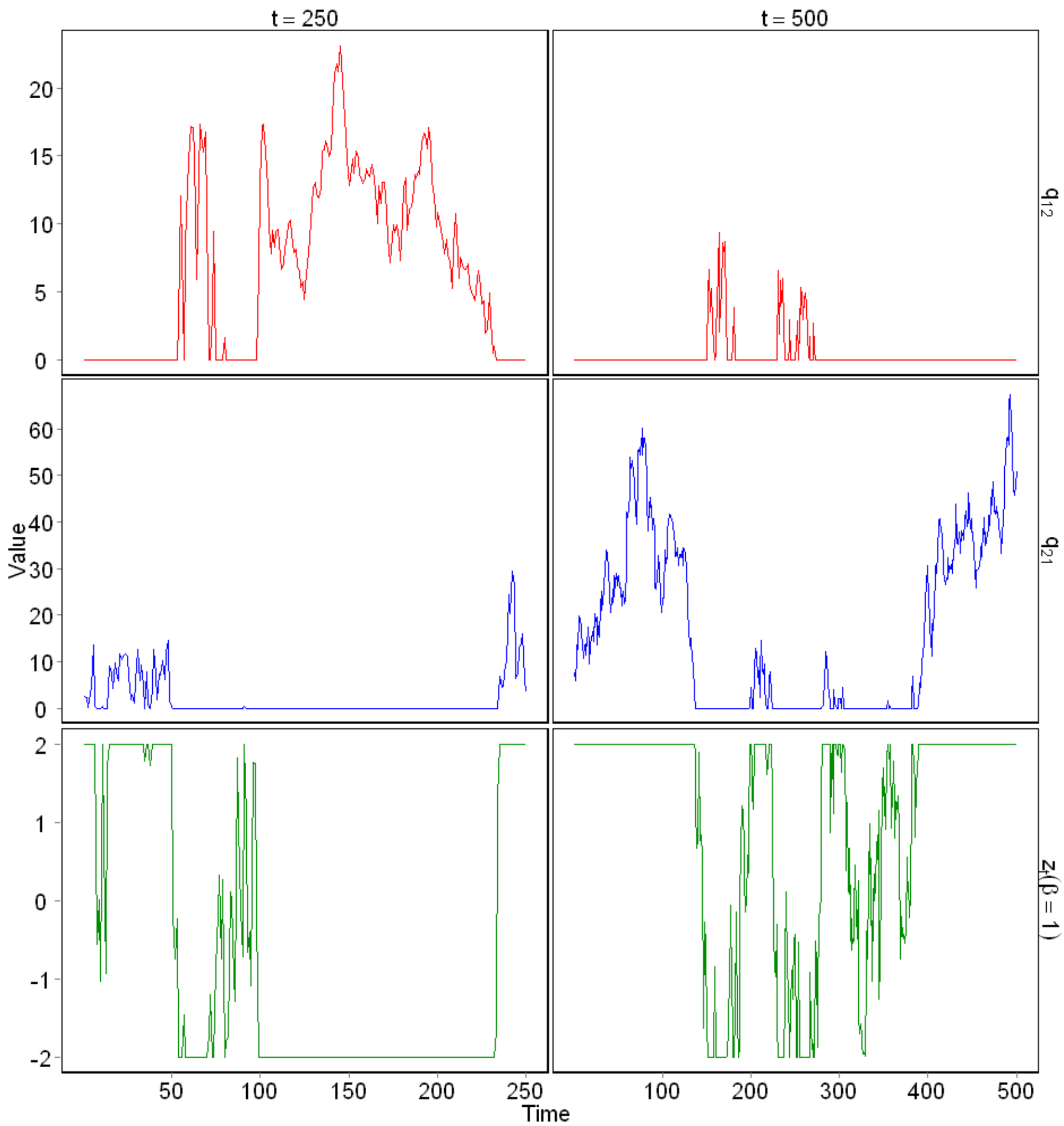


Figure 1-2 shows artificial prices for a time dimension length of $t = 250$ and $t = 500$. The prices are bound by the Spatial Equilibrium Condition (SEC). The cointegration vector for this model is equal to one by construction, therefore the error correction term $z_t(\beta = 1)$ is the difference between the prices in region 1 and region 2, that is $z_t(\beta = 1) = p_2 - p_1$. Figure 1.2 shows the performance of the error correction term $z_t(\beta = 1)$. Notice that within the neutral band no trade occurs, and it is only when $z_t(\beta = 1)$ is in the border of the neutral band when the LOP holds and when trade occurs. In this regard, the statement of Barrett & Li (2002), which asserts that trade is a necessary condition for integration but not for equilibrium can be called upon.

Figure 1-3 Example of the single simulation as in Figure 1.1 for trade from region 1 to region 2 q_{12}, trade from region 2 to region 1 q_{21}, and the error correction term $z_t(\beta = 1)$ in equilibrium



Once the TJM have been solved for equilibrium it is possible to use the prices obtained to estimate the TVECM. Now the attention is turned to the selection of the threshold model, for this purpose one has to pay attention to Figure 1-3, more specifically to the series concerning the error term z_t. The simulated data shows that there are trade reversals; hence z_t takes either positive or negative values as shown, this causes the equilibrium region to be bounded by the transport costs, such that:

$$\theta^L \leq z_t(\beta = 1) \leq \theta^U \tag{1.43}$$

with θ^L being the transport costs of moving a unit of product from region 1 to 2, and θ^U the transport costs of moving a unit of product from region 2 to 1. In a disequilibrium scenario when the error correction term takes values lower than θ^L there are profits from moving products from region 1 to 2. On the contrary, if $z_t(\beta = 1)$ is greater than θ^U, traders from region 2 to 1 make profits. Regarding the TVECM, this situation is considered as a three regimes model with two thresholds which can be written as:

$$\begin{aligned}\Delta p_t = {} & A_1' P_{t-1}(\beta) 1(z_{t-1}(\beta) < \theta^L) + A_2' P_{t-1}(\beta) 1(\theta^L \leq z_{t-1}(\beta) \leq \theta^U) \\ & + A_3' P_{t-1}(\beta) 1(z_{t-1}(\beta) > \theta^U) + u_t\end{aligned} \tag{1.44}$$

The profile likelihood for estimating the threshold and cointegration parameter proposed by Hansen & Seo (2002) can be extended into two thresholds. The original four steps remain unchanged; first a solution for θ^U and β is found; then a further step is added: holding θ^U and β constant it is done a second grid search for estimating θ^L is done.

Having set up the ground for the threshold model estimation it is possible to proceed to the estimation process. The TVECM is based on the normalization of one vector of prices, thus for the estimation it was decided to normalize prices in region 1; the long run relationship used on the estimation is denoted as:

$$z_t(\beta) = \beta p_{2,t} - p_{1,t} \tag{1.45}$$

Furthermore, it was decided to focus only on the threshold parameter, hence the estimation of the TVECM was performed by restricting $\beta = 1$, so as the long run relationship is denoted as:

$$z_t(\beta = 1) = p_{2,t} - p_{1,t} \tag{1.46}$$

Additionally, as trade reversals occur the correct TVECM has to be selected. In the absence of trade reversals a two-regime and one-threshold TVECM as depicted in Equation (1.28) is estimated. In the presence of trade reversals a three-regimes and two-threshold TVECM as depicted in Equation (1.44) is estimated. It is important to remember that on the model the unit root processes are randomly generated, hence it is not controlled for trade reversals.

Once the correct TVECM specification is set up, then one can proceed to the estimation. First in order to evaluate the extent, to which the results may be affected by the trimming parameter, π_0 is set up at three different values of 0.05, 0.10 and 0.15. For the short run dynamics the first lag price differential $\Delta p_{1,t-1}$ and $\Delta p_{2,t-1}$ were included. The estimations were carried out using R package tsDyn developed by Di Narzo, et al. (2009) v. 0.7-60. The first interesting outcome is that for a large number of artificial pair of prices it is not possible to estimate a TVECM as summarized in Table 1-1.

Table 1-1 Total number of simulations, and number and percentage of possible estimable TVECM

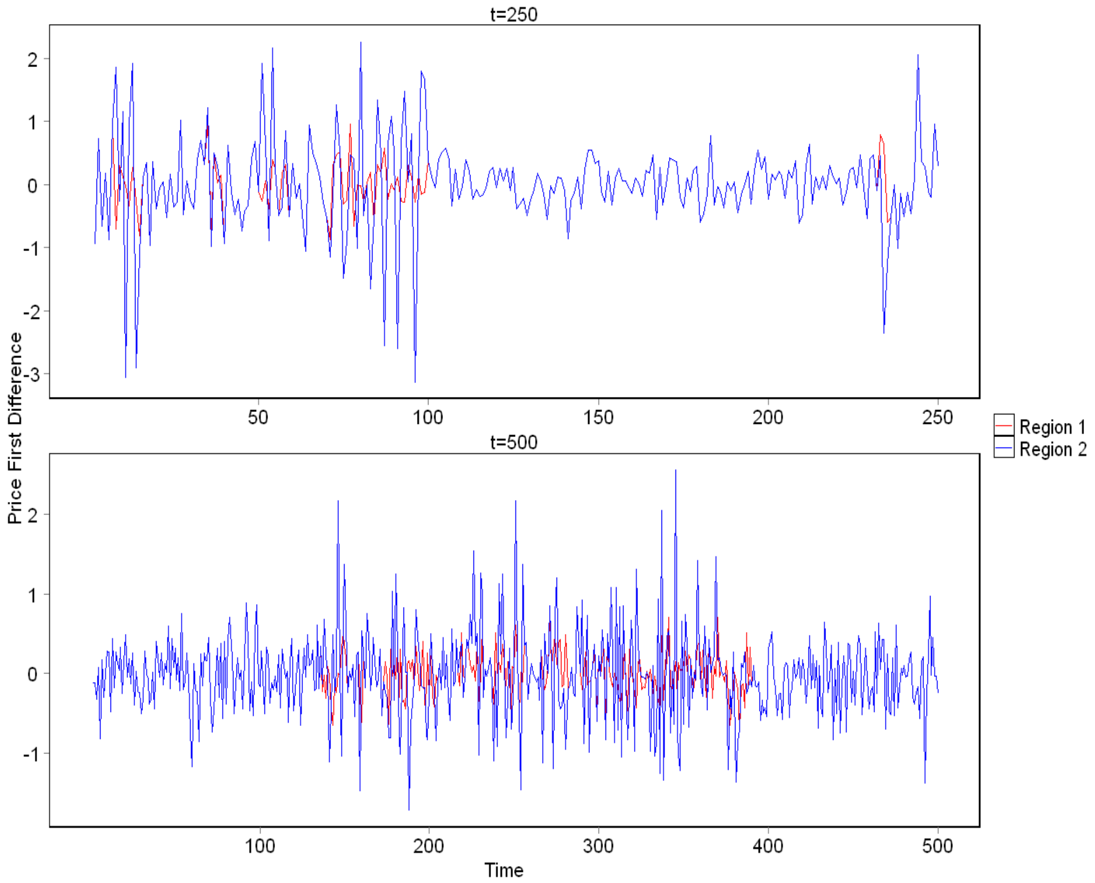
TVECM	Total	π_0	t=250		t=500	
			No. feasible TVECM	%	No. feasible TVECM	%
Two regimes and one threshold	372	0.05	3	0.81%	7	2.41%
		0.1	3	0.81%	4	1.38%
		0.15	1	0.27%	1	0.34%
Three regimes and two thresholds	628	0.05	212	33.76%	204	28.73%
		0.1	144	22.93%	142	20.00%
		0.15	89	14.17%	79	11.13%

Source: Author's own elaboration

The message the programme sends is the error "matrix is singular". In order to understand such an outcome first recall that the estimation of the TVECM is based on OLS regression as in Equations (1.31) and (1.32) using the set of exogenous variables $P_{t-1}(\beta)$ as in Equation (1.26), and the contemporaneous price differences Δp_t as the endogenous variables, such that loading coefficients are estimated as $\hat{A} = \left(P_{t-1}(\beta)' P_{t-1}(\beta)\right)^{-1} P_{t-1}(\beta)' \Delta p_t$. In order to perform the estimation of $\hat{A}$, the design matrix $P_{t-1}(\beta)' P_{t-1}(\beta)$ has to be invertible and non-singular. This condition is violated whit no variation of the elements contained in $P_{t-1}(\beta)$. Indeed the element which tends not to vary is the error correction term $z_{t-1}(\beta)$. First consider that the profile likelihood is based on allocating certain number of observations in separated regressions using the constrain $\pi_0 \leq n^{-1} \sum_{t=1}^{n} 1(p_t'(1) \leq \theta) \leq 1 - \pi_0$; second notice as shown in Figure 1-3, that the error correction term $z_{t-1}(\beta = 1)$ is bounded by the SEC and for a large number of observations it remains in the borders of the SEC, which is no variation. Violating such an assumption leads to a zero division in the parameter estimator. Indeed this violation is what does not allow estimating several TVECM using the artificial data. This occurs when all the observation for $z_{t-1}(\beta = 1)$ in one of the OLS regression have the same value, which is equivalent to no variation of the exogenous variable, so the estimations cannot be performed by the programme.

Another violation of the non-singular property is multicollinearity. Consider the case of perfect market cointegration (LOP) which is equivalent to a price transmission ratio equal to one[1] under this situation the prices co-movements are the same a shown in Figure 1-4

Figure 1-4 Example of the prices first differences $\Delta p_{1,t}$ and $\Delta p_{2,t}$ for the simulations as in Figure 1-1



Note from Figure 1-4 that for some periods the values overlap as there is perfect multicollinearity. The co-movement of the prices is the same, so indeed those observation which are perfectly integrated and fulfil the LOP are causing problems in the econometric

[1] The Price Transmission Ratio R_{ij} is defined by Fackler and Goodwin (2001) as "the measure of the degree to which demand and supply shocks (ϵ) arising in one region are transmitted to another region". It can be written mathematically as $R_{AB} = \frac{\partial p_i/\partial \epsilon_j}{\partial p_j/\partial \epsilon_j}$.

estimations. This is a signal of a compatibility problem between the pure equilibrium data and the TVECM.

In order to evaluate whether or not there is a problem between the true and the estimated threshold parameters in more detail, one has to pay attention to the estimation results. Table 1-2 summarizes the descriptive statistics of the threshold parameters.

Table 1-2 Descriptive statistics for the estimated threshold parameters

Threshold parameters	π_0	*t=250*				*t=500*			
		Average Estimated	σ	*Max*	*Min*	*Average Estimated*	σ	*Max*	*Min*
$\hat{\theta}$	0.05	-0.77	0.34	-0.39	-1.06	1.29	0.30	1.73	0.92
	0.10	-1.13	0.61	-0.72	-1.83	1.22	0.20	1.36	0.92
	0.15	-1.09	--	-1.09	-1.09	1.27	--	1.27	1.27
$\hat{\theta}^L$	0.05	-1.01	0.60	0.94	-1.99	-0.59	0.75	1.02	-1.91
	0.10	-1.14	0.57	1.12	-1.99	-0.87	0.65	0.69	-1.90
	0.15	-1.21	0.53	0.27	-1.99	-1.02	0.60	0.27	-1.94
$\hat{\theta}^U$	0.05	0.52	0.72	1.97	-1.28	1.11	0.63	2.00	-1.23
	0.10	0.70	0.64	1.90	-1.11	1.12	0.58	1.99	-0.62
	0.15	0.91	0.58	1.80	-0.38	1.20	0.62	1.98	-0.62

Source: Author's own elaboration

Recall that the true threshold parameters for $\hat{\theta}$, $\hat{\theta}^L$ and $\hat{\theta}^U$ are 2, -2 and 2 respectively. Those true parameters differ from the results shown in the previous Table.

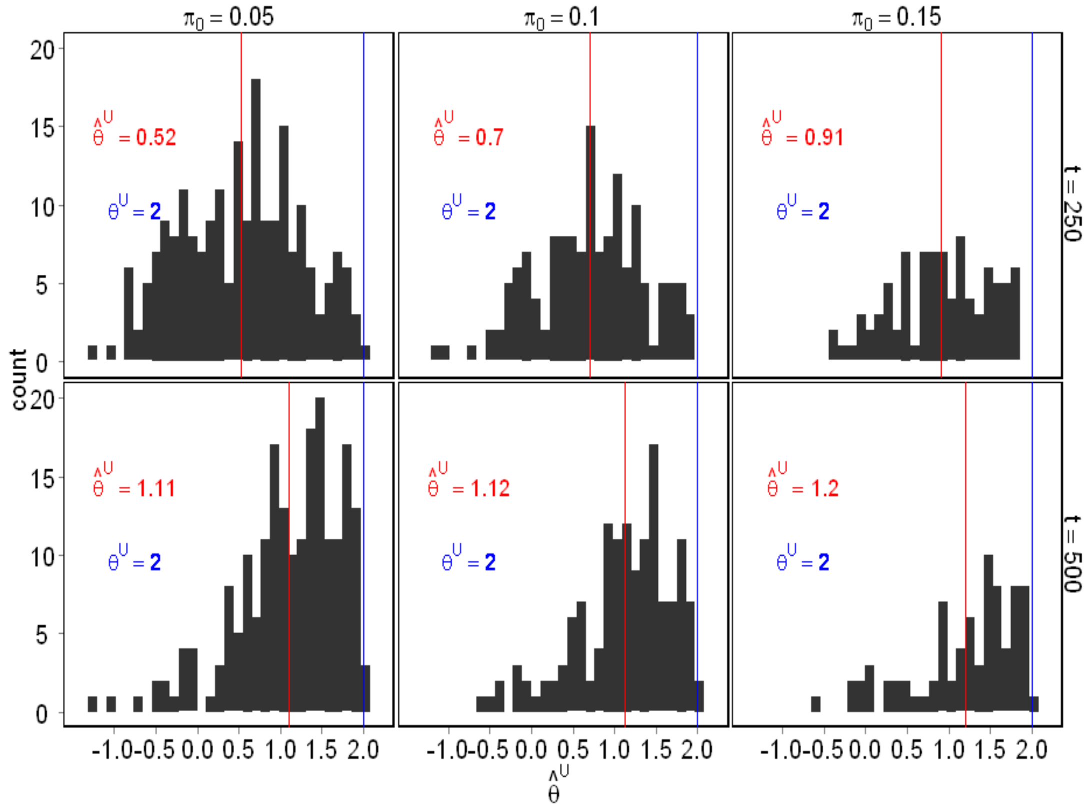
1.4. Analysis of Results

Figure 1-3 shows the performance of the error term $z_{t-1}(\beta = 1)$, which wanders around in the inner of the neutral band. This is the outcome of introducing different unit root processes in the supply functions for both regions. As trade does not occur the equilibrium is solved based on the autarchy prices, hence prices are not cointegrated although in equilibrium. When trade occurs it is the excess supply function which determines the equilibrium prices in both regions, hence prices follow the same unit root process. When this occurs the error term error $z_{t-1}(\beta = 1)$ is found on the boundary of the neutral band, and prices are not only in equilibrium but also cointegrated. As it was mentioned before a main issue is the fact that for large numbers of observations $z_{t-1}(\beta = 1)$ remains in the boundary of the neutral band, which is a problem for the estimation of the OLS regressions as discussed before and summarized in Table 1-1.

The trimming parameter π_0 ensures that a minimum number of observations are in each regime; more specifically, if it is set up at 0.05 at least 5% of the observations of $z_{t-1}(\beta = 1)$ have to be in the lower regime and at least 5% in the upper regime. In doing so using the data from the simulation data which is contained in the middle regime is moved into the upper and lower regimes. In other words, prices in equilibrium are treated as prices in disequilibrium. In this regard as π_0 increases the number of observations misallocated (dropped in the wrong regime) increases. It is interesting to note that the larger π_0 becomes or the more data is misallocated, the fewer the models which cannot be estimated.

Albeit the previous problem, for some simulations it is plausible to estimate the threshold parameters. For those parameters it is possible to derive not only the descriptive statistics as shown in Table 1-2, but histograms as well. Nonetheless in the case of a TVECM with two regimes and one threshold, the number of estimated parameters is considerably low; hence it does not make much sense to draw a histogram for such a case. Therefore, the case of a three regimes and two thresholds model is focused on. Figure 1-4 shows the histograms for the estimated threshold parameters.

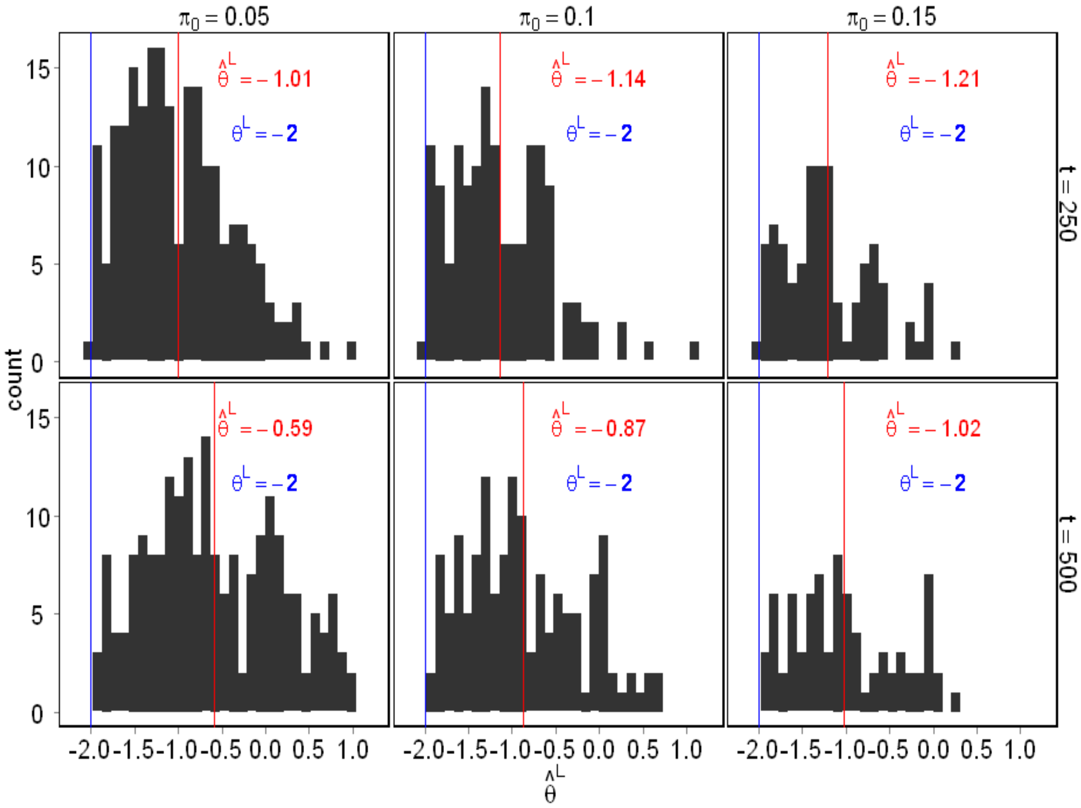
Figure 1-5 Histograms of the estimated upper thresholds parameters



The blue line depicts the value of the true upper threshold parameter $\theta^U = 2$, while the red line depicts the average value of the estimated upper threshold value $\hat{\theta}^U$. It is remarkable that for all the cases the true parameter is found either on the edge or outside the histogram, which points the existence of as a strong bias of the estimated parameters from the profile likelihood. In general it can be said that for the upper threshold the bias is negative and the parameter is underestimated. However, one can witness that as π_0 increases the underestimation decreases and the average estimated parameter gets closer to the true value. It is also possible to observe that the longer the time length, the less the biased the estimates are.

Regarding the lower threshold, Figure 1-6 depicts the histograms of the estimations for the lower threshold. In red the line and the average value for each average lower threshold parameter $\hat{\theta}^L$ is found; in blue the line and the true value for the true lower threshold parameter $\theta^U = -2$ is found.

Figure 1-6 Histograms of the estimated lower threshold parameters



From the previous Figure it can be seen that a problem persists: the true threshold value is either found on the edge or outside the histogram, hence, the estimations are biased. In addition, for the lower threshold, the bias is positive which means that the lower threshold parameter is overestimated. Again it is possible to distinguish a pattern, the greater π_0 gets, the closer the average estimated parameter moves from the true value, yet a higher time length exhibits a higher bias.

Summarizing the previous findings, there is a strong bias between the estimated parameters and their true values. For the upper threshold, the bias is reduced as π_0 and the time length increases. For the lower threshold the bias is reduced as π_0 increases and the time length decreases. The bias in both threshold parameters has implications on the neutral band which is defined as $\theta^L \leq z_{t-1}(\beta) \leq \theta^U$; substituting the values for the true parameters the neutral band can be written as $-2 \leq z_{t-1}(1) \leq 2$. The width of the true middle band can be calculated using $w = \theta^U - \theta^L$, which on this set up equals 4. The estimated neutral band it can be calculated as $\hat{w} = \hat{\theta}^U - \hat{\theta}^L$. The values for the neutral band width are summarized in Table 1- 3.

Table 1-3 Neutral band width $\widehat{w}$

π_0	$t=250$	$t=500$
0.05	1.53	1.69
0.10	1.84	2.00
0.15	2.12	2.22

Source: Author's own elaboration

Overall it can be seen that the bias on the neutral band width $\widehat{w}$ can be reduced by increasing π_0 and the time length *t*. However, increasing π_0 implies misallocating equilibrium data in the disequilibrium regimes, and still $\widehat{w}$ is biased with values around half of the true band width.

1.5. Chapter Conclusions

Overall the outcome of this research suggests that the estimated threshold parameters from the profile likelihood are biased. The upper threshold bias is negative, the lower threshold also shows a negative bias[2] and the neutral band is narrowed. Such a bias can be reduced by increasing the trimming parameter value and the time length. However increasing the trimming parameter reduces the number of plausible TVECM to estimate as more data is allocated to the wrong regime.

The fact that data is allocated to the wrong regime is, for instance, the major signal of incompatibility between the pure SEC and the TVECM. The error correction model considers some errors or equilibrium violations which are not considered in the SEC. It is argued that the TVECM were performed using the correct specification by considering the correct number of thresholds and regimes are used based on economic theory. Even so the results of the estimations perform poorly; for instance in the case of no trade reversals which correspond to a TVECM with two regimes and one threshold, the percentage of feasible estimations is never beyond 2.5%. Regarding the case of trade reversals which corresponds to a TVECM with two thresholds and three regimes, the percentage of feasible estimations ranges from 11 to 33 which is low. Therefore the argument of a correct specification is clearly not supported by the results; indeed using pure data in equilibrium as in the SEC for estimating a TVECM is a misspecification since no true prices beyond the neutral band are included.

The prices generated using the Takayama and Judge Price and Allocation Model (TJM) albeit being modified to create dynamics, are still in equilibrium and do not allow for deviations from such equilibrium to be observed. Although the SEC is analogous to the neutral band, the fact that no observations are found beyond the SEC makes pure equilibrium data incompatible with the TVECM because of two issues: no-variation of $z_{t-1}(\beta = 1)$ and perfect multicollinearity of the prices first differences $\Delta p_{1,t}$ and $\Delta p_{2,t}$. Hence the TVECM is not the correct specification for the SEC.

Although it has been shown that using prices obtained under the ideal economic model in the estimations of a TVECM leads to poor results, such an outcome can be closely linked to the econometric properties of the simulated data. Indeed such econometric properties serve to test cointegration econometrically, which is the focus of the following Chapter.

[2] The profile likelihood has shown to have the same bias as in Greb, et al., 2011

2. TESTING FOR LINEAR AND THRESHOLD ERROR CORRECTION UNDER THE SPATIAL EQUILIBRIUM CONDITION

Economic theory states that the Spatial Equilibrium Condition (SEC) is a region where prices are in equilibrium. The SEC is a weak form of the Law of One Price (LOP), whereby markets are integrated. Such a definition of market integration is often used indistinctively from the econometric definition of cointegration. The concept of cointegration considers a mean reverting process or a stationary process, which in the context of the error correction models is a restoration of the equilibrium. Such a mean reverting process or error correction mechanism is not observed either in the SEC or the LOP as prices are in equilibrium. It is shown that in the absence of such mean reverting process when using prices in pure equilibrium, cointegration is often rejected. Hence the economic concept of perfect market integration which considers a co-movement of prices in the equilibrium is incompatible with the econometric concept of co-movement of prices in cointegration.

2.1. The Economic Concept of Spatial Market Integration and the Econometric Concepts of Threshold Error Correction and Threshold Cointegration

Within Spatial Market Integration analysis there are important economic concepts which have served to support the use of the econometric methods for the analysis. The Spatial Equilibrium Condition (SEC) and the Law of One Price (LOP) are clear and widely accepted concepts. Less clear is the concept of market integration; following some authors' views it can be understood as the degree of market connectedness which is measured by price co-movement (Ravallion, 1986; McNew & Fackler, 1997; Goodwin & Piggott, 2001). In this regard the prices moving together fulfilling the LOP are cointegrated. Nevertheless Barrett (2005) points out that such a co-movement does not necessarily have to lead to a Pareto optimum; so it could be argued that inefficient allocations of resources or disequilibrium prices can also account for market integration. Albeit that the importance of inefficient (no Pareto optimum) pricing and allocation of resources in market integration is acknowledged, the primary approach which is still found throughout the literature of market integration is the LOP.

Within the literature it is often the case that the economic concept of market integration is usually used indistinctively from the econometric concept of cointegration, with little attention paid to the compatibility of both definitions. Regarding the compatibility between linear cointegration and market integration, McNew & Fackler (1997) found that economic integrated data cannot be accounted for as linearly cointegrated. The limitations that linear cointegration has regarding variables such as prices has been acknowledge in the literature, as for that the non-linear methods have gained importance in cointegration research, more specifically the concept of Threshold Cointegration.

The concept of Threshold Cointegration can be defined under two different perspectives. The most widely definition used within the literature is that offered by Balke & Fomby (1997) which concentrates on the performance of an adjustment process derived from a linear relationship. The adjustment process has threshold effects so that it is globally stationary and locally it has unit root. This idea has been extended to the so called error correction models, for which one can find several extensions in the literature, i.e Obstfeld & Taylor (2001), Caner & Hansen (2001), Lo & Zivot (2001), Enders & Siklos (2001), Hansen & Seo (2003) and Seo (2006). The second approach is offered by Gonzalo & Pitarakis (2006) who define the Threshold Cointegration as the threshold effect on the long run equilibrium. In their paper Gonzalo & Pitarakis (2006) acknowledge the fact that their definition of Threshold Cointegration lacks a Vector Error Correction Model (VECM) representation (Stigler, 2012) because it is not possible to define cointegration by means of a common unit root component as Granger does.

For the purpose of this study it is the definition for Threshold Cointegration offered by Balke & Fomby (1997) accounted for, yet it is acknowledged that such a definition should be better called "Threshold Error Correction" and that a most appropriate view of Threshold Cointegration is that offered by Gonzalo & Pitarakis (2006). The reasons for following such a definition are: (1) most of the literature in Spatial Market Integration focuses on non-linear adjustment process in the form of Error Correction Models (ECM), (2) by using such a definition, it is plausible to have the corresponding VECM, namely the TVECM and (3) the TVECM has become the standard model in Spatial Market Integration analysis as it is claimed/assumed to be the proper representation of the economic theory.

With the popularization of the TVECM and the concept of Threshold Cointegration, which from now on for this research is called Threshold Error Correction, it is important to revise whether such a concept is compatible with the economic definition of Spatial Market Integration. In order to do so, some linear and non-linear tests are implemented using artificial data. In the literature it is possible to find several tests for cointegration, the offer is wide for the case of linear tests. In order to narrow the scope, this research focuses on some test which in the author's view are the standard techniques used in Spatial Market Integration.

2.2. Tests for Linear and Threshold Error Correction

A core concept in cointegration analysis is the so called unit root process: I(1) which is defined as:

$$y_t = y_{t-1} + \varepsilon_t = y_0 + \sum_{s=1}^{t} \varepsilon_t \tag{2.1}$$

where ε_t is a i.i.d process, furthermore $E[y_t] = y_t$ and $var(y_t) = t\sigma^2$. It has been demonstrated that performing regression analysis with I(1) variables leads to spurious regressions. In light of that, Granger (1981) and Engle & Granger (1987) introduced the concept of linear cointegration for estimating stable relationships among non-stationary economic variables (Pfaff, 2008). A common model in cointegration analysis is the so called Vector Error Correction Model which can be written as:

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \tag{2.2}$$

where Y is a vector of variables and Π is a matrix which can be decomposed into $\alpha\beta'$. Although the set of variables contained on Y have a unit root, there is a linear combination of the variables which is a stationary process. The linear combination or error term can be written as:

$$z_t = \beta Y_t \tag{2.3}$$

where β is the cointegration vector which ensures the error term z_t to be I(0). The loading coefficient or adjustment parameter α ensures that any deviation from the equilibrium is restored back in the short run.

However in addition to the estimation of a Vector Error Correction Model, cointegration also has to be tested for. The first step is to verify whether the variable to analyse, y_t for instance, has a unit root, for that some of the most common tests are the so called Augmented Dikey-Fuller Test (ADF) and the Kwiatkowske, Phillips, Schmidt & Shin test (KPSS).

For the ADF Test, y_t is an autoregressive process of order *p*, such that the AR(p) process is written as:

$$y_t = \alpha_1 y_{t-1} + \cdots + \alpha_1 y_{t-P} + \varepsilon_t \tag{2.4}$$

then subtracting y_{t-1} yields to

$$\Delta y_t = \phi y_{t-1} + \sum_{j=1}^{p-1} \alpha_j^* \Delta y_{t-j} + \varepsilon_t. \tag{2.5}$$

with $\alpha_j^* = -(\alpha_{j+1} + \cdots + \alpha_p)$.To test the null hypothesis of a unit root is equivalent to test for $H_0: \phi = 0$, and the alternative states as $H_a: \phi < 0$ (Lütkepohl, 2004, p. 54). In the case where the null cannot be rejected it is often recommended that the KPSS Test be performed.

The KPSS Test (Kwiatkowski, et al., 1992) starts by considering the variable y_t of the following form:

$$y_t = \xi\tau + x_t + \varepsilon_t \qquad (2.6)$$

with τ denoting the trend with $\xi = 0$ a level stationary process, and with x_t a process such that

$$x_t = x_{t-1} + u_t \qquad (2.7)$$

where the error term u_t is i.i.d $(0, \sigma_u^2)$. From the error ε_t it can be calculated S_t such that

$$S_t = \sum_{i=1}^{t} \hat{\varepsilon}_t \qquad (2.8)$$

The null hypothesis is denoted as $H_0\colon \sigma_u^2 = 0$ and the alternative is $H_0\colon \sigma_u^2 > 0$. If the null holds x_t it is no longer a random walk but a constant, therefore y_t becomes a stationary process. Notice that here the null hypothesis is a stationary process I(0), while in the ADF test the null hypothesis is a unit root. The KPSS has the following test statistic

$$LM = \sum_{t=1}^{T} S_t^2 / \hat{\sigma}_\varepsilon^2 \qquad (2.9)$$

Both tests are not only useful when testing for stationarity or a unit root component in the variables, but also when testing for cointegration itself.

Once the variables have been tested for stationarity or a unit root, the following step is to test for cointegration. The so called Granger two-step procedure is based first on estimating a linear combination of the variables as in equation (2.3), such that the resulting error term z_t is a stationary process. The second step of the Granger procedure consists in testing if the error term is stationary or if it has a unit root. For that purpose the ADF and KPSS Tests can be used.

Another approach different to the Granger two-step procedure is the Johansen Trace Test (JTT). Introduced by Johansen (2000), it is considered a VECM such as the one in equation (2.2), nevertheless the matrix Π is decomposed such that

$$\Delta Y_t + AB' Y_{t-1} = +\Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{p-1} \Delta Y_{t-p+1} + \varepsilon_t \qquad (2.10)$$

Where the matrix A contains the loading coefficients α and the matrix B contains the cointegration parameters β. Two auxiliary regressions are performed to eliminate the short-run dynamic effect. For the first one ΔY is regressed on the lagged differences of Y_t in order to obtain the residuals R_{0t}. For the second regression, Y_{t-p} is regressed on the same set of regressors in order to obtain the residuals R_{1t}. It happens that both residuals have a linear relationship such that

$$R_{0t} = -AB' R_{1t} + \widehat{U}_t \qquad (2.11)$$

where R_{0t} is vector of stationary processes and R_{1t} is a vector of non stationary processes. The Johansen Test is based on finding the number of linear combinations $B'R_1$ which show the highest correlation with the stationary process R_{0t}. Indeed the linear combinations is the rank of the matrix Π denoted as $rk(\Pi)$. The testing procedure proposed by Johansen (1988) or JTT consist on testing the null hypothesis $H_0: rk(\Pi) = r_0$ versus the alternative $H_a: r_0 < rk(\Pi) \leq K$, where K is the number of variables contained in the vector Y. The test statistic for the null can be written as:

$$Tr(r) = -T\sum_{i=r+1}^{K} \ln\left(1-\hat{\lambda}_i\right) \tag{2.12}$$

where T denotes the number of observations, and $\hat{\lambda}_i$ denotes the eigenvalues.

Three possible outcomes are possible for the JTT. First if $rk(\Pi) = K$ all the variables are stationary. Second if $rk(\Pi) = 0$ the variables are not cointegrated. Third and lastly, if $0 < rk(\Pi) \leq K$ then the variables are integrated of order r. When the variables are integrated of order r, r is the number of linear combinations which ensure $B'Y_{t-1}$ to be a stationary process.

The previous cointegration tests the ADF, KPSS and JTT, are concerned with testing linear cointegration and do not consider non-linear behaviour, a threshold for instance.

Based on the threshold model proposed by Tong (1978), Balke & Fomby (1997) developed the idea of Threshold Error Correction, for which a major challenge is that unlike linear cointegration where there are two outcomes, cointegration and no cointegration, it has diverse possibilities. These sets of possibilities are summarized in the following table:

Table 2-1 Possible outcomes when testing for Threshold Error Correction

Hypothesis	Linearity	Threshold
No cointegration	(I) Linearity and no cointegration	(II)Threshold and no cointegration
Cointegration	(III) Linear cointegration	(IV) Threshold error correction

Source: Modified from Balke & Fomby (1997)

As stated by Balke & Fomby (1997) one can take any case as the null hypothesis; therefore any of the remaining three cases can be taken as the alternative hypothesis.

Balke & Fomby (1997) perform Monte Carlo simulations to examine several linear tests such as the ADF, KPSS and JTT among others. Their aim was to address the question of how suitable such tests were for testing for cointegration with artificial data generated by different threshold models. The idea behind such efforts is the assumption that even under the presence of a threshold in the error term, the error correction term will be a stationary globally, while locally it has a unit root.

Following the idea of Threshold Error Correction, Hansen & Seo (2002) developed a test in the context of a Threshold Vector Error Correction Model. Their approach was to test the null hypothesis of Threshold Error Correction (case IV) versus the alternative of linear cointegration (case III). Assuming that the cointegration vector β and the threshold parameter θ are known, the model under the null is denoted as:

$$\Delta Y_t = A' Y_{t-1}(\beta) + \varepsilon_t. \tag{2.13}$$

Furthermore the model for the alternative hypothesis is denoted as

$$\Delta Y_t = A_1' Y_{t-1}(\beta) 1(z_{t-1}(\beta) \leq \theta) + A_2' Y_{t-1}(\beta) 1(z_{t-1}(\beta) > \theta) + \varepsilon_t \tag{2.14}$$

Hansen & Seo (2002) showed that the null can be tested with the test statistic

$$\begin{aligned} LM(\beta,\theta) = {} & \operatorname{vec}\left(\widehat{A}_1(\beta,\theta) - \widehat{A}_2(\beta,\theta)\right)' \left(\widehat{V}_1(\beta,\theta) - \widehat{V}_2(\beta,\theta)\right)^{-1} \\ & \times \operatorname{vec}\left(\widehat{A}_1(\beta,\theta) - \widehat{A}_2(\beta,\theta)\right) \end{aligned} \tag{2.15}$$

where $\widehat{V}_1(\beta,\theta)$ and $\widehat{V}_2(\beta,\theta)$ are the Eicker-White covariance matrix estimators for $\operatorname{vec}\widehat{A}_1(\beta,\theta)$ and $\operatorname{vec}\widehat{A}_2(\beta,\theta)$. As Equation (2.12) is a simple OLS regression, it is possible to get the estimator for β under the null denoted as $\tilde{\beta}$, nevertheless as for θ there is not an estimator, the LM statistic has to be estimated at different values of θ such that

$$\mathrm{SupLM} = \sup_{\theta_L \leq \theta \leq \theta_U} LM(\tilde{\beta},\theta) \tag{2.16}$$

Equation (2.15) is a profile likelihood function for which the search region is $[\theta_L, \theta_U]$. The parameter θ_L is set at the value π_0, and the parameter θ_U is set at the value is set at the value $(1 - \pi_0)$. This imposes the constrain $\pi_0 \leq \mathrm{Prob}(z_{t-1} \leq \theta) \leq 1 - \pi_0$.

The estimator for $\tilde{\theta}$ is the value that maximizes Equation (2.16), although such an estimator will be different from the one obtained from the estimation of a TVECM using the Hansen & Seo's (2002) method. The reason lies within the fact that for Threshold Error Correction, the estimated parameter $\tilde{\beta}$ remains fixed and the profile likelihood is only performed for the threshold value (Hansen & Seo, 2002) Although the previous test allows testing for the Threshold Error Correction to be tested for, ideally one would like to directly test the null of non cointegration, versus the alternative of Threshold Error Correction (Balke & Fomby, 1997).

Seo (2006) proposed an approach that allows for the null of non linear cointegration to be tested for, versus the alternative of Threshold Error Correction. For that he proposed an error correction term with a known cointegration parameter as in equation (2.3). Then the TVECM is of the form

$$\Delta Y_t = A_1'(\theta) z_{t-1} 1\left(z_{t-1} \leq \theta^L\right) + A_2'(\theta) z_{t-1} 1\left(z_{t-1} > \theta^U\right)$$
$$+ \tilde{\mu}(\theta) + \Phi_1(\theta)\Delta Y_{t-1} + \cdots + \Phi_q(\theta)\Delta Y_{t-q} + \tilde{u}_t(\theta) \qquad (2.17)$$

with $\theta^U \leq \theta^L$, and a no adjustment region $\theta^L \leq z_{t-1}(\beta) \leq \theta^U$.

The null hypothesis is denoted as $H_0: \alpha_1 = \alpha_2 = 0$ and the alternative $H_a: \alpha_1 \neq \alpha_2$. Letting

$$\tilde{\Sigma}(\theta) = \frac{1}{n} \sum_{t=1}^{n} \tilde{u}_t(\theta) \tilde{u}_t(\theta)' \qquad (2.18)$$

the Wald statistic for testing the null when θ is fixed can be written as

$$W_n(\theta) = \mathrm{vec}\left(\tilde{A}(\theta)\right)' \mathrm{var}\left(\mathrm{vec}\left(\tilde{A}(\theta)\right)\right)^{-1} \mathrm{vec}\left(\tilde{A}(\theta)\right) \qquad (2.19)$$

whereby the superior statistic is defined as

$$\mathrm{supW} = \mathrm{sup}_{\theta \in \Gamma} W_n(\theta) \qquad (2.20)$$

It is important to note that there is a fundamental difference in the tests proposed by Hansen & Seo (2002) and Seo (2006). The first one considers a model with one threshold and two regimes, while the last one considers a model with two thresholds and three regimes. In both tests there is bootstrapping in order to obtain the distribution(s) of the threshold parameter(s).

2.3. Testing for Cointegration in the Equilibrium

After having an overview of the test to implement it is necessary to define the implementation strategy. The prices obtained under the simulations in Chapter 1 are used to implement the five cointegration tests as follows:

1. Test if the individual prices have a unit root individually (ADF and KPSS Tests)
2. Test for linear cointegration of the prices under the Engle & Granger's (1987) approach, which is equivalent to testing whether the error term $z_t(\beta = 1) = p_{2,t} - p_{1,t}$, has a unit root.
3. Test for linear cointegration of the prices using the JTT.
4. Test for Threshold Error Correction using Hansen & Seo's (2003) Test with the restriction $\tilde{\beta} = 1$
5. Test for Threshold Error Correction using Seo's (2006) Test with the restriction $\tilde{\beta} = 1$

For the purpose of this research the economic representation of integrated prices is equivalent to the econometric definition of Threshold Error Correction only if: the error term is globally stationary (linear cointegration) which is equivalent to rejecting non linear cointegration (I) in favour of linear cointegration (III), and the adjustment process has a threshold effect so that no linear cointegration (I) and linear cointegration (III) are rejected in favour of Threshold Error Correction (IV). Summarizing the following five conditions must be fulfilled:

1. For the ADF Test the process $z_t(\beta = 1)$ has to be I(0)
2. For the KPSS Test the process $z_t(\beta = 1)$ has to be I(0)
3. For the JTT there has to be one linear stable combination *r=1*
4. For Hansen and Seo's (2003) Test the null of linearity (III) has to be rejected in favour of the alternative of Threshold Error Correction (IV)
5. For Seo's (2006) Test the null of non linear cointegration (I) has to be rejected in favour of the alternative of Threshold Error Correction (IV)

Failing to fulfilling one of the previous conditions arises in concerns regarding the compatibility between the Spatial Equilibrium Condition and the TVECM.

2.3.1. Testing for a Unit Root

In order to perform cointegration analysis the first step is to test whether the variables have a unit root component. Following this idea the ADF and KPSS Tests were performed using the prices obtained from the simulations for a time length of 250 and 500. The results are reported in Table 2-2

Table 2-2 ADF and KPSS tests: percentiles for the rejection of the null

	ADF						KPSS					
t	p_1			p_2			p_1			p_2		
	α			α			α			α		
	0.01	*0.05*	*0.1*	*0.01*	*0.05*	*0.1*	*0.01*	*0.05*	*0.1*	*0.01*	*0.05*	*0.1*
250	0.02	0.08	0.16	0.04	0.09	0.16	0.99	0.99	0.99	0.99	0.99	0.99
500	0.08	0.15	0.21	0.08	0.16	0.22	1.00	1.00	1.00	0.99	0.99	0.99

Source: Author's own elaboration using the R package URCA developed by Pfaff (2008) v. 1.2-5

The results of the KPSS Test suggest that for most of the prices the null of stationarity is rejected. The outcome of the ADF Test is somehow different, with a level of confidence $\alpha = 0.01$ the null of a unit root is barely not rejected, however, as the level of confidence is increased the non rejection of the null increases. Overall the KPSS Test provides stronger evidence for a unit root process in the prices than the ADF Test.

2.3.2. Tests Results and Discussion

Before continuing with the results of the tests for cointegration one has to recall that such tests depend on OLS regressions for which the error term $z_t(\beta = 1)$ and the prices first lags $\Delta p_{1,t}$ and $\Delta p_{2,t}$ are used as exogenous variables. As it was shown in Chapter 1, when the prices fulfil the LOP, those prices often lead to problems in the design matrix and the OLS estimation cannot be performed for some tests. The simulations free of such estimation problems are reported as "feasible solutions" or the number of simulations for which it is possible to perform a specific test. In addition, as was discussed in Chapter 1, the simulations are done by the inclusion of a random unit root process which is not controlled, whereby the outcome of this is trade reversals on the simulations. Following such an outcome, the results of the test are reported for two groups: "trade reversals" and "no trade reversals". The results of the test are presented in the following Tables.

Table 2-3 Percentiles of the null rejection for the ADF and KPSS test

Group	t	ADF				KPSS			
		Feasible Solutions	α			Feasible Solutions	α		
			0.01	*0.05*	*0.1*		*0.01*	*0.05*	*0.1*
No trade reversal	250	363	0.81	0.91	0.93	364	0.10	0.22	0.30
	500	282	0.81	0.85	0.88	282	0.20	0.29	0.40
Trade reversals	250	628	0.01	0.08	0.15	628	0.94	0.98	0.99
	500	709	0.05	0.13	0.22	709	0.98	0.99	1.00

Source: Author's own elaboration using the R package URCA developed by Pfaff (2008) v. 1.2-5

Table 2-3 summarizes the results from the ADF and KPSS Tests of linear cointegration. The numbers in the previous table clearly show a difference between the two groups. In the absence of trade reversals the ADF Test often rejects the null of no linear cointegration; for the KPSS Test the rejection of the null of linear cointegration is low, nevertheless even with a level of significance $\alpha = 0.05$, the rejection is above 20% for both time lengths. The result is quite different in the presence of trade reversals; the ADF Test does not allow the null of no linear cointegration to be rejected often; this is supported by the KPSS results whit a strong rejection of the null of linear cointegration. The different outcomes of the two groups can be explained by pointing out that the trade reversal is a structural break; in the literature it has been acknowledged that the ADF and KPSS Test fail in the presence of structural breaks and provide misleading results.

The following step is to perform the JTT which involves testing two null hypotheses; $H_0^1\!: r = 0$ and $H_0^2\!: r = 1$. Only when H_0^1 is rejected and H_0^2 is not rejected are the prices linearly cointegrated. Table 4 summarizes the percentiles for rejecting each null, and the percentiles for the linearly cointegrated pairs of prices using the JTT.

Table 2-4 Percentiles for the null rejection and cointegration with the JTT

Group	t	Feasible Solutions	H_0	$\alpha=0.01$	$\alpha=0.05$	$\alpha=0.10$
No trade reversals	250	112	$r=0$	0.92	0.95	0.97
			$r=1$	0.05	0.11	0.20
			Cointegration	0.87	0.84	0.78
	500	200	$r=0$	0.84	0.87	0.89
			$r=1$	0.10	0.23	0.27
			Cointegration	0.75	0.64	0.62
Trade reversals	250	628	$r=0$	0.09	0.16	0.21
			$r=1$	0.00	0.01	0.03
			Cointegration	0.09	0.15	0.19
	500	709	$r=0$	0.22	0.37	0.48
			$r=1$	0.01	0.03	0.09
			Cointegration	0.21	0.34	0.40

Source: Author's own elaboration using the R package URCA developed by Pfaff (2008) v. 1.2-5

The JTT supports the evidence found in the ADF and KPSS Tests for cointegration. In the absence of trade reversals the evidence of linear cointegration is strong, especially in the simulations with 250 observations. In the presence of trade reversals the support for linear cointegration is weak.

From the results of the linear cointegration tests it can easily be argued that the evidence for linear cointegration is strong. Yet before stating that it is important to check whether for the same simulation the three tests offer the same conclusions, otherwise with counterfactual test results it is not possible to conclude that prices are linearly cointegrated. Table 2-5 summarises the number of simulations for which the three tests suggest linear cointegration.

Table 2-5 Number and percentage of simulations for which the three linear tests suggest cointegration

Group	*t*	*Total*	*α=0.10*		*α=0.05*		*α=0.01*	
			Number	*%*	*Number*	*%*	*Number*	*%*
No trade reversals	250	372	31	12.40%	53	21.20%	77	30.80%
	500	290	20	4.00%	32	6.40%	47	9.40%
Trade reversals	250	628	1	0.40%	5	2.00%	20	8.00%
	500	710	48	9.60%	58	11.60%	89	17.80%

Source: Author's own elaboration

As seen in Table 2-5 the number of simulations which can be considered linearly cointegrated is considerably low; overall the percentages of simulations which are linearly cointegrated ranges from 0.4 to 30%. Note that the total number of simulations for each group and time length are reported; this is different from the number of feasible solutions which are not reported here. It is important to point out that it was not possible to perform at least one test for some of the simulations which were not considered linearly cointegrated. In general it can be concluded that economic integrated prices obtained under the SEC cannot be considered as linearly cointegrated; such a finding is not new. For example, McNew & Fackler (1997) have already acknowledged the fact that integrated prices do not necessarily lead to linear relationships.

After having tested for linear cointegration, the task is to test for Threshold Error Correction. The first test used is that proposed by Hansen & Seo (2002) which considers a two regime one threshold model and tests the null of "linear cointegration" versus the alternative of "Threshold Error Correction"; the results for the test are summarized in Table 2-6.

Table 2-6 Percentiles for the null rejection using the Hansen & Seo Test

Group	*t*	*Feasible solutions*	π_0	α*=0.10*	α*=0.05*	α*=0.01*
No trade reversal	250	111	0.05	0.14	0.05	0.01
			0.10	0.13	0.05	0.00
			0.15	0.23	0.12	0.01
	500	111	0.05	0.35	0.22	0.07
			0.10	0.34	0.23	0.07
			0.15	0.33	0.19	0.08
Trade reversal	250	629	0.05	0.21	0.16	0.10
			0.10	0.21	0.15	0.10
			0.15	0.14	0.09	0.04
	500	709	0.05	0.23	0.15	0.05
			0.10	0.23	0.15	0.06
			0.15	0.24	0.14	0.05

Source: Author's own elaboration using the R package tsDyn developed by Di Narzo (2009) v. 0.7-60

The results suggest that there is little evidence for Threshold Error Correction since for most of the cases the null of "linear cointegration" (case III) is not rejected. Note that increasing the trimming parameter π_0 does not have an impact on the null rejection. It is at significance level of $\alpha = 0.10$ when one can observe the highest percentages for the null rejection; yet still the figures are 35% at the most. It is important to recall that the Hansen & Seo (2002) Test considers a TVECM with one regime and two thresholds; hence for the simulations with no trade reversals the test is the correct specification, while for the simulations with trade reversals the test is not the correct specification. Following such an argument, one could expect different results for both groups; however the results are quite similar. A possible explanation for such an outcome can be that the simulations for both groups do not include observations beyond the SEC. The Hansen & Seo Test (2002) is based on a TVECM for which there are observations inside the neutral band, which is equivalent to the SEC, and observations in the outer regime which are missin in the simulations. When performing the test and imposing the restriction $\pi_0 \leq \mathrm{Prob}(z_{t-1} \leq \theta) \leq 1 - \pi_0$, similar to the estimation process described in Chapter 1, observations belonging to the neutral band are misallocated in the outer regime. As both groups of simulations have the same situation, the test is not a correct representation, being miss-specified for both groups. This is an argument in favour of both groups having similar results as it is suggested in table 2.6

Additionally in Threshold Error Correction one has to test the null of "linearity and no cointegration" (case I) versus the alternative of "Threshold Error Correction" (case IV). For that Seo (2006) Test is performed. The results are summarized in Table 2-7.

Table 2-7 Percentiles for the null rejection using the Seo Test

t	*Group*	π_0	*Feasible solutions*	*α=0.10*	*α=0.05*	*α=0.01*
250	No trade reversal	0.05	52	0.73	0.97	0.92
		0.10	56	0.73	0.93	0.95
		0.15	105	0.70	0.97	0.88
	Trade reversals	0.05	431	0.76	0.94	0.86
		0.10	432	0.79	0.94	0.92
		0.15	406	0.78	0.96	0.94
500	No trade reversal	0.05	56	0.25	0.29	0.39
		0.10	76	0.29	0.32	0.32
		0.15	82	0.33	0.34	0.39
	Trade reversals	0.05	405	0.11	0.13	0.18
		0.10	434	0.10	0.12	0.12
		0.15	449	0.10	0.11	0.15

Source: Author's own elaboration using the R package tsDyn developed by Di Narzo (2009) v. 0.7-60

The first outcome is that the trimming parameter π_0 has no effect on the null rejection. Thus it is interesting to observe that for both groups belonging to the same time length the results are similar. It is for both time dimensions when the results suggest different outcomes. In the case of 250 observations, the rejection of the null is high, which means that no cointegration is rejected in favour of Threshold Error Correction. Nonetheless, for the case of 500 observations the null rejection is low, which means that no cointegration cannot be rejected in favour of Threshold Error Correction. One could argue that such differences are due to the fact that in a greater time length the variation of the prices will be higher and also the variation of the error correction term $z_t(\beta = 1)$ across time. Nonetheless, this also could have an effect on the number of feasible solutions which is quite similar for both time lengths. Finally, it is important to remark that the Seo Test is a misspecification for the SEC, as it is based on a TVECM which considers the neutral band and two outer regimes. The SEC does not consider the outer regimes.

After conducting the five tests using the data which was accomplished under a scenario of perfect market integration, the subsequent task is to conciliate all the results and evaluate whether such data holds for the hypothesis of Threshold Error Correction.

2.4. Conciliated Results and Concluding Remarks

Following the concept of Threshold Error Correction by Balke & Fomby (1997), the error term of variables which are threshold-error corrected, globally is stationary and locally it has unit roots. Following this idea, in Section 2.3.1 five conditions are given which have to be fulfilled in order to have Threshold Error Correction. Table 2.8 shows the number of simulations which fulfilled the five conditions.

Table 2-8 Number and percentage of simulations which satisfies the five conditions for Threshold Error Correction

Group	*t*	*Total*	π_0	*α=0.10*		*α=0.05*		*α=0.01*	
				Number	*%*	*Number*	*%*	*Number*	*%*
No trade reversals	250	372	0.05	1	0.27%	2	0.54%	1	0.27%
			0.10	0	0.00%	0	0.00%	0	0.00%
			0.15	3	0.81%	2	0.54%	0	0.00%
	500	290	0.05	0	0.00%	0	0.00%	1	0.34%
			0.10	0	0.00%	0	0.00%	1	0.34%
			0.15	0	0.00%	0	0.00%	1	0.34%
Trade reversals	250	628	0.05	0	0.00%	0	0.00%	1	0.16%
			0.10	0	0.00%	0	0.00%	0	0.00%
			0.15	0	0.00%	0	0.00%	0	0.00%
	500	710	0.05	1	0.14%	1	0.14%	2	0.28%
			0.10	1	0.14%	1	0.14%	2	0.28%
			0.15	1	0.14%	2	0.28%	3	0.42%

Source: Author's own elaboration

The consolidated results confirm what the individual tests have already shown; the prices obtained under the Takayama Judge Price and Allocation Models which are bounded by the Spatial Equilibrium Condition, although economically integrated are not econometrically neither linear cointegrated nor Threshold Error corrected. This serves to argue that the economic concept of market integration limited either to the strong form of the LOP, or the weak form of the LOP (the spatial equilibrium condition), alone itself is not compatible with the econometric concept of Threshold Error Correction. In this regard they should not be used indistinctively as is often done in the literature. Such an outcome is because the econometric concept of cointegration for the tests presented here is based on the Threshold Vector Error Correction Model (TVECM).

It was discussed before that the TVECM and the SEC are not compatible, as the latter one does not consider observations or prices beyond disequilibrium. Indeed a core component of the tests for cointegration is disequilibrium being corrected. The correction mechanism in the econometric context is observed as a mean reverting process; that is a stationary process which reverts to its mean value and is regarded as price co-movement. The prices co-movement from the econometric test is different from the one considered in the definition of market integration. While for market integration it is the co-movement of prices following the LOP, in the error correction models the co-movement does not only mean that prices are moving in the equilibrium, it also means a restoration of the equilibrium. Indeed the restoration of the equilibrium can only be observed when the equilibrium has been violated, which does not occur for the simulations used in this research. Thus, the statement made by Barrett (2005) regarding market integration being consistent with “Pareto-inefficient distributions” has to be considered in order to have compatibility between the economic concept of market integration and the econometric concept of Threshold Error Correction. In other words disequilibrium should be considered in the economic theory which is the focus of the next Chapter. Finally the weak support for Threshold Error Correction can serve as an argument in favour of a better definition of Threshold Cointegration, such as that offered by Gonzalo & Pitarakis (2006).

3. EQUILIBRIUM AND DISEQUILIBRIUM MODELING IN SPATIAL MARKET INTEGRATION

The standard econometric tool in spatial price transmission analysis, the Threshold Vector Error Correction Model (TVECM) includes an inner regime often called the neutral band, which is analogous to what in economic theory is defined as the spatial equilibrium condition (SEC). Furthermore, the TVECM includes outer regime(s) in which error correction returns prices to the equilibrium depicted by the neutral band. However, while spatial equilibrium theory describes the SEC, it says nothing specific about the behavior of prices when this condition is violated. Hence, it provides no firm theoretical underpinning for the error correction specification in the outer regime(s) of the TVECM. Indeed, if the SEC always holds, there will be no observation of prices in the outer regime, and no basis for the estimation of a TVECM in the first place. In this paper five possible ways of modifying the standard spatial equilibrium model to make it compatible with the TVECM are proposed. Prices simulated using these modifications are used to estimate the TVECM. The results suggest that the TVECM is not a correct representation for efficient markets.

3.1. Acknowledging the Relevance of Disequilibrium in Spatial Market Integration

The concept of Spatial Market Integration suffers from a unique definition; and even though market integration refers to price co-movement in the equilibrium and in disequilibrium has been acknowledged, in the literature it is often regarded as the Law of the One Price (LOP) which focuses on a long run equilibrium relationship. Thus, the mainstream focus of Spatial Market Integration is the equilibrium, which according to neo-classical theory states that markets are cleared at any given time, hence correct allocation of resources and correct pricing takes place leading to a Pareto optimum. Such an approach is the basis of the Takayama and Judge Price and Allocation Models (TJM) which are the core economic theory in Spatial Market Integration analysis, leaving out the explanatory causes for disequilibrium and how the equilibrium is restored. This is counterfactual to many empirical applications which use econometric techniques of which in the short run violations of the equilibrium are corrected by the arbitrage. Thus, the assumption that the errors are corrected and explanations for how the equilibrium is restored lack sound economic theory in order to understand the economic phenomena. A strong critic to the lack of sound economic theory in Spatial Market Integration can be found in Wymer (1996) who states: "*This use of error correction models appears to have arisen more from atheoretical time-series consideration than from an approach that begins with economic theory*".

The objective of the author with this chapter is to propose different models that can serve to create data which violates the Spatial Equilibrium Condition (SEC) based on economic theory. Following the spirit of the previous chapters, the data generated under the models is used in estimating Threshold Vector Error Correction Models in order to evaluate the compatibility of the economic theory and the econometric methods.

3.2. A Brief Introduction to the Disequilibrium Models

Compared to the vast literature on equilibrium modelling, disequilibrium modelling research is scarce and more orientated towards macroeconomics, rather than the context of Spatial Market Integration. However, much of the theoretical principles ruling disequilibria can be extended to the particular case of the Spatial Equilibrium Condition.

Andreassen (1993) provides a comprehensive overview of disequilibrium modelling pointing out the role of expectations; his argument is that observed prices and quantities depend on agents' expectations for prices and quantities whereby agents signal their expectations to the markets which respond by allocating quantities to each agent. When agents' expectations are not fulfilled disequilibrium occurs. A similar argument is offered by Srivastava & Bhaskara Rao (1990), who claim that spillover effects lead to distinguishing between notional and effective demand and supply by showing how an agent constrained to trade less than he expects revises his plans in other markets. Other sources of disequilibrium mentioned in the literature are stocks, as pointed out by Green & Laffont (1981). Maddala (1990) states that sources of disequilibrium are policy interventions aimed at stabilizing prices; he quotes the following five types of market intervention mentioned by Mc.Nicol (1978): (1) purchase alone with the material held in storage indefinitely, (2) purchases coupled with supply restriction, (3) purchases and sales unrestricted on supply, (4) restrictions on supply, (5) purchases and sales coupled with supply restrictions. Indeed restrictions on the supply size can prevent the allocation of the expected trade to the agents as pointed by Andreassen (1993) and Srivastava & Bhaskara Rao (1990).

Regarding the strategy for modelling disequilibria the use of regimes is often noted as a common factor, as in the work done by Fair & Jaffe (1972), Maddala & Nelson (1974), Laffont & Garcia (1977), Maddala (1986) and Weddepohl (1996). The distinction between regimes is often based on the relationship between excess demand and supply such that one regime is characterized by the condition $d_t < s_t$ and the other by the condition $d_t > s_t$, with an equilibrium $d_t = s_t$, where d_t denotes the demand and s_t the supply. Another plausible way to distinguish between regimes is by means of the contemporaneous and lagged prices, for instance a regime with $p_t < p_{t+1}$ and another regime with $p_t > p_{t+1}$, where p denotes the price and t the time dimension. Apart from the regimes, another characteristic of the disequilibrium models is an adjustment process derived from the excess supply and demand. For example Weddepohl (1996) developed different models to describe disequilibrium price adjustment; his work is based on different regime delimited by a threshold value, which in his research is the amount of trade. The adjustment process he describes is based on the excess demand which causes a trade surplus; such a surplus must be repaid in the following periods at a constant rate. In summary, disequilibrium models are strongly based on misallocations among supplies, demands and agents' expectations, while the restoration to the equilibrium is based on supply and demand shifts. Indeed these theoretical elements, if not implemented and studied in detail, have been acknowledged in Spatial Market Integration Analysis. In this regard it is possible to argue that the criticisms put forward by Wymer (1996) might be refuted as the Error Correction Models have not arisen from a purely atheoretical-time-series perspective. The fact that the time series techniques have become the standard tool is not only related to the fact that they provide strong support in favour of the LOP; some authors have acknowledge the importance of arbitrage of shifts in supply in demand for restoring the equilibrium. The main weakness is that the economic theory in Spatial Market Integration has not been extended to a disequilibria situation.

3.3. Modelling Disequilibrium and the Spatial Equilibrium Condition

So far an overview of how disequilibrium occurs has been given. In general a plausible approach to tackle the problem of disequilibrium modelling is by inefficient trade as suggested in the literature. For instance consider that the effective quantity $q^*_{t,11}$ of trade can differ from the quantity of trade in the equilibrium $q_{t,ij}$; if that is the case an inefficient allocation of supply and demand, as well as incorrect pricing will occur. In order to distinguish between effective trade, effective supply, effective demand and effective prices from the equilibrium, first the inverse supply and demand functions must be rewritten such that:

$$p^{*d}_{t,j} = \lambda_j - \omega_j y^*_{t,j} \tag{3.1}$$

$$p^{*s}_{t,i} = \nu_{t,i} + \eta_i x^*_{t,i}, \tag{3.2}$$

while the matrix of transport costs can be rewritten as

$$\mathbf{Q}^*_{t,ij} \equiv \begin{bmatrix} q^*_{t,11} & q^*_{t,21} & \cdots & q^*_{t,n1} \\ q^*_{t,12} & q^*_{t,22} & \cdots & q^*_{t,n1} \\ \vdots & \vdots & \ddots & \vdots \\ q^*_{t,11} & q^*_{t,2n} & \cdots & q^*_{t,nn} \end{bmatrix}, \tag{3.3}$$

The matrix of transport costs does not have any modification at this stage and remains as in Equation (1.9). The Net Social Payoff as in Equation (1.4) can be rewritten as:

$$NSP^* = \sum_t \Big(\sum_j \lambda_j \sum_j y^*_{t,j} - \tfrac{1}{2} \sum_j \omega_j \big(\sum_j y^*_{t,j}\big)^2 - \sum_i (\nu_{t,i}) \sum_j x^*_{t,i} - \tfrac{1}{2} \sum_j \eta_i \big(\sum_i x^*_{t,i}\big)^2 - \sum_j \sum_i \tau_{ji} q^*_{t,ji} \Big) \tag{3.4}$$

In order to solve for the optimum solution, NSP^* has to be maximized subject to the following constrains:

$$\begin{bmatrix} 1 & & & & 1 & & & & & 1 & & & \\ & 1 & & & & 1 & & & & & 1 & & \\ & & \ddots & & & & \ddots & & & & & \ddots & \\ & & & 1 & & & & 1 & \cdots & & & & 1 \\ -1 & -1 & \cdots & -1 & & & & & & & & & \\ & & & & -1 & -1 & \cdots & -1 & & & & & \\ & & & & & & & & \ddots & & & & \\ & & & & & & & & & -1 & -1 & \cdots & -1 \end{bmatrix} \begin{bmatrix} q^*_{t,11} \\ q^*_{t,12} \\ \vdots \\ q^*_{t,1n} \\ q^*_{t,21} \\ q^*_{t,22} \\ \vdots \\ q^*_{t,2n} \\ \vdots \\ q^*_{t,n1} \\ q^*_{t,n2} \\ \vdots \\ q^*_{t,nn} \end{bmatrix} \geqq \begin{bmatrix} y^*_{t,1} \\ y^*_{t,2} \\ \vdots \\ y^*_{t,n} \\ -x^*_{t,1} \\ -x^*_{t,2} \\ \vdots \\ -x^*_{t,3} \end{bmatrix} \tag{3.5}$$

and

$$y^* \geqq 0, x^* \geqq 0, \mathbf{Q}^* \geqq 0 \tag{3.6}$$

When the effective variables are different from the equilibrium variables such that $q^*_{t,ij} \neq q_{t,ij}$, $y^*_{t,i} \neq y_{t,i}$, $y^*_{t,j} \neq y_{t,j}$, $x^*_{t,i} \neq x_{t,i}$, $x^*_{t,j} \neq x_{t,j}$, $p^*_{t,i} \neq p_{t,i}$ and $p^*_{t,j} \neq p_{t,j}$, the price difference is not bounded by the SEC such that $p^*_{t,i} - p^*_{t,j} > \tau_{ji}$. On the contrary if the effective variables are equal to the equilibrium variables such that $q^*_{t,ij} = q_{t,ij}$, $y^*_{t,i} = y_{t,i}$, $y^*_{t,j} = y_{t,j}$, $x^*_{t,i} = x_{t,i}$, $x^*_{t,j} = x_{t,j}$, $p^*_{t,i} = p_{t,i}$ and $p^*_{t,j} = p_{t,j}$, the price difference are bounded by the SEC such that $p^*_{t,i} - p^*_{t,j} \leq \tau_{ji}$. This is equivalent to having two regimes, one when the effective variables are in equilibrium and another when the effective variables are found in disequilibrium. This setup follows the approach of disequilibrium models of having observations belonging to different regimes.

So far the model provides the general idea behind having a regime of equilibrium and disequilibrium. The constraints denoted in Equation (3.5) ensures a positive balance between trade, supply and demand, while the constrain denoted in Equation (3.6) ensures that the variables trade, supply and demand will be positive; nevertheless it does not provide any theoretical mechanism which causes an incorrect allocation of resources such that the SEC is violated. The following models will focus on different mechanisms which serve to model the disequilibrium.

3.3.1. Lagged Trade Disequilibrium Model

The Takayama and Judge Price and Allocation Models are based on the neo-classical theory, which holds that markets are cleared at any given time. This implies that in a specific period of time the supply, demand, trade and prices are determined simultaneously; however such an assumption can be questioned, especially in spatially separated locations. The movement of product among regions is not immediately effective and can be delayed for some periods so that it can be easily arguable that the effective trade at period *t* will correspond to the equilibrium trade at period *t-k* such that $q_{t-k,ij} = q^*_{t,ij}$. It is only when the condition $q_{t-k,ij} = q^*_{t,ij} = q_{t,ij}$ is fulfilled that prices are in equilibrium such that $p^*_{t,i} = p_{t,i}$ and $p^*_{t,j} = p_{t,j}$, the solution is a Pareto optimum such that the prices fulfil the SEC, that is $p^*_{t,i} - p^*_{t,j} \leq \tau_{ji}$. Otherwise when $q_{t-1,ij} = q^*_{t,ij} \neq q_{t,ij}$, then $p^*_{t,i} \neq p_{t,i}$ and $p^*_{t,j} \neq p_{t,j}$ which implies an inefficient allocation of resources and the prices are not bouded by the SEC such that $p^*_{t,i} - p^*_{t,j} > \tau_{ji}$.

In order to set up the model it is necessary to know the solution in the equilibrium for the matrix of trade $\mathbf{Q}_{t,ij}$, since the product arrives delayed k periods of time, the matrix can be rewritten as $\mathbf{Q}_{t-k,ij}$ such that

$$\mathbf{Q}_{t-k,ij} \equiv \begin{bmatrix} q_{t-k,11} & q_{t-k,21} & \cdots & q_{t-k,n1} \\ q_{t-k,12} & q_{t-k,22} & \cdots & q_{t-k,n2} \\ \vdots & \vdots & \ddots & \vdots \\ q_{t-k,1n} & q_{t-k,2n} & \cdots & q_{t-k,nn} \end{bmatrix} \tag{3.8}$$

The constrain which shifts trade $q_{t-k,ij} = q^*_{t,ij}$ is restricted only to the cases $i \neq j$, otherwise the effective internal supply[3], supply and demand would correspond to lagged values as well, with the lagged values being the equilibrium. This implies ignoring the diagonal elements of the matrices in Equations (3.3) and (3.8) such that the constraint can be written as

$$\begin{bmatrix} 0 & q^*_{t,21} & \cdots & q^*_{t,n1} \\ q^*_{t,12} & 0 & \cdots & q^*_{t,n1} \\ \vdots & \vdots & 0 & \vdots \\ q^*_{t,11} & q^*_{t,2n} & \cdots & 0 \end{bmatrix} \equiv \begin{bmatrix} 0 & q_{t-1,21} & \cdots & q_{t-1,n1} \\ q_{t-1,12} & 0 & \cdots & q_{t-1,n2} \\ \vdots & \vdots & 0 & \vdots \\ q_{t-1,1n} & q_{t-1,2n} & \cdots & 0 \end{bmatrix} \tag{3.9}$$

and is referred to as the disequilibrium constraint. The model can be solved by maximizing the NSP* as in Equation (3.4) subject to the constraints denoted in Equations (3.5), (3.9) and (3.6). This model is from now on referred to as the Lagged Trade Disequilibrium Model or simply LTD.

3.3.2. White Noise Disequilibrium Model

A common assumption in economics is that for observable variables often there are implicit unobservable errors. For instance consider that for a single period of time *t*, the correct allocation of resources is determined so markets can be cleared. Nevertheless, although trade occurs in equilibrium on average, unobservable errors can take place and affect the effective trade. Plausible causes in favour of such argument is that during transportation losses occur, also it is also plausible to argue that there are errors during the shipping process, hence although the effective quantity of trade is close to the equilibrium amount of trade, there are some differences which on average are zero.

Using the previous arguments one can define the errors as white noise processes $m_{t,ji} \sim N(0,1)$ which are added to the quantity of trade. Under this model the violations of the spatial equilibrium condition occur when the white noise process is different from zero such that $m_{t,ji} \neq 0$, which implies the condition $q_{t,ij} \neq q^*_{t,ij}$ such that $p^*_{t,i} - p^*_{t,j} > \tau_{0,ji}$. It is when

[3] The internal supply is defined ad the amount of trade ($q_{t,ij}$) which takes place within the same region ($i = j$), or the quantity of the supply of a region which stays in the region.

$m_{t,ji} = 0$ that the condition $q_{t,ij} = q^*_{t,ij}$ holds and the prices are bounded by the SEC such that $p^*_{t,i} - p^*_{t,j} \leq \tau_{0,ji}$.

For implementing this model it is necessary to modify the restriction denoted in Equation (3.5) so that it includes the white noise parameters $m_{t,ji} \sim N(0,1)$. Recall that Equation (3.5) in matrix form can be written as

$$\begin{bmatrix} \mathbf{G}^*_{\mathbf{Y}} \\ \mathbf{G}^*_{\mathbf{X}} \end{bmatrix} \mathbf{Q}^* \geqq \begin{bmatrix} y^* \\ -x^* \end{bmatrix} \tag{3.10}$$

such that

$$\begin{bmatrix} \mathbf{G}^*_{\mathbf{Y}} \\ \mathbf{G}^*_{\mathbf{X}} \end{bmatrix} \equiv \begin{bmatrix} 1 & & & & 1 & & & & & 1 & & & \\ & 1 & & & & 1 & & & & & 1 & & \\ & & \ddots & & & & \ddots & & & & & \ddots & \\ & & & 1 & & & & 1 & \cdots & & & & 1 \\ -1 & -1 & \cdots & -1 & & & & & & & & & \\ & & & & -1 & -1 & \cdots & -1 & & & & & \\ & & & & & & & & \ddots & & & & \\ & & & & & & & & & -1 & -1 & \cdots & -1 \end{bmatrix} \tag{3.11}$$

The new restriction is obtained by adding to the all the elements $q^*_{t,ij}$ with $j \neq i$ the white noise parameter $m_{t,ij}$. The restriction is written as in Equation (3.12).

The problem is solved by maximizing the NSP^* as in Equation (3.4) subject to the constraints denoted in Equations (3.6) and (3.12). Under this model the disequilibrium constraint is contained in Equation (3.12). Note that the equilibrium is not necessary for solving the problem. This model is from now on referred to as the White Noise in Disequilibrium model or simply WND.

$$
\begin{bmatrix}
1 & & & & 1 & & & & & 1 & & & \\
 & 1 & & & & 1 & & & & & 1 & & \\
 & & \ddots & & & & \ddots & & & & & \ddots & \\
 & & & 1 & & & & 1 & \cdots & & & & 1 \\
-1 & -(1+m_{t,12}) & \cdots & -(1+m_{t,1n}) & & & & & & & & & \\
 & & & & -(1+m_{t,21}) & -1 & \cdots & -(1+m_{t,2n}) & & & & & \\
 & & & & & & & & \ddots & & & & \\
 & & & & & & & & & -(1+m_{t,n1}) & -(1+m_{t,n2}) & \cdots & -1
\end{bmatrix}
\begin{bmatrix}
q^*_{t,11} \\ q^*_{t,12} \\ \vdots \\ q^*_{t,1n} \\ q^*_{t,21} \\ q^*_{t,22} \\ \vdots \\ q^*_{t,2n} \\ \vdots \\ q^*_{t,n1} \\ q^*_{t,n2} \\ \vdots \\ q^*_{t,nn}
\end{bmatrix}
\geq
\begin{bmatrix}
y^*_{t,1} \\ y^*_{t,2} \\ \vdots \\ y^*_{t,n} \\ -x^*_{t,1} \\ -x^*_{t,2} \\ \vdots \\ -x^*_{t,3}
\end{bmatrix}
\tag{3.12}
$$

3.3.3. Moving Average Restriction Disequilibrium Model

As it was discussed before, the assumption that for a single period of time the variables trade, supply, demand and prices are determined simultaneously might be quite restrictive; especially in spatially separated locations. Traders have to plan in advance in order to ship in manner and time, so rather than waiting to have the quantity of trade which corresponds to the equilibrium they trade the effective trade $q^*_{t,ij}$. The formation of the effective trade $q^*_{t,ij}$ takes place under risk aversion so that traders are not willing to trade beyond a limit; such a limit is formed on the basis of previous quantities of effective trade. Indeed the limit is a restriction, which for this research, can be defined as a linear function of previous realizations of trade, hence the restriction can be seen as a finite autoregressive process such that

$$r^*_{t,ij} = c + \phi_1 q^*_{t-1,ij} + \phi_2 q^*_{t-2,ij} + \cdots + \phi_k q^*_{t-p,ij} + \varepsilon_t \tag{3.13}$$

Equation (3.13) is a representation of an autoregressive process of order p denoted as AR(p). Alternatively the finite AR(p) can be written as an infinite moving average process MA(∞) of the form

$$r^*_{t,ij} = \bar{q}^*_{ij} + \textstyle\sum_l^\infty \psi_l \, \varepsilon_{t-l} \tag{3.14}$$

Note that for the MA(∞) the contemporaneous restriction is an average value of trade $\bar{q}^*_{ij}$ plus the accumulation of previous errors.

The disequilibrium occurs when the restriction is lower than the trade in equilibrium, that is when $r^*_{t,ij} < q_{t,ij}$, this implies that the effective trade will be equal to the restriction such that $q^*_{t,ij} = r^*_{t,ij}$, hence $q^*_{t,ij} < q_{t,ij}$. This leads to prices being in disequilibrium and not bounded by the SEC such that $p^*_{t,i} - p^*_{t,j} > \tau_{0,ji}$. Equilibrium occurs when the restriction is greater or equal to the trade in equilibrium such that $r^*_{t,ij} \geq q_{t,ij}$, this implies that the effective trade will be lower or equal to the restriction such that $q^*_{t,ij} \leq r^*_{t,ij}$, hence $q^*_{t,ij} = q_{t,ij}$, which implies prices that prices are bounded by the SEC such that $p^*_{t,i} - p^*_{t,j} \leq \tau_{0,ji}$.

Furthermore the restriction holds only for every $q^*_{t,ij}$ such that $j \neq i$, otherwise the internal trade is affected. The restriction can be written as

$$\begin{bmatrix} 0 & q^*_{t,21} & \cdots & q^*_{t,n1} \\ q^*_{t,12} & 0 & \cdots & q^*_{t,n2} \\ \vdots & \vdots & 0 & \vdots \\ q^*_{t,1n} & q^*_{t,2n} & \cdots & 0 \end{bmatrix} \leqq \begin{bmatrix} 0 & r^*_{t,21} & \cdots & r^*_{t,n1} \\ r^*_{t,12} & 0 & \cdots & r^*_{t,n2} \\ \vdots & \vdots & 0 & \vdots \\ r^*_{t,1n} & r^*_{t,2n} & \cdots & 0 \end{bmatrix} \tag{3.15}$$

and is the disequilibrium constrain. Note that the autoregressive process makes the model a recursive one as the contemporaneous solutions depend on previous solutions. Furthermore the model needs a starting value at least for every $q^*_{t-1,ij}$ in order to solve the subsequent periods.

This problem is solved by allowing the initial solution to be the equilibrium such that $q_{0,ij}^{*}$=$q_{0,ij}$, so there is no restriction for *t=0.*

The model can be solved by maximizing NSP^{*} as in Equation (3.4) subject to the constraints denoted in Equations (3.5), (3.6) and (3.15). The solution in the equilibrium is necessary only for the initial value and not for the subsequent periods. This model is from now on referred as Moving Average Restriction Disequilibrium model or simply MARD.

3.3.4. Restrictive Recursive Disequilibrium Model

Similar to the previous model with a restriction, some exogenous factors can limit the effective trade among spatially separated regions. For instance consider the transport capacity, i.e. number of trucks, which may vary due to externalities such as reparation, renovation or use for other activities. Traders can be constrained to the availability of such resources, and effective trade can differ from the trade in the equilibrium. In order to set up a restriction assume that trade in equilibrium $q_{t,ji}$ is known, now the restriction is denoted as $r_{t,ji}$ and is a random number such that $r_{t,ji} \sim \mathrm{U}(\bar{q}_{ji}, \max(q_{t,ji}))$, where $\bar{q}_{ji} = \left(\sum_t q_{t,ji}\right)/t$ is the average amount of trade in equilibrium and $\max(q_{t,ji})$ is the maximum amount of trade in equilibrium. The restriction works so that the amount of trade for period *t* cannot be greater than the restriction for period *t*, which leads to the constraint $q_{t,ji}^{*} \leq r_{t,ji}$. If the condition $q_{t,ji} \leq r_{t,ji}$ is fulfilled, then $q_{t,ji} = q_{t,ji}^{*}$, and prices are bounded by the SEC such that $p_{t,i}^{*} - p_{t,j}^{*} \leq \tau_{0,ji}$. On the contrary, if $q_{t,ji} > r_{t,ji}$, then $q_{t,ji} > q_{t,ji}^{*}$ and $q_{t,ji}^{*} = r_{t,ji}$, here the trade corresponds to a disequilibrium and prices are not bounded by the SEC, hence $p_{t,i}^{*} - p_{t,j}^{*} > \tau_{0,ji}$.

So far the restriction serves to create a mechanism for prices in disequilibrium when the restriction takes place and for prices in equilibrium when the restriction does not take place. The following task is to create a linkage for prices among the time in which the solution for the contemporaneous period of time *t* depends on the solution of the lagged time period *t-1*. For doing so the difference between the trade in equilibrium, $q_{t-1,ji}$, and the trade with the restriction $q_{t-1,ji}^{*}$ is considered, which can be denoted as $\delta_{t-1,ji}$ such that

$$\delta_{t-1,i} = \sum_j \left(q_{t-1,ji} - q_{t-1,ji}^{*}\right) \tag{3.16}$$

The parameter $\delta_{t-1,i}$ is the remaining part that was not traded due to the restriction $r_{t-1,ji}$. This amount is added to the contemporaneous time period *t* in the supply, thus the supply function for the period *t* is denoted as:

$$x_{t,i}^{*} = \theta_{t,i} + \delta_{t-1,ji} + \gamma_j p_{t,i}^{S*} \tag{3.17}$$

Rearranging the terms the inverse supply function can be written as:

$$p_{t,i}^{S*} = \nu_{t,i} - \eta_i \delta_{t-1,ji} + \eta_i x_{t,i}^* = \nu_{t,i} + \eta_i \left(x_{t,i}^* - \delta_{t-1,ji} \right) \tag{3.18}$$

The parameter $\delta_{t-1,ji}$ shifts positively the supply, which has a negative impact on the price as shown in Equations (3.17) and (3.18). As the inverse supply function is affected the NSP^* has to be rewritten as

$$NSP^* = \sum_t \left(\sum_j \lambda_j \sum_j y_{t,j}^* - \frac{1}{2} \sum_j \omega_j \left(\sum_j y_{t,j}^* \right)^2 - \sum_i \left(\nu_{t,i} - \eta_i \delta_{t-1,i} \right) \sum_j x_{t,i}^* - \frac{1}{2} \sum_j \eta_i \left(\sum_i x_{t,i}^* \right)^2 - \sum_j \sum_i \tau_{ji} q_{t,ji}^* \right) \tag{3.19}$$

The new constrain can be written as:

$$\begin{bmatrix} 0 & q_{t,21}^* & \cdots & q_{t,n1}^* \\ q_{t,12}^* & 0 & \cdots & q_{t,n2}^* \\ \vdots & \vdots & 0 & \vdots \\ q_{t,1n}^* & q_{t,2n}^* & \cdots & 0 \end{bmatrix} \leqq \begin{bmatrix} 0 & r_{t,21} & \cdots & r_{t,n1} \\ r_{t,12} & 0 & \cdots & r_{t,n2} \\ \vdots & \vdots & 0 & \vdots \\ r_{t,1n} & r_{t,2n} & \cdots & 0 \end{bmatrix} \tag{3.20}$$

Like the previous models, this constrain is referred as the disequilibrium constrain. Note that the new constraint denoted in Equation (3.20) in a sense works similarly to the constraint denoted in Equation (3.15) from the Moving Average Restriction Disequilibrium model: both are restrictions on trade. Nevertheless in this set up the inclusion of the parameter $\delta_{t-1,ji}$ is a mechanism which links the NSP^*across the time. Hence the linkage is done trough the objective function, while in the MARD model the linkage is done trough the restriction itself. The model can be solved by maximizing Equation (3.19) subject to the constraints denoted in Equations (3.5), (3.6) and (3.20). The solution for the equilibrium is needed in order to set up the restriction. This model is from now on referred to as the Restrictive Recursive Disequilibrium Model or simply RRD.

3.3.5. White Noise Equilibrium Model

From the previous four models, LTD, WND, MARD, and RRD a framework in which both equilibrium and disequilibrium occur was set up. The basic condition for disequilibrium to occur is $q_{t,ij}^* \neq q_{t,ij}$, and the basic condition for equilibrium to occur is $q_{t,ij}^* = q_{t,ij}$. Now assume that disequilibrium occurs consecutively in the range of observations from t up to $t + m$, then in the time period $t + m + 1$ the solution corresponds to an equilibrium; which implies that the errors from previous periods are immediately corrected as the equilibrium has been restored. Nevertheless, it is of interest to see if the observations in disequilibrium, that is $p_{t,i}^* - p_{t,j}^* > \tau_{0,ji}$, behave differently than data in equilibrium.

Following the previous question one can look at the research done by McNew & Fackler (1997) which generated data in pure equilibrium under a model with random transport costs. Following this idea the transport costs τ_{ji} can be denoted as

$$\tau_{t,ji} = \tau_{0,ji} + |\varepsilon_{t,ji}| \tag{3.20}$$

where $\tau_{o,ji}$ is the minimum value of the transport costs and $\varepsilon_t \backsim \mathrm{N}(0,1)$is a white noise component so that the matrix of transport costs can be written as

$$\mathbf{T}_{t,ij} \equiv \begin{bmatrix} 0 & \tau_{t,21} & \cdots & \tau_{t,n1} \\ \tau_{t,12} & 0 & \cdots & \tau_{t,n2} \\ \vdots & \vdots & 0 & \vdots \\ \tau_{t,1n} & \tau_{t,2n} & \cdots & 0 \end{bmatrix} \tag{3.21}$$

This modification to the model will give equilibrium prices as an outcome, so there are no violations of the equilibrium condition; nevertheless is possible to observe deviations from $\tau_{o,ji}$ which on average are zero, so that the spatial equilibrium condition can be written as

$$p_{t,i} - p_{t,j} \leq \tau_{0,ji} + |\varepsilon_{t,ji}| \tag{3.22}$$

and the LOP which is equivalent to the error term evaluated at $\beta = 1$ can be denoted as

$$z_t(\beta = 1) = p_{t,i} - p_{t,j} = \tau_{0,ji} + |\varepsilon_{t,ji}| \tag{3.23}$$

Recall that the TVECM considers a constant threshold for which the neutral band can be denoted as $p_{t,i} - p_{t,j} \leq \hat{\theta}$ where the threshold parameter $\hat{\theta}$ is constant across time. Alternatively the neutral band can be written as $p_{t,i} - p_{t,j} \leq \hat{\tau}_{ji}$, where $\hat{\tau}_{ji}$ is the unbiased estimated threshold parameter from the TVECM, so that each $z_t(\beta = 1) > \hat{\tau}_{ji}$ is an observation which belong to the outer regime; only when $\hat{\tau}_{ji} \geq \mathrm{Max}(\tau_{t,ji})$ will there be no observation in the outer regime. Note that since further constrain which distorts the optimum amount of trade are not considered, the condition $q^*_{t,ij} = q_{t,ij}$ is always fulfilled. The idea of generating such a model is to compare how data in pure equilibrium performs versus data in equilibrium/disequilibrium.

The model can be solved by maximizing the Equation (3.4) subject to the constraints denoted in Equations (3.5) and (3.6) with a matrix of transport costs denoted as in Equation (3.21). This model is from now on referred to as the White Noise Equilibrium Model or simply WNE.

3.4. Data Generation and TVECM Estimation

After having provided the theoretical background the data generation process follows. Two regions are considered with the inverse supply and demand functions

$$p^{*s}_{1,t} = 5 + \sum_{s=1}^{t} \varepsilon_t + 0.1x^*_{1,t} \quad (3.24) \qquad p^{*d}_{1,t} = 20 - 0.1y^*_{1,t} \quad (3.25)$$

$$p^{*s}_{2,t} = 2.5 + \sum_{s=1}^{t} \varepsilon_t + 0.05x^*_{2,t} \quad (3.26) \qquad p^{*d}_{2,t} = 20 - 0.2y^*_{2,t} \quad (3.27)$$

The matrix of transport costs for the LTD, WND, MARD, and RRD models is denoted as:

$$\mathrm{T}_{12} = \begin{bmatrix} 0 & 2 \\ 2 & 0 \end{bmatrix} \quad (3.28)$$

and for the model WNE it is denoted as:

$$\mathrm{T}_{t,12} = \begin{bmatrix} 0 & \tau_{t,21} \\ \tau_{t,12} & 0 \end{bmatrix} \quad (3.29)$$

with $\tau_{t,12} = \tau_{t,21} = 2 + |\varepsilon_{t,ji}|$ and $\varepsilon_{t,ji} \sim \mathrm{N}(0,1)$.

For the MARD model, the restriction is the AR(3) process

$$r^*_{t,ij} = 0.5q^*_{t-1,ij} + 0.3q^*_{t-2,ij} + 0.2q^*_{t-3,ij} + \varepsilon_t \quad (3.30)$$

For the five models a time length dimension of $t = 200$ is selected. Additionally, given the nature of the random walk process in Equations (3.24) and (3.26), trade reversals are likely to occur. In order to distinguish among simulations, those who have trade reversals and those who do not are made into two groups whereby a total of 500 simulations are obtained for each group.

The general technique for solving the models is to maximize the objective function subject to a set constrains. Within the set of constrain one can distinguish among three types of constrains: (1) a positive balance between trade, supply and demand, (2) positive values for trade, supply and demand; and (3) disequilibrium in trade.

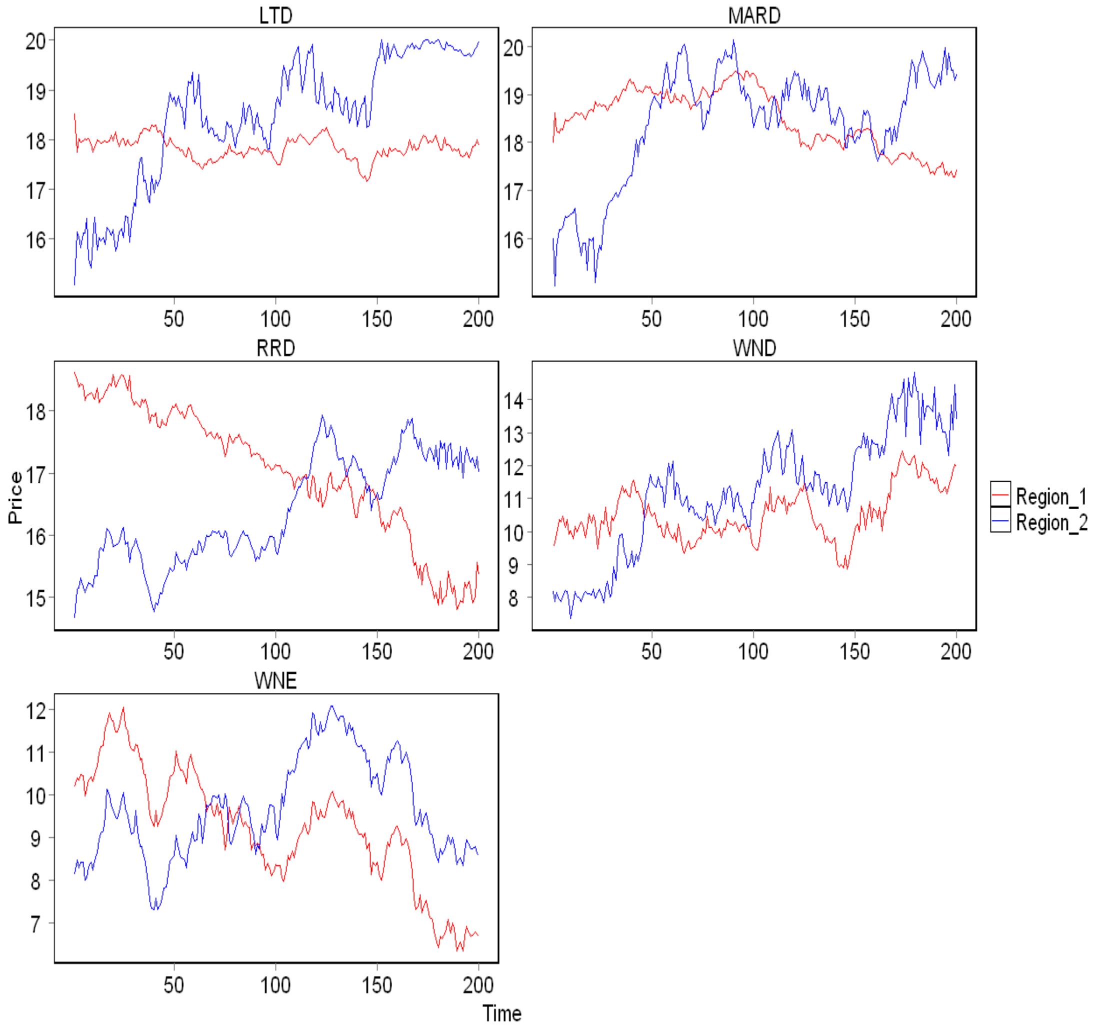
Table 3-1 summarizes the five models so as to provide an overview of the set of equations required for solving each one, as well as common characteristics needed in order to obtain the simulations.

Table 3-1 Models equations and components for the simulations

<table>
<tr><th></th><th>Lagged Trade Model</th><th>White Noise Disequilibrium</th><th>Moving Average Restriction Disequilibrium</th><th>Recursive Disequilibri</th><th>White Noise Equilibrium</th></tr>
<tr><td>Time dimension</td><td colspan="5">200 observations</td></tr>
<tr><td>Simulations with trade reversals</td><td colspan="5">500 simulations</td></tr>
<tr><td>Simulations without trade reversals</td><td colspan="5">500 simulations</td></tr>
<tr><td>Number of regions</td><td colspan="5">2 regions</td></tr>
<tr><td>Inverse supply function</td><td colspan="5">Equations (3.24) and (3.26)</td></tr>
<tr><td>Inverse demand function</td><td colspan="5">Equations (3.25) and (3.27)</td></tr>
<tr><td>Matrix of transport costs</td><td colspan="4">Equation (3.28)</td><td>Equation (3.29)</td></tr>
<tr><td>Objective Function (NSP)</td><td colspan="3">Equation (3.4)</td><td>Equation (3.19)</td><td>Equation (3.4)</td></tr>
<tr><td>Constrain for a positive balance among trade, supply and demand</td><td>Equation (3.5)</td><td>Equation (3.12)</td><td colspan="3">Equation (3.5)</td></tr>
<tr><td>Constrain for positive values in trade, supply and demand</td><td colspan="5">Equation (3.6)</td></tr>
<tr><td>Constrain for disequilibrium</td><td>Equation (3.9)</td><td>Equation (3.12)</td><td>Equation (3.15)</td><td>Equation (3.20)</td><td>NA</td></tr>
</table>

The first important elements and the only one used on the TVECM estimations are the prices for Region 1 and Region 2 which are denoted as $p^*_{1,t}$ and $p^*_{2,t}$ respectively. To give an illustration of how prices simulated under the five models perform, Figure 3.1 shows as an example a single simulation performed under each of them.

Figure 3-1 Example of one simulation for each of the five models



The prices shown in figure 3.1 are a mixture of prices in equilibrium such that $p^*_{t,i} - p^*_{t,j} \leq \tau_{0,ji}$, and prices in disequilibrium $p^*_{t,i} - p^*_{t,j} > \tau_{0,ji}$, as discussed before. This can be observed in Figure 3-2 which shows the performance of the error term $z_t(\beta = 1)$ for the set of simulations which prices are observed in Figure 3-1.

Figure 3-2 Example of a single simulation as in Figure 3.1 for the Error Term $\boldsymbol{z_t(\beta = 1)}$

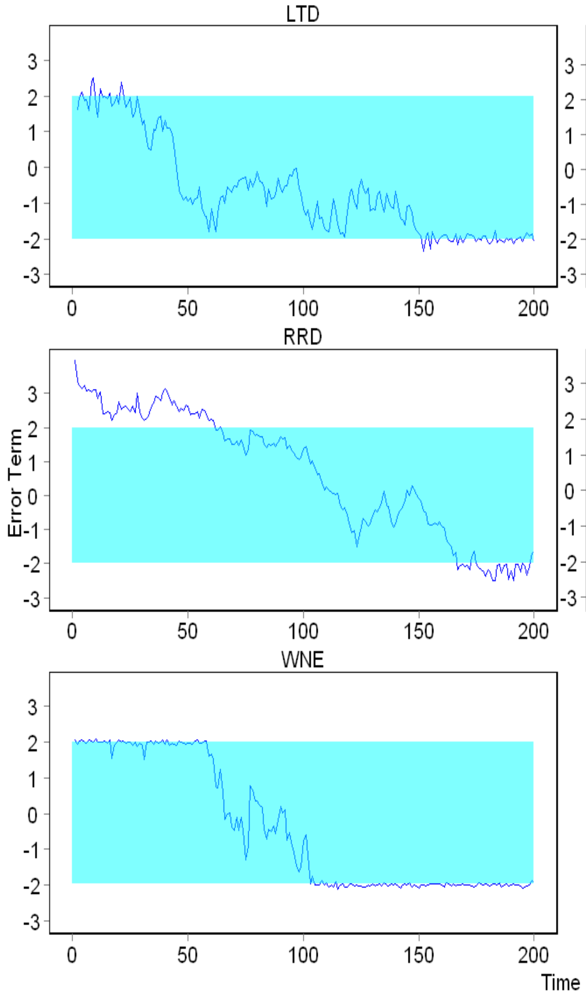
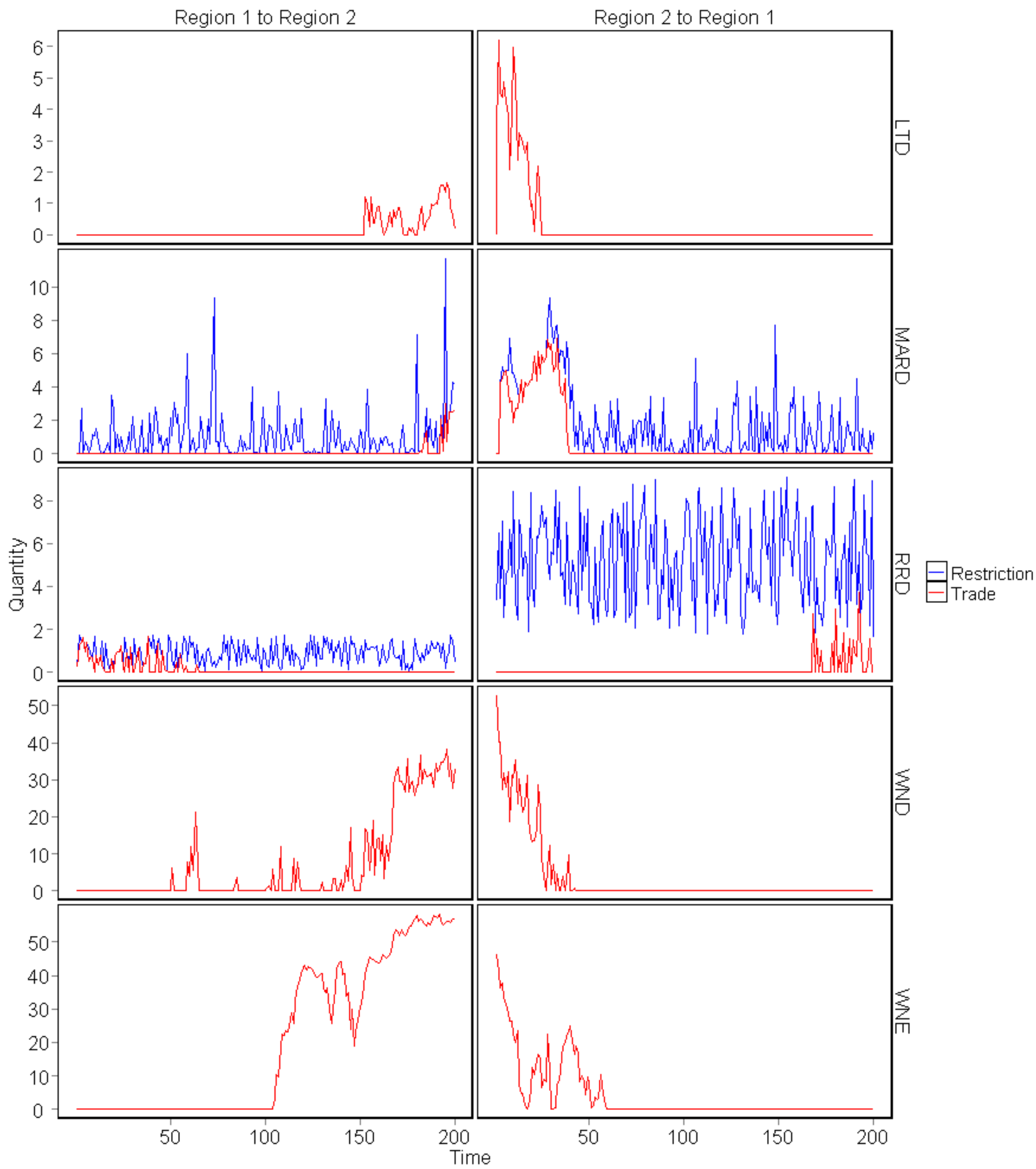


Figure 3-2 shows how, for one example of each model, the error term error term $z_t(\beta = 1)$ performs; the blue light area represents the Spatial Equilibrium Condition on which prices are bounded as $p^*_{t,i} - p^*_{t,j} \leq \tau_{0,ji}$. Outside the blue light area the prices are in equilibrium such that the condition $p^*_{t,i} - p^*_{t,j} > \tau_{0,ji}$ holds. Note that in the examples there are observations below and above the SEC because of trade reversals, so that the direction of the trade changes, while when prices are bounded by the SEC no trade takes place.

In order to illustrate the performance of trade, Figure 3-3 shows the variable trade for a single simulation under each of the models; additionally the restriction for the models MARD and RRD are shown.

Figure 3-3 Example of a single simulation as in Figure 3.1 for the quantities of trade $\boldsymbol{q}^*_{12,t}$ and $\boldsymbol{q}^*_{21,t}$, and the restrictions $\boldsymbol{r}^*_{12,t}$, $\boldsymbol{r}^*_{12,t}$.



Once the simulations are done, the obtained prices are used for the estimation of a TVECM using the profile likelihood method as shown in Hansen & Seo (2002). The simulations have to consider the correct specification of a TVECM. In the absence of trade reversals a TVECM with one threshold and two regimes as follows is estimated

$$\Delta P_t = \begin{cases} A^U z_{t-1} + \Psi_1^{\mathrm{U}} \Delta P_{t-1} + \cdots + \Psi_{\mathrm{k}}^{\mathrm{U}} \Delta P_{t-k} + u_t^U \ \ if \ \ z_{t-1} > \theta \\ A^N z_{t-1} + \Psi_1^{\mathrm{N}} \Delta P_{t-1} + \cdots + \Psi_{\mathrm{k}}^{\mathrm{N}} \Delta P_{t-k} + u_t^N \ \ if \ \ z_{t-1} \leq \theta \end{cases} \tag{3.31}$$

For the simulations with trade reversal it is estimated a TVECM with three regimes and two thresholds is estimated, such that

$$\Delta P_t = \begin{cases} A^U z_{t-1} + \Psi_1^{U}\Delta P_{t-1} + \cdots + \Psi_k^{U}\Delta P_{t-k} + u_t^U & if \;\; z_{t-1} > \theta^U \\ A^N z_{t-1} + \Psi_1^{N}\Delta P_{t-1} + \cdots + \Psi_k^{N}\Delta P_{t-k} + u_t^N & if \; \theta^L \leq \; z_{t-1} \leq \theta^U \\ A^L z_{t-1} + \Psi_1^{L}\Delta P_{t-1} + \cdots + \Psi_k^{L}\Delta P_{t-k} + u_t^L & if \;\; z_{t-1} < \theta^L \end{cases} \tag{3.32}$$

With $z_{t-1} = z_{t-1}(\beta = 1) = p_{2,t} - p_{1,t}$, and ΔP_t a matrix which contains the vectors with the first lags for region one and two denoted as $\Delta \mathrm{p}_{1,t}$ and $\Delta \mathrm{p}_{2,t}$ respectively such that

$$\Delta P_t = \begin{bmatrix} \Delta \mathrm{p}_{1,t} \\ \Delta \mathrm{p}_{2,t} \end{bmatrix} = \begin{bmatrix} \Delta p_{1,1} & \Delta p_{1,2} & \dots & \Delta p_{1,200} \\ \Delta p_{2,1} & \Delta p_{2,1} & \dots & \Delta p_{2,200} \end{bmatrix} \tag{3.33}$$

Additionally in the estimation of the TVECM one has to consider restriction for the trimming parameter π_0, so as $\pi_0 \leq Prob(z_{t-1} \leq \theta) \leq 1 - \pi_0$. Following the methodology in Chapter 1, the estimation of the TVECM is done using three different values for π_0: 0.05, 0.10 and 0.15.

In summary, the TVECM has to be done for each model; for each model there are two groups, trade reversals and no trade reversals; for each group there are 500 simulations; for each simulation three different trimming parameter values are considered, 0.05, 0.10 and 0.15. This is shown in Table 3-2

Table 3-2 Number of TVECM to estimate from the simulations

Model	Group	$\pi_0 = 0.05$	$\pi_0 = 0.10$	$\pi_0 = 0.15$
LTD	Trade Reversals	500	500	500
	No Trade Reversals	500	500	500
MARD	Trade Reversals	500	500	500
	No Trade Reversals	500	500	500
RRD	Trade Reversals	500	500	500
	No Trade Reversals	500	500	500
WND	Trade Reversals	500	500	500
	No Trade Reversals	500	500	500
WNE	Trade Reversals	500	500	500
	No Trade Reversals	500	500	500

Source: Author's own elaboration

The estimations were done using the R package tsDyn developed by Di Narzo (2009) v. 0.7-60

3.5. Results from the TVECM

The first result is that for all the simulations it is not possible to estimate a TVECM as was the case in Chapter 1. Table 3-3 summarizes the number and percentage of estimated TVECM.

Table 3-3 Number and percentage of feasible TVECM estimations for each set up

Model	Group	$\pi_0 = 0.05$		$\pi_0 = 0.10$		$\pi_0 = 0.15$	
		No.	%	No.	%	No.	%
LTD	Trade Reversals	238	47.60%	218	43.60%	193	38.60%
	No Trade Reversals	0	0.00%	0	0.00%	0	0.00%
MARD	Trade Reversals	483	96.60%	227	45.40%	165	33.00%
	No Trade Reversals	123	24.60%	15	3.00%	2	0.40%
RRD	Trade Reversals	451	90.20%	212	42.40%	125	25.00%
	No Trade Reversals	27	5.40%	12	2.40%	0	0.00%
WND	Trade Reversals	190	38.00%	114	22.80%	90	18.00%
	No Trade Reversals	33	6.60%	0	0.00%	0	0.00%
WNE	Trade Reversals	366	73.20%	325	65.00%	189	37.80%
	No Trade Reversals	0	0.00%	0	0.00%	0	0.00%

Source: Author's own elaboration

The problem for many TVECM is that the programme sends the error message "matrix is singular". As discussed in Chapter 1, the models as in Equations (3.31) and (3.32) are estimated with OLS regressions. The estimator for the loading coefficients A can be written as $\hat{A} = (P_{t-1}(\beta)'P_{t-1}(\beta))^{-1}P_{t-1}(\beta)'\Delta p_t$, with $P_{t-1}(\beta)$ being a vector which contains the exogenous variables as in Equation (1.26). To perform the OLS, the design matrix $P_{t-1}(\beta)'P_{t-1}(\beta)$ has to be non-singular. In the simulations although prices are in equilibrium the LOP is not fulfilled for many observations. This implies that the error term $z_{t-1}(\beta = 1)$ contains variation, and that there is not perfect multicollinearity in the prices first differences Δp_t. Nevertheless, as shown Figure 3.2 the error term tends to be quite stable for some periods, especially in the models LTD, WND and WNE. Actually if the deviations from the LOP are zero on average, that is an error term such that $z_t(\beta = 1) = \tau_{ij} + \varepsilon_t$ with $\varepsilon_t \sim N(0,1)$, those small deviations are not sufficient variation which allows for an OLS regression to be estimated. The non-singular property is also violated with little variation.

Now focusing on the estimation results, Table 3-4 summarizes the descriptive statistics for the estimated threshold parameters in a similar fashion as it was done in Chapter 1.

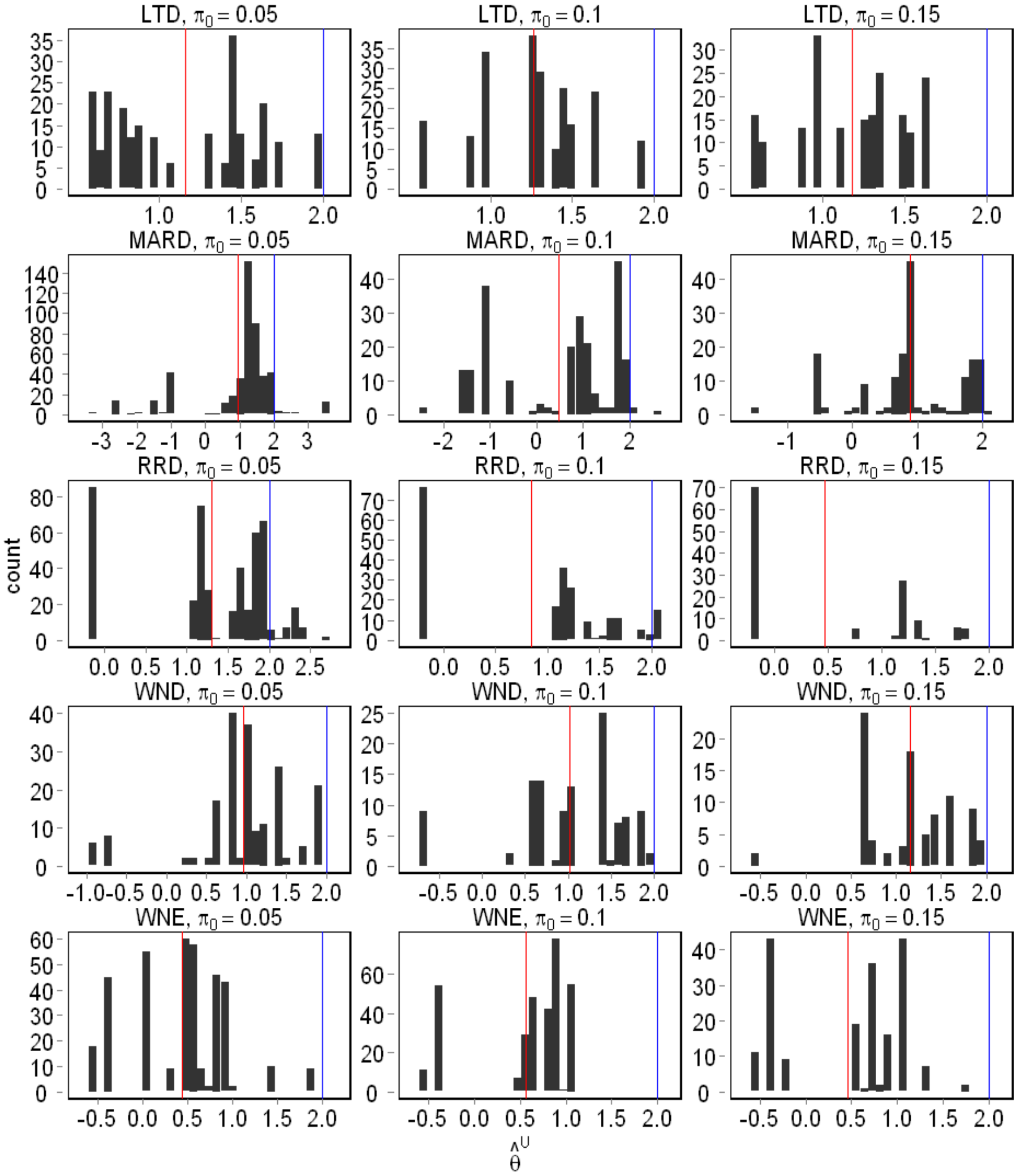
Table 3-4 Average estimated threshold parameters $\bar{\boldsymbol{\theta}}$ descriptive statistics for the five models

Model	Threshold	$\hat{\theta}$			$\hat{\theta}^L$			$\hat{\theta}^U$		
	π_0	0.05	0.1	0.15	0.05	0.1	0.15	0.05	0.1	0.15
LTD	$\bar{\theta}$	----	----	----	0.04	-0.07	-0.39	1.16	1.26	1.18
	σ	----	----	----	0.84	0.8	0.55	0.43	0.33	0.32
	Max	----	----	----	1.52	1.33	0.62	1.97	1.93	1.62
	Min	----	----	----	-1.54	-1.22	-1.16	0.57	0.57	0.58
MARD	$\bar{\theta}$	2.32	2.29	2	-0.34	-0.96	-1.05	0.96	0.46	0.89
	σ	1.29	0.76	0.54	1.5	1.33	0.75	1.2	1.27	0.79
	Max	5.2	4.26	2.38	1.93	1.24	0.24	3.44	2.61	2.07
	Min	0.76	1.14	1.62	-7.58	-4.35	-2.97	-3.39	-2.41	-1.52
RRD	$\bar{\theta}$	1.4	1.14	----	0.43	-0.17	-0.79	1.3	0.85	0.47
	σ	0.19	0.16	----	1.16	1.16	0.96	0.79	0.81	0.75
	Max	2.11	1.31	----	2.05	1.39	0.95	2.65	2.07	1.77
	Min	1.01	0.93	----	-1.99	-1.99	-1.98	-0.18	-0.18	-0.18
WND	$\bar{\theta}$	1.4	----	----	-0.34	-0.57	-0.54	0.97	1.02	1.16
	σ	0.31	----	----	0.92	0.64	0.66	0.63	0.67	0.51
	Max	1.68	----	----	1.42	0.94	0.94	1.89	1.91	1.91
	Min	1	----	----	-2.69	-2.21	-1.95	-0.92	-0.72	-0.59
WNE	$\bar{\theta}$	----	----	----	-0.54	-0.56	-0.75	0.43	0.57	0.46
	σ	----	----	----	0.57	0.49	0.67	0.54	0.51	0.64
	Max	----	----	----	0.81	0.55	0.67	1.91	1.03	1.76
	Min	----	----	----	-1.66	-1.66	-1.66	-0.61	-0.55	-0.55

Source: Author's own elaboration using the R package tsDyn developed by Di Narzo (2009) v. 0.7-60

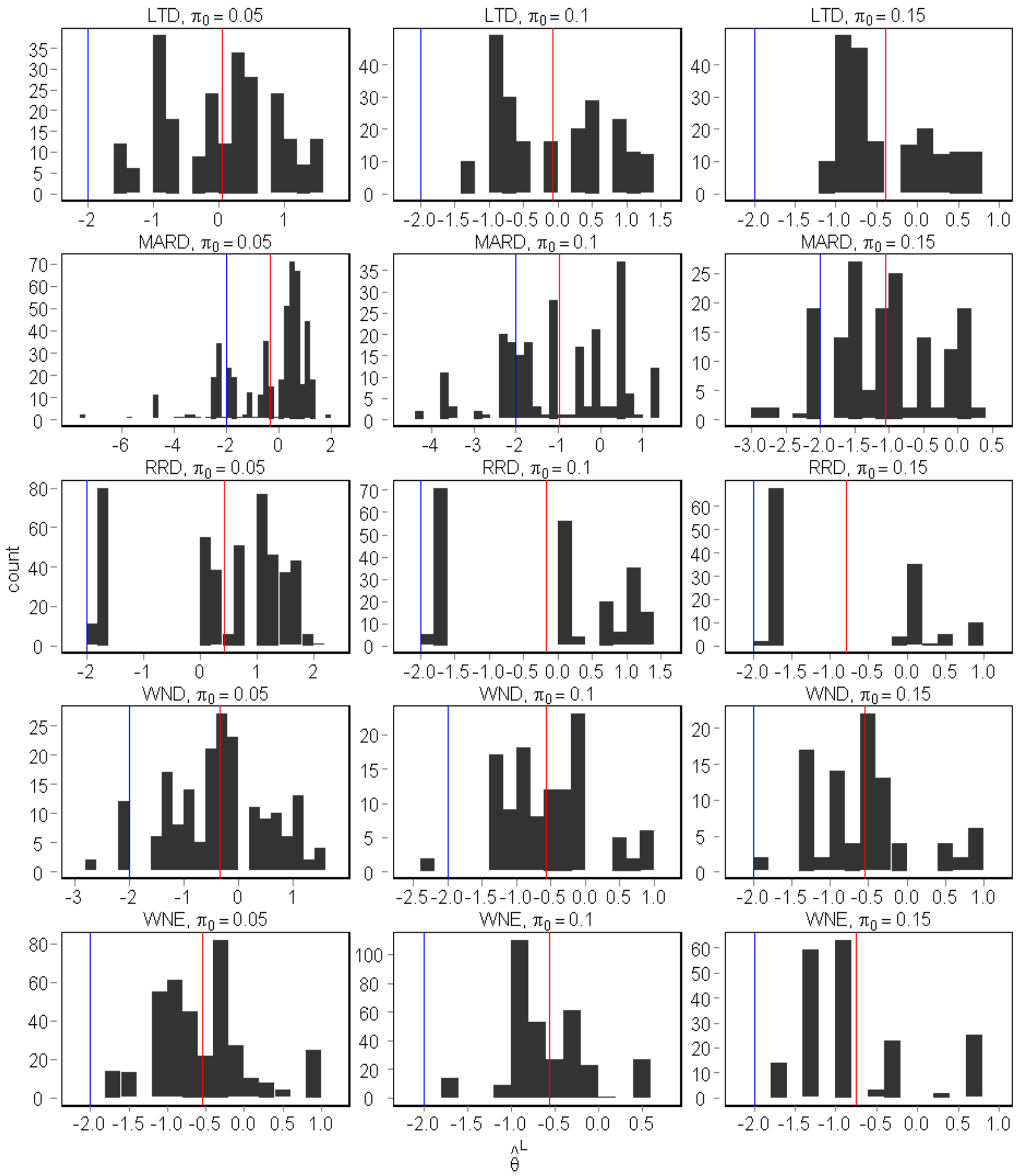
Apart from the descriptive data, the histograms are of interest in order to see the data frequency. Figure 3-4 shows the histograms for the upper threshold $\hat{\theta}^U$. The blue line denotes the value of the true parameter θ^U which is equal to two, the red line denotes the average for all the estimated values $\bar{\theta}^U$ reported in Table 3-3

Figure 3-4 Upper threshold parameter histograms for the five models, trade reversals



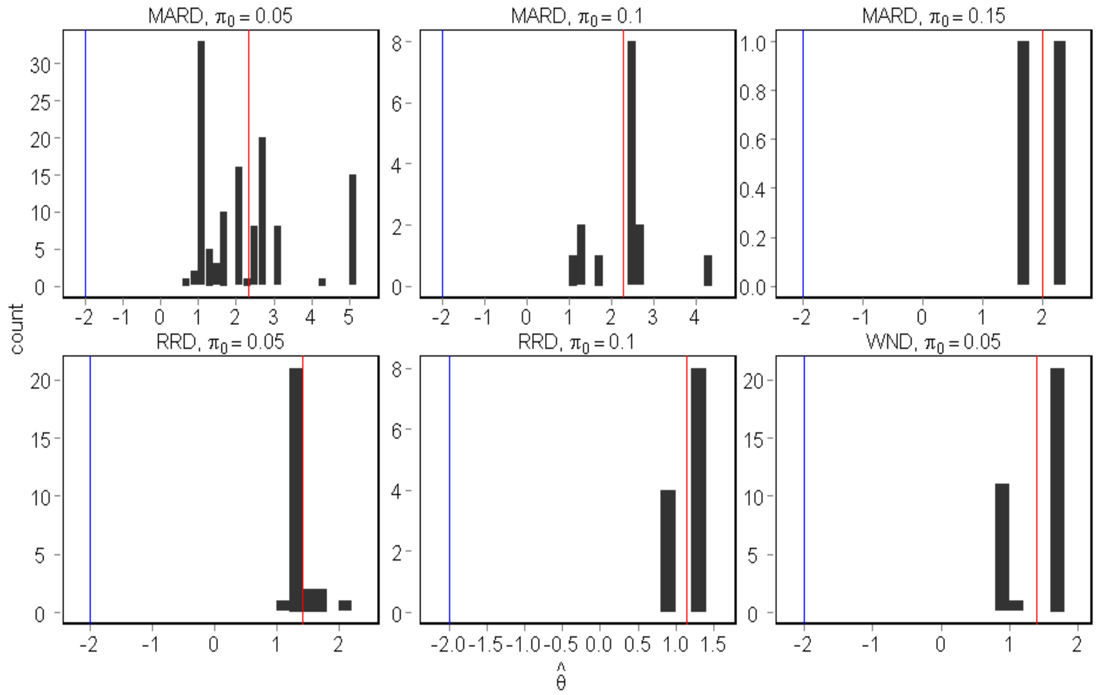
Regarding the histograms for the the lower threshold $\hat{\theta}^L$, they are shown in Figure 3-5. The blue line denotes the value of the true parameter θ^L which is equal to minus two, the red line denotes the average for all the estimated values $\bar{\theta}^L$ reported in Table 3-3

Figure 3-5 Lower threshold parameter histograms for the five models, trade reversals



The two previous figures shown the threshold estimates for the case of trade reversals. Now for the simulations with no trade reversals only one threshold can be estimated. As it was reported in Table 3-3, for some of the models it was not possible to get estimates hence no histograms can be obtained for such cases. Figure 3.6 shows the histograms for those models and π_0 on which the TVECM estimation is possible. The blue line denotes the value of the true parameter θ which is equal to two, the red line denotes the average for all the estimated values $\bar{\theta}$ reported in Table 3-3

Figure 3-6 Threshold parameter histograms for the five models, no trade reversals



As it can be seen from the figures there are differences between the true values and the averages for the estimates. Following the same methodology as in chapter one, the effect that the threshold bias has on the neutral band is considered. The neutral band is defined as $\theta^L \leq z_{t-1}(\beta) \leq \theta^U$ and $0 \leq z_{t-1}(\beta) \leq \theta$ for the case of trade reversals and no trade reversals respectively; substituting the true values yields $-2 \leq z_{t-1}(\beta) \leq 2$ and $0 \leq z_{t-1}(\beta) \leq 2$ respectively. The width of the neutral band can be calculated using the expressions $w^{TR} = \theta^U - \theta^L$ and $w^{NTR} = \theta$ for the case of trade reversals and no trade reversals, respectively; by doing so it happens that w^{TR} equals four, and w^{NTR} equals two. The idea is to compare the true values with the estimates. Indeed using the estimated parameters the results for the estimated neutral band denoted as $\widehat{w}$ such that $\widehat{w}^{TR} = \hat{\theta}^U - \hat{\theta}^L$ and $\widehat{w}^{NTR} = \hat{\theta}$ for the case of trade reversals and no trade reversals respectively. The results are shown in Table 3-5.

Table 3-5 Estimated neutral band width for the five model

Neutral band width	π_0	LTD	MARD	RRD	WND	WNE
$\widehat{w}^{NTR}$	0.05	----	2.32	1.40	1.40	----
	0.10	----	2.29	1.14	----	----
	0.15	----	2.00	----	----	----
$\widehat{w}^{TR}$	0.05	1.12	1.30	0.87	1.31	0.97
	0.10	1.33	1.42	1.02	1.59	1.13
	0.15	1.57	1.94	1.26	1.70	1.21

Source: Author's own elaboration

3.6. Discussion

The first outcome, which has been discussed before to some extent, is that even if data in disequilibrium is observed, a considerable number of the simulations are not suitable for the estimation of a TVECM. Regarding the groups, the figures are especially low for no trade reversals. In the absence of trade reversals the price co-movement is more likely to be close to the LOP, the error term $z_t(\beta = 1)$ is often found to move around the threshold or the transport costs, hence the variation of the error term $z_t(\beta = 1)$ is low. Moreover as $z_t(\beta = 1)$ approaches the LOP, the price first differences $\Delta p_{1,t}$ and $\Delta p_{2,t}$ are the same and multicollienarity becomes a problem. The two main problems mentioned previously: low variation of the error term $z_t(\beta = 1)$ and multicollienarity between the price first differences $\Delta p_{1,t}$ and $\Delta p_{2,t}$ are frequently observed in the LTD, WND, and WNE Models; hence many simulations fail in the TVECM estimation. Regarding the trimming parameter π_0, the larger π_0 is, the less the TVECM that can be estimated; this is a general outcome regardless of the group and model. In general it can be said that three factors will have a negative impact on the TVECM estimation: a low variation of the error term $z_t(\beta = 1)$, multicollienearity between the price first differences $\Delta p_{1,t}$ and $\Delta p_{2,t}$ and a large value for the trimming parameter π_0.

As for the estimation results, it can be observed that having data in disequilibrium produces biased threshold parameter estimations. For the case of the upper threshold, for all the models the parameter $\hat{\theta}^U$ is underestimated on average. Nevertheless, the Models RRD and MARD have estimations which are less biased; indeed such models are those for which a larger number of observations outside the neutral band are observed; furthermore such deviations from the equilibrium are larger than in the LTD, WND and WNE Models. As for the trimming parameter, a clear pattern of whether π_0 has an impact or not on the bias cannot be derived; the evidence from the models is mixed. Regarding the lower threshold estimated parameter $\hat{\theta}^L$, the results show an overestimation for all the models and trimming parameter; yet the MARD Model has the less biased estimations. As in the upper threshold results, the trimming parameter does not have an influence on the bias. Finally for the non trade reversals unique threshold estimated parameter $\hat{\theta}$ the results suggest an underestimation of the parameter for all the models. Additionally, regarding the bias of the parameters it is important to observe two common characteristics on the histograms: (1) different values exhibit high frequencies which are closer and (2) for some ranges of values no observations are contained; thus the estimated parameters seem to belong to different distributions.

The individual threshold estimations do not seem to offer much insight on how the type of model and the trimming parameter affect the bias; thus the neutral band is also analysed. Indeed the results from the neutral band (Table 3.4) offer a clear picture. First it is possible to observe the effect of the trimming parameter: for the group of no trade reversals as the trimming parameter π_0 increases the estimated neutral band width $\hat{w}^{NTR}$ decreases, which is a bias increase. On the contrary for the trade reversals group as the trimming parameter π_0 increases the estimated neutral band width $\hat{w}^{TR}$increases, which is a bias decrease. Furthermore, it can be observed that overall the MARD Models has the best performance as it exhibits the least biased results.

3.7. Concluding Remarks

The estimated parameters results are shown to differ from the true parameters, either when using pure data in equilibrium or using a combination of data in equilibrium/disequilibrium. Thus, the revised and modified economic models here proposed remain incompatible with the Threshold Vector Error Correction Models. The first and more important signal of incompatibility is the percentage of simulations which allow for estimating a TVECM. Such an outcome is due to the little variation of the error term $z_t(\beta = 1)$ and multicolinearity between the first price differentials $\Delta p_{1,t}$ and $\Delta p_{2,t}$. It has been acknowledged that even though there are observations contained outside the neutral band such that $z_t(\beta = 1) > \theta$ holds, if such observation move close to the threshold parameter θ such that $z_t(\beta = 1) \approx \theta$, the OLS estimations as in the case of the loop fulfilment $z_t(\beta = 1) = \theta$ cannot be performed. Such econometric results have great implications for the economic analysis. For instance, consider efficient markets in which the LOP is fulfilled most of the time and markets are cleared fast. Prices from such markets cannot be represented by a TVECM, as the observations in the outer regimes will not allow for the econometric estimation to be carried out. Thus, the TVECM is not a suitable representation of efficient markets. The second sign of incompatibility are the biased results of the neutral band widths $\widehat{w}^{NTR}$ and $\widehat{w}^{TR}$, for which the trimming parameter has a counterfactual effect; in the first one there is a negative relation with π_0, while in the second one the relation is positive. This has to be studied more in detail by accounting for the number of observations which truly belong to each regime. This confirms the outcome that the TVECM is not the correct econometric instrument for analyzing efficient markets.

The models implemented here have served to resemble circumstances which create disequilibria in the markets in a simple manner; such disequilibria have shown to not drift so far from the equilibrium. Nevertheless, the models can be extended to more realistic situations, i.e. storage, rationale expectations, production and supply plans, market power and tariffs and quotas, among others; such implementations can provide a better theoretical understanding of market efficiency and integration. In the next Chapter a number of models which consider such scenarios are revised in order to provide plausible directions that research has to follow.

4. ADDRESSING FURTHER RESEARCH IN ECONOMIC AND ECONOMETRIC THEORY

Following the incompatibility between efficient markets and the Threshold Vector Error Correction Model (TVECM), alternatives that research ought to follow in order to improve the understanding of the economic phenomena of Spatial Market Integration are discussed. Further research should emphasize the improvement of some ambiguous economic and econometric concepts upon which theory relies on. To do so it seems reasonable that economic and econometric models should be revised to provide a better understanding of the price formation process within Spatial Market Integration research. Thus, theoretical economic models can provide information about the variables which intervene, their relationships and their properties; from those insights the correct econometric representation can be derived. The issue deserves more attention; for instance empirical applications often provide evidence that is counterfactual to the theory, with those empirical studies being the basis for policy recommendations that are of interest to many stakeholders.

4.1. Further Theory to be Considered

The fragile understanding of the economic theory and theoretical implications behind the economic phenomena of Spatial Market Integration was acknowledged by McNew (1996). Part of the work done in the previous Chapters attempts to provide a better understanding of such phenomena, while the other part is focused on the compatibility/incompatibility issues between economic theory and the econometric methods. The general conclusion derived is that for efficient markets the Threshold Vector Error Correction Model is not an accurate representation. Yet the issue deserves to be studied more in detail; for instance the previous models are based on the seminal work done by Takayama & Judge (1964) whereby they solved the spatial equilibrium as formulated by Samuelson (1952). Their original formulations included models for a single commodity, as implemented in this research, and for multiple products nevertheless the models do not have a dynamic nature. Other limitations of the models implemented here are that they neglect the role of storage, the formation of agents' expectations, simultaneous trade flows between regions, tariffs and quotas and other price stabilization schemes, among others. Within the literature there are different models which have implemented such factors and can serve to provide a better understanding of how price formation occurs within the context of Spatial Market Integration. Moreover, the fact that the Spatial Equilibrium Condition cannot be estimated using a TVECM can be an outcome not only related with the economic theory but with the econometric concept as well; the relevant question here is how to understand the threshold effects. So far the most used definition of Threshold Cointegration is the offered by Balke & Fomby (1997), nevertheless the definition offered by Gonzalo & Pitarakis (2006) appears to be the correct one as it will be discussed.

In the following pages some economic and econometrics considerations are presented in a brief manner. From the author's perspective the models and definitions can serve to address future research and provide a better understanding of the economic phenomena of Spatial Market Integration.

4.1.1. The Takayama and Judge Spatial and Temporal Price and Allocation Models

In their seminal paper Takayama & Judge (1964) note that the models they present only cover the spatial dimension; hence the time dimension is neglected. In order to cope with such a limitation, seven years later Takayama & Judge (1971) presented new modifications to the models that incorporated the time dimension as well as other elements to depict more realistic economic scenarios.

Within the static model, Takayama & Judge (1971) introduced a model for which an import tariff π_{ij} is imposed, and an export subsidy σ_{ij} is paid, such that the Net Social Payoff as in Equation (1.11) can be written as

$$CS = (\lambda - \mathbf{\Omega} y)'y - (\nu + \mathbf{H}x)'x - (\mathbf{T} + \pi - \sigma)'\mathbf{Q} \; ; \tag{4.1}$$

note that the tariff has an effect similar to an increase the transport costs while the subsidy has an effect similar to a reduction in the transport costs.

Another component included in the models is an import-export quota denoted as c_{ij}, such that the constraint as in Equation (1.12) is rewritten as:

$$\begin{bmatrix} \mathbf{G_Y} \\ \mathbf{G_X} \\ \mathbf{G_C} \end{bmatrix} \mathbf{Q} \geqq \begin{bmatrix} y \\ -x \\ c \end{bmatrix} \tag{4.2}$$

where $\mathbf{G_C}$ denotes a matrix containing one for every elements $c_{ij} \neq 0$.

Regarding monopolistic behaviour, Takayama & Judge (1971) considered an economic scenario where two regions trade a single homogeneous good; such a good is produced by a single producer which has production plants in the regions. The solution is found by maximizing the profits from the sales $\mathbf{\Pi}$ which are equal to the total revenue minus the total costs, including the transport costs from moving the product among regions. The outcome on such a model is similar to what is obtained when restrictions are included, interestingly the market prices between regions might differ by more than the transport costs.

For the temporal models the main assumption is similar to what it was done in this research, the inverse demand and supply functions are time variant such that $y_t = f\left(p_t^d\right)$ and $x_t = f(p_t^s)$. Note the absence of the subindices *i* and *j*, this is because the model considers a single region, nonetheless, it can be extended to multiple regions. The product can be transferred between time periods such that the quantity of trade can be denoted as $q_{t,t+1}$, with the costs of delivering a product across time (storage costs, interest, insurance, etc…) denoted as $b_{t,t+1}$; moreover Takayama & Judge (1971) consider storage to be carried out by the government and by speculators. Another manner to set up a model is to consider adaptive revisions on to a horizon planning, such that new information available is used, i.e. speculators adapting under a government's policy adjustment process; the programming technique for such type of model is recursive, in a sense this approach is similar to the RRD Model presented in the Chapter Three.

In general, the different models proposed by Takama & Judge (1971) work as extensions of the original models by depicting more realistic scenarios. Yet they still suffer from some limitations, for instance, if there are n markets at the most $n - 1$ trade flows can be observed. In real life such an assumption is often not fulfilled, i.e. the ethanol trade flow between Brazil and the US goes in both directions. In that regard, an extension of the TJM to the so called Maxwell-Boltzman Entropy Model was proposed by Yang, et al. (2010) so as to have more than $n-1$ trade flows.

4.1.2. The Williams & Wright Models

William & Wright (1991) provide sound economic theory for modelling markets for agricultural commodities. Their approach is to put emphasis on storage as they consider factors such as future surplus disposal, buffer stocks and supply controls to have either been neglected or not been studied in detail. Additionally, they point out interesting issues to consider; for example they consider stocks to not be public, as storage is handled by private agents. Furthermore they recognize that for storing it is not possible to borrow from the future and that decisions regarding storage have to be done in an anticipatory manner.

The basic model starts by denoting an individual storing firm i for which the costs of storing an amount s_t from period t to period $t+1$, such that the costs of the total storage are:

$$K^i[s_t] = ks_t \tag{4.3}$$

where k is the constant marginal and average physical storage cost, and the aggregation at the industry level is:

$$S_t = \sum_i s_t^i \tag{4.4}$$

The collective consumption at period t is denoted as q_t, the aggregated realized production is denoted as h_t such that:

$$q_t = h_t + S_{t-1} - S_t = A_t - S_t \tag{4.5}$$

where A_t denotes the available product. Moreover, the consumption is related to the price via the inverse demand function such that:

$$P_t = P[q_t] \tag{4.6}$$

There is a constant interest rate denoted as r. In order to solve the model one needs to find the contemporaneous storage S_j to maximize the discounted stream of expected future surplus such that:

$$V_t = \sum_{j=t}^{T} \mathrm{E_t}\left[\int_0^{A_j - S_j} P[q]dq - kS_j\right] \Big/ (1+r)^{j-t} \tag{4.7}$$

is maximized subject to

$$S_j \geq 0 \qquad (4.8)$$

For every period T the surplus V_t is optimized up to the final period; the optimization is done by backward induction of the final period so that the next solution corresponds to the period $T-1$, which can be written as:

$$V_t = \int_0^{A_{T-1}-S_{T-1}} P[q]dq - kS_{T-1} + \mathrm{E_t}\left[\int_0^{h_T+S_{T-1}} P[h_T + S_{T-1}]dq\right] / (1+r)^{j-t} \qquad (4.9)$$

and is maximized with respect to S_{T-1}. As there cannot be future storage, the problem is solved by allocating the availability A_{T-1} between periods $T-1$ and T, so that the optimal storage amount corresponds when the marginal consumption in periods T and $T-1$ are equal, accounting for marginal storage costs and interest.

Based on data obtained from the basic model, William & Wright (1991) provided a useful insight into the time series properties for theoretical prices in agricultural markets. They studied autocorrelations and found that prices are correlated with storage, with high storage costs negatively affecting the correlation. Following the results of the first-order autocorrelations, William & Wright (1991) explored the presence of a unit root process on the theoretical data; the findings suggest that for some variables the null of a unit root is often not rejected. In addition they investigated to what extent the long run is in a steady state or whether the variables are characterized by booms and busts, the applicability of an ARIMA process representation and forecasting. In the following 20 years after the publication of such models, there have been considerable developments of the econometric techniques used in market analysis. The implementation of theoretical prices using such techniques could serve to understand what type of data is useful for the analysis, and to find an adequate econometric instrument for the estimations.

4.1.3. The Rational Expectations Models

Another type of models is focused on the expectation formations of commodities. Examples of such approaches are the work done by Gilbert & Palaskas (1989); they consider efficient storage when prices vary very little except when new information is available. In that regard they argue that expected future prices are likely to differ from expected future conditions as they are jointly determined with current prices, for that they base their work on Muth's (1961) Rational Expectations Model. They conclude that for five commodities there is no evidence of forward looking behaviour, and point out market intervention as an explanation for such an outcome. In a similar fashion, Trivedi (1989) derives a model with rational expectations for perennial crops. In this way production is determined on the basis of the past current price levels whereby inventories include two components: transaction and speculation. Finally, he also considers the effect of differences between expected and current prices. The role of rational expectations has been extended to disequilibrium models; examples are the work done by Maddala (1989) based on Muthian rational expectations or the work done by Palaskas & Gilbert (1990).

Albeit its popularity, rational expectations have received some criticism as the learning process is omitted so that the process in which agents process the information and develop their own forecast is not accounted for (Pesaran, 1987; Rudd & Whelan, 2006).

4.1.4. The Econometric Concept of Threshold Cointegration

At the beginning of the second Chapter, the differences between the concepts of Threshold Error Correction and Threshold Cointegration were pointed out; moreover the major conclusion of the Chapter is that the Spatial Equilibrium Condition does not fit whit the concept of Threshold Error Correction. The problem might be due to the econometric definition, for instance the idea of Threshold Cointegration as proposed by Gonzalo & Pitarakis (2006) can fit better with economic theory. Gonzalo & Pitarakis (2006) consider a nonlinear cointegration relationship between two variables y_{1t} and y_{2t} such that it has a threshold denoted as γ and can be written as:

$$y_{1t} = \beta y_{2t} + \theta y_{2t} 1(q_{t-1} > \gamma) + z_t \tag{4.10}$$

where $\Delta y_{2t} = \epsilon_{2t}$ and $\Delta z_t = \rho z_{t-1} + u_t$ such that $\rho < 0$ and z_t is a stationary equilibrium error. Taking the first differences from Equation (4.10) yields

$$\Delta y_{1t} = \beta \Delta y_{2t} + \theta \Delta(y_{2t} 1_{t-1}) + \Delta z_t = \rho z_{t-1} + \theta y_{2t-1} \Delta 1_{t-1} + \nu_t \tag{4.11}$$

where $\nu_t = \theta \epsilon_{2t} I_{t-1} + \beta \epsilon_{2t} + u_t$. Then the Error Correction Model (ECM) can be denoted as:

$$\Delta y_{1t} - \theta y_{2t-1} \Delta 1_{t-1} = \rho z_{t-1} + \nu_t. \tag{4.12}$$

The previous ECM derived is contains the threshold parameter in the long run equilibrium and not in the error term as the TVECM does. On this regard, the threshold effect on TVECM is limited to the adjustment process; moreover following the definition of the SEC it is expected that the estimated loading coefficients in the neutral band $\hat{A}^N$ to be zero. The results drawn from the tests suggested incompatibility between the SEC and the TVECM, mainly because the SEC does not consider any errors to occur. In this regard it might be worth exploring whether the threshold effect fits better to the economic theory in the long run. For instance, it can be argued to treat trade as the threshold variable, such that when no trade occurs the long run can be denoted as $y_{1t} = \beta_t y_{2t} + u_t$, which implies that the cointegration vector β_t is time variant and the relationship is spurious. It is when trade occurs that the long run relationship can be written as $y_{1t} = \beta_0 y_{2t} + u_t$ such that the cointegration vector is time invariant β_0 and the long run relationship is stable. Following this idea, the neutral band ought not to be treated as an adjustment regime of which adjustments are expected to be zero; it is more accurate to refer to the neutral band as a long run equilibrium relationship with threshold effects: Threshold Cointegration.

4.2. Linking the Economic Theory to the Empirical Applications

The economic and econometric theories addressed in the previous Chapters are the foundations on which the empirical analyses within Spatial Market Integration rely upon. However, empirical findings do not often support the theoretical statements. Such is the case of two studies developed to asses the market integration among maize markets in Mexico and the United States of America (US).

The first empirical study (Appendix II) is concerned with pure price analyses, partially focused on addressing the suitability of different linear and non-linear Error Correction Models in the context of Spatial Market Integration whereby the following three approaches are considered: Vector Error Correction Models, Asymmetric Price Transmission and Threshold Vector Error Correction Models. In order to test for the correct model specification the JTT for linear cointegration, the Hansen & Seo (2003) test for Threshold Error Correction and the F-test for asymmetric price transmission as in v.Cramon-Taubadel (1998) are implemented. The study considers prices for maize in five Mexican regions and the aggregated data at the national level and the prices at the Gulf of Louisiana (US). The cointegration relationships are pair wise, such that each pair consists of an individual price series for both Mexico and the US. The results from the test are summarized in the following table:

Table 4-1 Tests' outcomes

Pair	Johansen Trace Test	F-Test	Hansen & Seo Test
$p_t^{US}, p_t^{MX_{Nat}}$	Linear Cointegration	Asymmetry	Linear Cointegration
$p_t^{US}, p_t^{MX_{RI}}$	Linear Cointegration	Asymmetry	Linear Cointegration
$p_t^{US}, p_t^{MX_{RII}}$	Linear Cointegration	Asymmetry	Linear Cointegration
$p_t^{US}, p_t^{MX_{RIII}}$	Linear Cointegration	Asymmetry	Linear Cointegration
$p_t^{US}, p_t^{MX_{RIV}}$	Linear Cointegration	Linear Cointegration	Threshold Error Correction
$p_t^{US}, p_t^{MX_{RV}}$	Linear Cointegration	Asymmetry	Threshold Error Correction

Source: Araujo-Enciso (2011)

Ideally the Threshold Vector Error Correction is the correct representation of Spatial Market Integration in terms of the economic theory, yet it is weakly supported in the empirical study. The results for the first four of pairs are in favour of Asymmetric Price Transmission, for the fifth model the evidence moves in favour of Threshold Error Correction, for the last model the evidence is mixed since Asymmetry and Threshold Error Correction appear to hold. Hence, one can ask under which theoretical circumstances linear cointegration or asymmetric behaviour will hold against the threshold effect. Indeed asymmetries appeal to the idea of market power, such that prices adjust faster when margins are squeezed rather that when they are stretched (v.Cramon-Taubadel, 1998) Thus considering monopolies or monopolistic behaviour in theoretical models can serve to explore the causes and consequences of asymmetric adjustments. As for the econometric techniques implemented in the application, it was recommended by one of the reviewers to perform the estimations using a multivariate approach as pair wise models neglect some interaction among the markets, thus making an interesting point. So far the TVECM is limited to pair wise analyses; hence during the analyses information regarding markets relationships can be lost. By deriving artificial prices from a model considering a network of markets it could be possible to asses the amount of information lost by limiting the TVECM to the pair wise case.

The second application (Appendix III) is concerned with prices in the form of volatility; the innovative characteristic is that it makes use of additional information such a trade. The case of study is as before maize markets in Mexico and the US. The idea behind such research is to determine whether the supply shocks in the Mexican market can explain price variation in the form of volatility. Due to the fact that supply is composed of other variables, i.e. stocks, production and imports, and having information only about the imports, it is only when import shocks are large enough that their effect causes price variation. Thus, the model for the analysis is a TVAR as in Lo & Zivot (2001), in which imports and volatility are both treated as endogenous variables. The hypothesis is that there is an import threshold value which causes volatility in the Mexican maize prices, in other words international trade causes volatility on the domestic prices only beyond certain amount of imports. The results of implementing the test developed by Lo & Zivot (2001) suggest that the models should consider two regimes and one threshold value. Contrary to the initial assumption, it is not trade that drives volatility but rather the other way around. The first regime results in trade and volatility to be unrelated; in the second regime volatility is driving trade, such that when imports go beyond the threshold value an increasing volatility causes imports to decrease. Additionally, the second regime is characterized as containing a few observations, roughly 5%, which are import peaks. Although the relationship between price volatility and trade relies on some theoretical background, the use of a threshold model is more intuitively justified. Thus no sound theory can underpin the hypothesis and use of TVAR models. In this regard artificial data obtained by modelling theoretical markets such as stocks, prices, imports and production can serve to explore relationships among the variables as already done by William & Wright (1991). From the study of such relations one can derive which type of econometric model serves to analyse those variables relationships in empirical applications and which type of data can be useful in understanding market dynamics. Additionally, the theoretical models can be extended to the study of other issues such as volatility which has gained attention as a consequence of the recent food and economic crisis.

4.3. Summary of Findings and Future Research

Overall the main aim of the author with the present thesis is to provide a first insight on the compatibility between the economic theory and the econometric methods with regards to Spatial Market Integration. Therefore, for answering such a question simple models have been implemented in order to get an overview, but such models are not the definitive answer. To the author's knowledge, there are at least two books which provide sound economic theory and more realistic alternatives for modelling agricultural markets than those implemented here. Those models proposed by Takayama & Judge (1971) and William & Wright (1991) aim to create theoretical scenarios which can help to understand the economic phenomena of Spatial Market Integration. In addition to those models, the Rational Expectations Models can offer other directions; nevertheless, they are designed for providing a bit of background which supports econometric techniques rather than for simulating a theoretical scenario. Still, some of their features fit well whit the economic theory. Such new alternatives proposed for modelling ought not to be seen as a definitive solution, their limitation in most of the cases is that markets are considered to be in equilibrium. Although William & Wright (1991) argue that before attempting to understand the disequilibrium mechanism it is necessary to fully understand the equilibrium, in the author's view equilibrium and disequilibrium should be studied together; indeed that is the approach followed in the present thesis.

To what extent the results here are driven by the simplicity of the models can be questioned. Nevertheless, the purpose hereby is to create the simplest case for Spatial Market Integration, which is two markets trading a single homogeneous good with prices bounded by constant transport costs. Furthermore, such a simple case is the one that often is assumed when performing empirical analysis due to the econometric model's limitations. By contrasting the ideal economic theoretical data with the presumed econometric models it is concluded that efficient markets cannot be represented as a TVECM; this outcome also holds when disequilibrium is allowed to occur and such disequilibrium is close to zero. Apart from the concern regarding the compatibility between the economic theory and econometric models, there are still further issues remaining to be addressed.

First, the analysis is limited to the case of perfectly integrated markets, the fulfilment of the LOP, so that the cointegration vector is always restricted to one. By allowing other values for the cointegration vector, the development of the error term is affected; studying the effect that the cointegration vector has on the TVECM estimation in more in detail deserves more attention.

Second, under which circumstances the prices performance lead to the preference of a linear VECM versus threshold effects, which theoretically is the correct specification, should be investigated. This is closely linked to the results from the empirical application to the Mexican and US maize markets. If the TVECM itself does not consider the proper threshold effect, then it will be miss-specified and probably rejected in favour of other specifications. The definition of Threshold Cointegration offered by Gonzalo & Pitarakis (2006) can provide a better representation. Additionally a high rejection of Threshold Error Correction is linked to the econometric properties of the prices; the work done by William & Wright (1991) should be extended by implementing the current econometric techniques to address this issue.

Third, more variables should be included in order to provide with more realistic scenarios in the domain of market integration; yet the more variables the more complex the models become. In order to distinguish the effect that new variables have on the models, such variables have to be carefully introduced. The idea is to have a controlled experiment that allows understanding the individual or joint effects of the variables on the equilibrium and other variables. Then the true relationships among the variables can be observed, such that the proper econometric instrument can be selected and supported by economic theory.

Finally, the development of sound economic theory is necessary in order to have clear and unique definitions regarding core concepts which often are used in a misleading manner. Rather than attempting to dismiss the current research, the author would like to encourage researchers to improve the foundations of economic theory within Spatial Market Integration research. Without clear definitions, it seems implausible that the proper econometric techniques can be selected. Over recent decades Spatial Market Integration has gained relevance, not only for researchers but also for policy makers, NGO's, farmers and other stakeholders which are interested in understanding the price formation process. Having analyses which rely upon inappropriate econometric representations of the economic phenomena can lead to inaccurate conclusions.

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APPENDIX I: GAMS CODES

This section contains the GAMS codes used in generating the artificial data. The parameters in all the cases were taken from the example provided in the seminal paper by (Takayama & Judge, 1964).

Simulations in Chapter One and Two are generated using the file "EQ.gms". The simulations for Chapter Three depend on several files as following:

- Lagged Trade Disequilibrium Model: Files "EQ.gms" and "LTD.gms"
- White Noise Disequilibrium Model: File "WND.gms"
- Moving Average Restriction Disequilibrium Model: File "MARD.gms"
- Restrictive Recursive Disequilibrium Model: Files "EQ.gms", "R_DES.gms" and "R_DES_T.gms"

White Noise Equilibrium Model: Files "WNE.gms"

File EQ.gms

```
*** This file creates the equilibrium data based on random dynamic parameter: vt(i,t)
execseed = gmillisec(jnow);
***** The dimensions are declared
Sets
t          Time dimension /1*500/
i          Supply part /1*2/
j          Demand part /1*2/
same(i,j)   Same markets /1.1, 2.2/
***** The transport costs are time invariant
Table  tc(i,j) Transport Costs Table
  1 2
1 0 2
2 2 0
***** The inverse supply and demand functions parameters are declared
***** All the parameters are time invariant but vt(i,t)
Parameters
vs(i)      Static intercept inverse supply function /1 5, 2 2.5/
n(i)       Static slope inverse supply function /1 1, 2 0.5/
l(j)       Static intercept demand function /1 20, 2 20/
w(j)       Static slope demand function /1 -0.1, 2 -0.2/
e(i,t)     Error
u(i,t)     Cumulative error
vt(i,t)    Dynamic intercept inverse supply function
tc(i,j)    Transport Costs;
***** The parameter vt(i,t) is a random walk which contains a random error
***** e(i,t) normally distributed
e(i,t)=normal(0,1);
loop(t, e(i,t+1)=e(i,t)+e(i,t+1));
u(i,t)=e(i,t);
vt(i,t)=vs(i)+u(i,t);
***** The variables are declared
Positive Variables
x(i,t) supply
y(j,t) demand
q(i,j,t) trade
***** The objective function is declared
Variable
CPS Consumer and Producer Surplus;
***** The equations, objective function and constrains are declared
Equations
Supply(i,t)     Supply constrain
Demand(j,t)     Demand constrain
MW              Maximum Welfare;
MW..  CPS =E=   Sum(t,
             SUM(j, l(j)*y(j,t)+0.5*w(j)*y(j,t)*y(j,t))
            -SUM(i, vt(i,t)*x(i,t)+0.5*n(i)*x(i,t)*x(i,t))
```

```
            -SUM((i,j), tc(i,j)*q(i,j,t)));

Demand(j,t)..     SUM(i, q(i,j,t))-y(j,t)=G=0;
Supply(i,t)..    -SUM(j, q(i,j,t))+x(i,t)=G=0;


****** The model is declared and solved
MODEL TAKAYAMA /ALL/;
takayama.iterlim=10000000;
takayama.reslim=2000000;
takayama.workspace=100;

option nlp=coinipopt;

SOLVE TAKAYAMA USING NLP MAXIMIZING CPS;

***** The GDX file is created
execute_unload  'EQ' t, j, i, l, w, n, vs, vt, tc, q, x, y, Demand, Supply, u, e;
```

File R_DES.gms

```
*** This file takes the parameters and solved variables from the equilibrium (EQ.gdx) as a basis for setting up a restriction
*** The restriction limits trade, and the difference between trade in equilibrium and restricted is used as feedback on the supply for the next period of time

execseed = gmillisec(jnow);

**** Declare the dimensions of the problem
Sets

t          Time dimension /1*200/
j          Supply part /1*2/
i          Demand part /1*2/
Same(j,i)     Same markets /1.1, 2.2/
alias (t,tt)

**** Declare the parameters for the inverse demand and supply funtions
Parameters
vs(j)      Static intercept inverse supply function
n(j)       Static slope inverse supply function
l(i)       Static intercept demand function
w(i)       Static slope demand function
e(j,t)     Error
u(j,t)     Cumulative error
vt(j,t)    Dynamic intercept inverse supply function
tc(j,i)    Transport Costs
dt(j,i,t)  Shift in the supply curve
qe(j,i,t)  Trade in Equilibrium as parameter;

*** The variables are declared
Positive Variables
xr(j)    Supply
yr(i)    Demand
qr(j,i)  Trade
q(j,i,t) Trade in Equilibrium as variable;


* Load the parameters, the parameters for solving the problem with restriction are the same as
* for the problem without restriction
Execute_Load 'EQ' l, w, n, vt, tc, u, e, q;

 * Once loaded the parameters the restrictions are generated using the data for trading in the equilibrium
* First the parameters for the restriction are declared
Parameters
max_qe(j,i)      Maximum of trade in equilibrium
average_qe(j,i)  Average of trade in equilibrium
rt(j,i,t)        Sorted restriction of trade
dt(j,i,t)        Shift on the suply curve;
qe(j,i,t)=q.l(j,i,t);
max_qe(j,i) = smax(t, qe(j,i,t));
average_qe(j,i) = sum(t, qe(j,i,t))/200;
rt(j,i,t)=uniform(average_qe(j,i),max_qe(j,i));

display rt;


* Declare the initial values for the parameters
```

```
Parameters
d(j,i)      Initial shift on the supply curve
v(j)        Initial parameter plus the initial shift
r(j,i)      Initial restriction
tc(j,i)     Transport Costs;
d(j,i)=0;
v(j)=vt(j,"1")-(n(j)*sum(i$(NOT Same(j,i)),d(j,i)));
r(j,i)=rt(j,i,"1");


Variable

CPSr  Consumer and Producer Surplus;


*** Declare the new equations
Equations
Supplyr(j)        Supply constrain
Demandr(i)        Demand constrain
Restriction(j,i)  Restriction in trade
MWr               Maximum Welfare;

MWr..  CPSr =E=   SUM((i), l(i)*yr(i)+0.5*w(i)*yr(i)*yr(i))
                 -SUM((j), v(j)*n(j)*xr(j)+0.5*n(j)*xr(j)*xr(j))
                 -SUM((j,i), tc(j,i)*qr(j,i));

Demandr(i)..      SUM(j, qr(j,i))-yr(i)=G=0;
Supplyr(j)..     -SUM(i, qr(j,i))+xr(j)=G=0;

**Note that the restriction only takes place for the supply (trade) between different regions and not the supply within the region
Restriction(j,i)$(NOT Same(j,i))..  qr(j,i)=L=r(j,i);


option nlp=coinipopt;

MODEL TAKAYAMA /ALL/;

option savepoint=2;
takayama.iterlim=0;
SOLVE TAKAYAMA USING NLP MAXIMIZING CPSr;
takayama.iterlim=1000;

file meanwhile
put meanwhile

 ***** The Model is static, it is the loop where the time dimensions is controlled for
 loop(t,
 r(j,i)=rt(j,i,t);
 d(j,i)=qe(j,i,t)-qr.l(j,i);
 v(j)=vt(j,t)-(n(j)*sum(i$(NOT Same(j,i)),d(j,i)));
 display r,d,v;
 put_utility 'gdxout'/'takayama_p' t.tl:0;
 put "output to file" t.tl:0 "with sudffix output"/;
 execute_unload t, j, i, l, w, n, v, tc, d, r, qr, xr, yr, Demandr;
 SOLVE TAKAYAMA USING NLP MAXIMIZING CPSr;
 );
```

File R_DES_T.gms

```
*** This file retrieves the individual GDX files generated on the code "R_DES.gdx" and put the results together as a time series

**** Declare the dimension of the problem
Sets
t           Time dimension /1*200/
j           Supply part /1*2/
i           Demand part /1*2/;


**** The dynamic and static parameters are declared
parameters
Demandr_T(t,i)   Price of the good
qr_T(t,j,i)     Trade among regions restriction
xr_T(t,j)       Supply
yr_T(t,i)       Demand
l_T(t,i)        Intercept demand function
w_T(t,j)        Slope demand function
n_T(t,j)        Slope supply function
v_T(t,i)        Intercept supply function
d_T(t,j,i)      Shift on the supply curve
r_T(t,j,i)      Restriction on trade
l(i)            Intercept demand function
w(j)            Slope demand function
n(j)            Slope supply function
v(i)            Intercept supply function
d(j,i)          Shift on the supply curve
r(j,i)          Restriction on trade;


***** The variables are declared
variables
xr(j)          Output from the supply
yr(i)          Output from the demand
qr(j,i)        Output from trade in restriction
;

***** Declare the equations to later retrieve the restriction and the prices
Equation
Demandr(i)      Output from price in restriction
Restriction(j,i) Restriction on trade;

xr.l(j)=0; yr.l(i)=0; qr.l(j,i)=0; Demandr.m(i)=0;

***** Create the bat file
file kcp /kcp.bat/;
kcp.nw=0; kcp.nd=0;

***** Set up the loop for conciliating the separate static disequilibrium solution into a unique dynamic solution
loop (t,
l(i)=0;w(j)=0;n(j)=0;v(i)=0;d(j,i)=0;r(j,i)=0;
putclose kcp, 'rm TAKAYAMA_p.gdx'/
              'cp TAKAYAMA_p', (ord(t)+1),'.gdx TAKAYAMA_p.gdx'/;
execute "kcp.bat";
execute_loadpoint "TAKAYAMA_p.gdx";
Demandr_T(t,i)= Demandr.m(i);
qr_T(t,j,i)= qr.l(j,i);
```

```
xr_T(t,j)=xr.l(j);
yr_T(t,i)=yr.l(i);
put_utilities 'GDXIN' /'takayama_p't.tl:0 '.gdx';
execute_LOAD l,w,n,v,d,r;
l_T(t,i)=l(i);
w_T(t,j)=w(j);
n_T(t,j)=n(j);
v_T(t,i)=v(i);
d_T(t,j,i)=d(j,i);
r_T(t,j,i)=r(j,i);
);

**** Create the GDX file
execute_unload  'RRD' Demandr_T, qr_t, r_t, xr_t, yr_t,l_t,w_t,n_t,v_t,d_t,r_t;
```

File WNE.gms

```
*** This file creates the equilibrium data the model works in the same manner as in the EQ.gams file, the difference is that transport costs are time variant

execseed = gmillisec(jnow);
Sets
t          Time dimension /1*500/
i          Supply part /1*2/
j          Demand part /1*2/
same(i,j)   Same markets /1.1, 2.2/

Table  tc(i,j) Transport Costs Table
    1 2
1 0 2
2 2 0

Parameters
vs(i)      Static intercept inverse supply function /1 5, 2 2.5/
n(i)       Static slope inverse supply function /1 1, 2 0.5/
l(j)       Static intercept demand function /1 20, 2 20/
w(j)       Static slope demand function /1 -0.1, 2 -0.2/
e(i,t)     Error
u(i,t)     Cumulative error
vt(i,t)    Dynamic intercept inverse supply function
tc(i,j)    Transport Costs
tct(i,j,t)  Transport Costs plus a white noise
tu(t)       Error in transport costs;

e(i,t)=normal(0,1);
loop(t, e(i,t+1)=e(i,t)+e(i,t+1));
u(i,t)=e(i,t);
vt(i,t)=vs(i)+u(i,t);
 **** Here the transport costs are set up with a random white noise component which is normally distributed
tu(t)=normal(0,1);
tct(i,j,t)$(NOT same(i,j))=(tc(i,j))+((tu(t)*tu(t))**(0.5));


Positive Variables
x(i,t) supply
y(j,t) demand
q(i,j,t) trade

Variable
CPS Consumer and Producer Surplus;

Equations
Supply(i,t)     Supply constrain
Demand(j,t)     Demand constrain
MW              Maximum Welfare;

MW..  CPS =E=   Sum(t,
               SUM(j, l(j)*y(j,t)+0.5*w(j)*y(j,t)*y(j,t))
              -SUM(i, vt(i,t)*x(i,t)+0.5*n(i)*x(i,t)*x(i,t))
              -SUM((i,j), tc(i,j)*q(i,j,t)));

Demand(j,t)..     SUM(i, q(i,j,t))-y(j,t)=G=0;
Supply(i,t)..    -SUM(j, q(i,j,t))+x(i,t)=G=0;
```

```
MODEL TAKAYAMA /ALL/;
takayama.iterlim=10000000;
takayama.reslim=2000000;
takayama.workspace=100;

option nlp=coinipopt;

SOLVE TAKAYAMA USING NLP MAXIMIZING CPS;

execute_unload  'WNE' t, j, i, l, w, n, vs, vt, tc, q, x, y, Demand, Supply, u, e;

execute '=gdx2xls WNE.gdx';
```

File LTD.gms

```
*** This file creates the LTD Model, it relies on the general equilibrium model as in the file EQ.gms

execseed = gmillisec(jnow);
Sets
t          Time dimension /1*201/
i          Supply part /1*2/
j          Demand part /1*2/
same(i,j)   Same markets /1.1, 2.2/


Parameters
n(i)       Static slope inverse supply function
l(j)       Static intercept demand funtion
w(j)       Static slope demand function
vt(i,t)    Dynamic intercept inverse supply function
tc(i,j)    Transport Costs;

Positive Variables
xl(i,t)      Supply
yl(j,t)      Demand
q(i,j,t)     Trade Equilibrium

Execute_Load 'EQ' l, w, n, vt, tc, q;

 **** The trade from the equilibrium is loaded, then it first lagged value t-1 is set up as a new parameter
Parameter
ql(i,j,t)   Lagged Trade;
ql(i,j,t)=q.l(i,j,t-1);


Variable
CPSl Consumer and Producer Surplus;

Equations
Supplyl(i,t)        Supply constrain
Demandl(j,t)        Demand constrain
Restriction(j,i)    Restriction
MWL                 Maximum Welfare;

MWL..  CPSl =E= SUM(t,
               SUM(j, l(j)*yl(j,t)+0.5*w(j)*yl(j,t)*yl(j,t))
              -SUM(i, vt(i,t)*xl(i,t)+0.5*n(i)*xl(i,t)*xl(i,t))
              -SUM((i,j), tc(i,j)*q(i,j,t)));

Demandl(j,t)..       SUM(i, q(i,j,t))-yl(j,t)=G=0;
Supplyl(i,t)..       -SUM(j, q(i,j,t))+xl(i,t)=G=0;
Restriction(j,i,t)$(NOT Same(i,j))..  q(i,j,t)=L=ql(i,j,t);

MODEL TAKAYAMA /ALL/;
takayama.iterlim=10000000;
takayama.reslim=2000000;
takayama.workspace=100;

option nlp=coinipopt;

SOLVE TAKAYAMA USING NLP MAXIMIZING CPSl;
execute_unload  'LTD' t, j, i, l, w, n, vt, tc, ql, xl, yl, Demandl, Supplyl;
```

File MARD.gms

```
*** This file creates the MARD Model

execseed = gmillisec(jnow);
Sets
t          Time dimension /1*200/
i          Supply part /1*2/
j          Demand part /1*2/
same(i,j)   Same markets /1.1, 2.2/

Table  tc(i,j) Transport Costs Table
  1 2
1 0 2
2 2 0

***** The initial restrictions
Table  qa(i,j) Average trade
  1    2
1 0    1000
2 1000 0

**** The parameters are declared
Parameters
vs(i)       Static intercept inverse supply function /1 5, 2 2.5/
v(i)        Initial Value of the inverse supply intercept
n(i)        Static slope inverse supply function /1 1, 2 0.5/
l(j)        Static intercept demand function /1 20, 2 20/
w(j)        Static slope demand function /1 -0.1, 2 -0.2/
e(i,t)      Error in the supply
eq(i,j,t)   Error in the trade
eqp(i,j,t) Positive error in trade
u(i,t)      Cumulative error
vt(i,t)     Dynamic intercept inverse supply function
tc(i,j)     Transport Costs
qm(i,j,t)  Dynamic Average Trade
qat(i,j,t)  Moving Average Restriction
pdt(j,t)    Dynamic Demand Price
pst(i,t)    Dynamic Supply Price;

*** the random walk is generated
e(i,t)=normal(0,1);
loop(t, e(i,t+1)=e(i,t)+e(i,t+1));
u(i,t)=e(i,t);
vt(i,t)=vs(i)+u(i,t);
**** initial value for the intercept is declared
v(i)=vt(i,"1");
***** error for the trade restriction is declared
eq(i,j,t)=normal(0,1);
eqp(i,j,t)=(eq(i,j,t)*eq(i,j,t)**(0.5));

Positive Variables
x(i) supply
y(j) demand
q(i,j) trade

Variable
CPS Consumer and Producer Surplus;

Equations
```

```
Supply(i)        Supply constrain
Demand(j)        Demand constrain
Averaget(i,j)    Average trade
MW               Maximum Welfare;
MW..  CPS =E=   SUM(j, l(j)*y(j)+0.5*w(j)*y(j)*y(j))
                -SUM(i, v(i)*x(i)+0.5*n(i)*x(i)*x(i))
                -SUM((i,j), tc(i,j)*q(i,j));
Demand(j)..           SUM(i, q(i,j))-y(j)=G=0;
Supply(i)..          -SUM(j, q(i,j))+x(i)=G=0;
Averaget(i,j)..       q(i,j)$(NOT same(i,j))=L=qa(i,j)
MODEL TAKAYAMA /ALL/;
takayama.iterlim=10000000;
takayama.reslim=2000000;
takayama.workspace=100;
option nlp=coinipopt;
SOLVE TAKAYAMA USING NLP MAXIMIZING CPS;
**** the static problem is controlled in the loop to have dynamic sets
loop (t,
v(i)= vt(i,t);
qm(i,j,t)=q.l(i,j);
qat(i,j,t)=qa(i,j);
pdt(j,t)=Demand.m(j);
pst(i,t)=Supply.m(i);
qa(i,j)=0.5*qm(i,j,t-1)+0.3*qm(i,j,t-2)+0.2*qm(i,j,t-3)+eqp(i,j,t-1);
SOLVE TAKAYAMA USING NLP MAXIMIZING CPS;
);
display qm, qat, pdt, pst;
execute_unload  'MARD' t, j, i, l, w, n, vs, vt, tc, q, x, y, Demand, Supply, u, e, qm, qat, pdt, pst;
```

File WND.gms

```
*** This file creates the WND Model
execseed = gmillisec(jnow);
***** The dimensions are declared
Sets
t          Time dimension /1*500/
i          Supply part /1*2/
j          Demand part /1*2/
same(i,j)   Same markets /1.1, 2.2/
***** The transport costs are time invariant
Table  tc(i,j) Transport Costs Table
  1 2
1 0 2
2 2 0
***** The inverse supply and demand functions parameters are declared
***** All the parameters are time invariant but vt(i,t)
Parameters
vs(i)      Static intercept inverse supply function /1 5, 2 2.5/
n(i)       Static slope inverse supply function /1 1, 2 0.5/
l(j)       Static intercept demand function /1 20, 2 20/
w(j)       Static slope demand function /1 -0.1, 2 -0.2/
e(i,t)     Error
u(i,t)     Cumulative error
vt(i,t)    Dynamic intercept inverse supply function
tc(i,j)    Transport Costs
m(i,j,t)   Error term in transport costs;
***** The parameter vt(i,t) is a random walk which contains a random error
***** e(i,t) normally distributed
e(i,t)=normal(0,1);
loop(t, e(i,t+1)=e(i,t)+e(i,t+1));
u(i,t)=e(i,t);
vt(i,t)=vs(i)+u(i,t);
***** The parameter m(i,j,t) is a white noise error
m(i,j,t)=normal(0,1);
***** The variables are declared
Positive Variables
x(i,t) supply
y(j,t) demand
q(i,j,t) trade
***** The objective function is declared
Variable
CPS Consumer and Producer Surplus;
***** The equations, objective function and constrains are declared
Equations
Supply(i,t)     Supply constrain
Demand(j,t)     Demand constrain
MW              Maximum Welfare;
```

```

MW..  CPS =E=   SUM(t,
                  SUM(j, l(j)*y(j,t)+0.5*w(j)*y(j,t)*y(j,t))
                 -SUM(i, vt(i,t)*x(i,t)+0.5*n(i)*x(i,t)*x(i,t))
                 -SUM((i,j), tc(i,j)*q(i,j,t)));

Demand(j,t)..       SUM(i, q(i,j,t))-y(j,t)=G=0;
Supply(i,t)..      -SUM(j, q(i,j,t)+m(i,j,t))+x(i,t)=G=0;


****** The model is declared and solved
MODEL TAKAYAMA /ALL/;
takayama.iterlim=10000000;
takayama.reslim=2000000;
takayama.workspace=100;

option nlp=coinipopt;

SOLVE TAKAYAMA USING NLP MAXIMIZING CPS;

***** The GDX file is created
execute_unload  'WND' t, j, i, l, w, n, vs, vt, tc, q, x, y, Demand, Supply, u, e;
```

Appendix II: Evidence of Non-Linear Price Transmission Between Maize Markets in Mexico and the US

This paper was first presented at the 27th Conference of the International Association of Agricultural Economist, 16-22 August 2009. The final version was published in Spanish language under the title “Análisis de transmisión de precios entre los mercados de maíz mexicanos y el mercado estadounidense: métodos lineales y no lineales” in the Revista Española de Estudios Agrosociales y Pesqueros, No. 229, year 2011. Due to copyright restrictions here is included the original version, the final one can be downloaded directly from the following link:

http://www.magrama.es/ministerio/pags/biblioteca/revistas/pdf_REEAP/r229_39_78.pdf

Abstract

The present work provides evidence that non linear price transmission between Mexico and the US maize prices exists, at country and regional level. The models suggest that Mexican prices adjust at changes in US prices. Despite asymmetry was statistically rejected, it is likely that it might occur for thriving parameters different that zero in the error correction term. The results suggest on which way the research might be improved in order to assess such cointegration relationship accurately.

Keywords: cointegration, asymmetric price transmission, vector error correction model, error correction term, loading parameter, Mexico, US, maize.

Introduction and motivation

Maize is the most important agricultural product in Mexico; it occupies the largest share of cropped area and is the main component of the Mexicans' diet. Unlike other countries were maize production is regionalized, in Mexico it is spread all over the territory, as for that the production systems differ broadly. For example Fiess & Lederman (2004) distinguish two maize production systems in Mexico: high input (wealthy farmers) and low input (poor farmers). The two major Maize varieties cropped in Mexico are white and yellow, being white maize the most important with over 70% of the total production.

The performance of maize production in Mexico has been shaped by a set of complex events including: the disappearance of the National Company of People´s Subsistence (CONASUPO), a state company that controlled the domestic market for several crops; the shift of land devoted to maize to other crops (fruits and vegetables); the abandonment of land; subsidies; and meteorological phenomena in some cases. Starting in the 80's a liberalization process started, allowing maize imports to grow in Mexico in order to satisfy domestic demand, this caused a shift on the Mexican maize market toward an integration with international markets, mainly the US. Later with the NAFTA (North American Free Trade Agreement) enforcement, the field was prepared for free markets in Agricultural products including maize. For instance over the period 2000-2006, the volume of imports from the US equalled roughly 23% of total domestic maize production (73% of yellow maize production) highlighting Mexico´s incapacity to produce enough maize, mainly yellow. Despite both varieties, maize and yellow, differs on their usage under some circumstances they become substitutes. Given the high amount of yellow maize imports from the US, one might expect to find cointegration between maize yellow US prices and white maize prices in Mexico. Furthermore, the US yellow maize price is used as the reference price for calculating subsidies to maize producers in Mexico.

Before and after total liberalization of maize markets between Mexico and the US took place in January 2008, there has been a strong controversy regarding the effects of maize imports on Mexican production. It is often argued that imports from US have negatively influenced domestic prices and destroyed domestic production systems. Fanjul & Fraser (2003) argue that maize producers' prices in Mexico have fallen due to increasing imports and dumping; this argument is strongly supported by other authors such as Calva (1996) and Vega & Ramirez (2004). Furthermore, it is argued that emigration from rural into urban areas and the US was enhanced by income reduction, which was mainly based on maize production (Richter, et al., 2007; Yunez-Naude, 1998).

Some authors have tried to measure the price relation for maize in Mexico and the US. Fiess & Lederman (2004) found prices in Mexico and the US to be co-integrated; nonetheless other authors such as Araujo-Enciso (2008) & Motamed, et al. (2008) have found that the estimated Vector Error Correction Model (VECM) are weak to assert for market integration. Plausible reasons for that is the use of a linear approach. The aim of this paper is to fill the gap in the literature and to test whether US maize prices have an impact on the Mexican maize prices, and to study the study of this impact using time series econometric techniques.

Methods

Maize is traded between Mexico and the US under a set of variables, observable and unobservable, that shape the prices' performance. Under many circumstances prices are the solely source of information for markets; therefore the linkage between markets might be measured using such prices.

The previous weak findings of cointegration between maize markets in Mexico and the US, does not necessarily implies no market integration; for instance the assumption of a linear relationship might cause misleading results as well as regional data aggregation. The following research is based on the so called Vector Error Correction Model, which considers a linear relationship, and the Asymmetric Price Transmission analysis which allow for a certain type of non-linearity.

Linear error correction

The approach followed for the first analysis is to use a standard linear vector error correction model (VECM). The endogenous variables are the logarithm of the maize prices for Mexico and the US, denoted as $\mathrm{LogP}_t^{\mathrm{MX}}$ and $\mathrm{LogP}_t^{\mathrm{US}}$ respectively. The linear VECM is:

$$\Delta LogP_t = \Pi LogP_{t-1} + \Gamma_1 \Delta \mathrm{LogP}_{t-1} + \cdots + \Gamma_{k-1} \Delta \mathrm{LogP}_{k-t-1} + \mu + \varepsilon_t \quad (1)$$

Where Π is a matrix with a rank value of *r*, it goes from *0* to *p*, and denotes the number of long-run relationships. Matrix Π can be decomposed into:

$$\Pi = \alpha\beta' \quad (2),$$

Being $\boldsymbol{\beta}$ a matrix containing all the long-run relationships parameters, and $\boldsymbol{\alpha}$ the short-run adjustment coefficient or loading factors.

Two variables are said to be co-integrated if they are of order one (I (1)), and they have a linear combination I(0). The Augmented Dicked-Fuller Test (ADF) is used to determine the order of the series, being the null hypothesis a Unit Root (I (1)), versus the alternative of a stationary process (I(0)). In order to perform the ADF is necessary to include the number of lagged variables, which is selected following the Akaike Info (AIC), and/or Hannan-Quinn (HQC), and/or Schwarz (SC) criterions.

The following step is to test for cointegration between the series. The Johancen Trace (JTT) approach serves for determining the cointegration rank *r*. It tests for the null hypothesis of exactly *r* positive eigenvalues, versus the null hypothesis of more positive *r* eigenvalues. As in the ADF, it is necessary to include the lagged variables following one or more of the three criterions below.

A limitation of the present model is the basic assumption of a unique loading factor among the two variables. For instance some circumstances might cause non linearity behaviour on the model. On the present studies it is considered the so called Asymmetric Price Transmission (APT) as an alternative to improve the results.

Asymmetric error correction.

When price transmission differs between a positive or negative value on the deviations from the equilibrium, an asymmetric behaviour or process is present (Meyer & Cramon-Taubadel, 2004). Such behaviour might occur either in the long-run equilibrium or the short run adjustment. Following Meyer & Cramon-Taubadel (2004), the model for Asymmetric Price Transmission (APT) in the short run has the following form:

$$\Delta \mathrm{LogP}_t^A = c + \sum_{j=1}^{K} \beta \Delta \mathrm{LogP}_{t-j+1}^B + \phi^+ \mathrm{ECT}_{t-1}^+ + \phi^- \mathrm{ECT}_{t-1}^- + \gamma_t \qquad (3)$$

Were the error correction term (ECT) or long-run equilibrium is first estimated as a simple linear autoregressive (VAR) form with zero lags:

$$\mathrm{LogP}_t^A = c + \beta \mathrm{LogP}_t^B + u \qquad (4)$$

being *u* the deviation between the prices, which is corrected in the short run by the loading factors. Rearranging (4) is obtained:

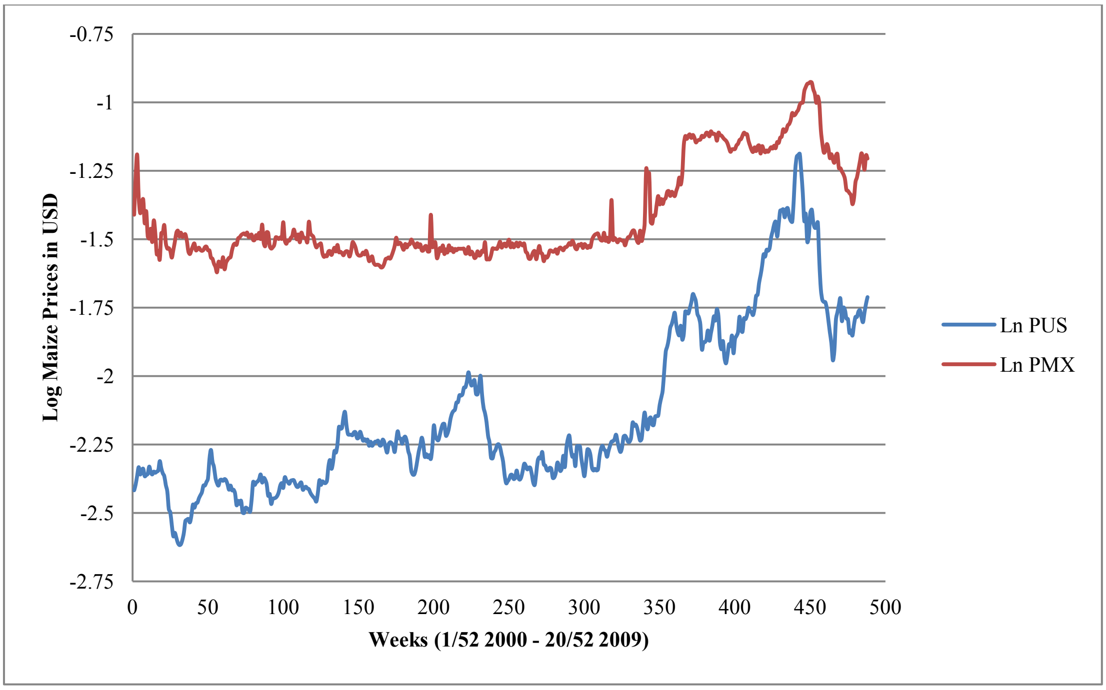
$$\mathrm{ECT} = \mathrm{LogP}_t^A - c - \beta \mathrm{LogP}_t^B = u \qquad (5)$$

Therefore splitting *u* into its positive and negative values is equivalent to separate the ECT. In that regard by doing so is possible to estimate ATP as in equation (3). Although the approach followed by the ATP is different from the VECM, the assumptions of non-stationary (ADF test) and cointegration (JTT approach) must be hold for the pair of series.

Data

The Mexican Ministry of Agriculture (SAGARPA) publishes annual average rural prices at the national and regional levels starting from 1980. However, 27 years (observations) is insufficient for carrying out a cointegration analysis. Fiess & Lederman (2004) and Araujo-Enciso (2008) generated monthly prices from these annual series using monthly deflators; however, this method is clearly fraught with difficulties. An alternative is to use consumer level maize prices, collected by the Ministry of Economy (SNIIM). The main concern with such data is that is that consumer prices might differ from processor or producer prices on their performance. Nevertheless, since the data is gathered on a weekly basis at several sales points in the country, from a statistical point of view it might be rich in information. The US maize prices are export prices free on board at the Louisiana Gulf port reported on a weekly basis obtained from the USDA. The data covers the period from the 1st week of 2000 until the 20th week of 2009 (488 observations). The prices are transformed to logarithms in order to interpret the estimated parameters as elasticises.

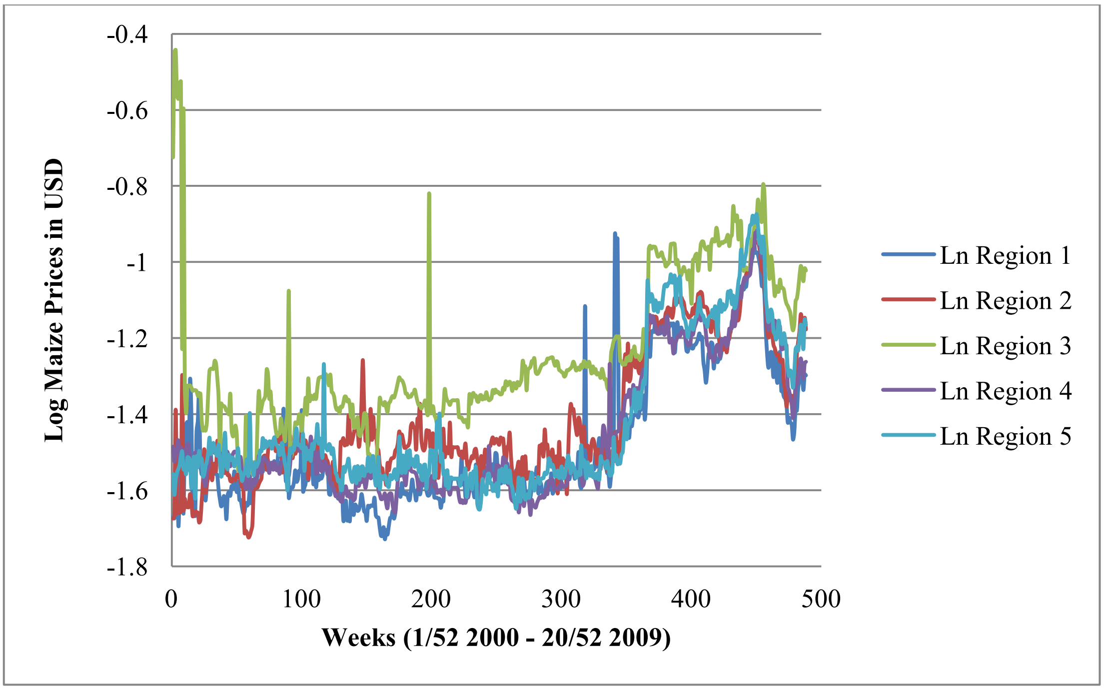
Figure 2. Logarithms of the weekly maize prices Mexico and US



Source: USDA and SNIIM. Prices for Mexico were converted to USD using the weekly average exchange rate from Banxico

Figure 2 shows the aggregated prices at country level for Mexico, and prices for USA. The Mexican average price is gotten from the figures in the thirty two states that compromise the country. As the Mexican Ministry of Agriculture classifies the thirty two states in five geographical regions, the aggregated prices for the five regions were calculated as well (Figure 3).

Figure 3. Logarithms of the weekly maize prices in Mexico by region (2000 week 1 - 2007 week 26)



Source: Prices for were converted to USD using the weekly average exchange rate from Banxico

As Figure 3 shows the performance of the prices among regions is quite different in some periods of time. The major concern of this is that data aggregation leads to loss of information and misleading results in the price transmission analysis as showed by Cramon-Taubadel, et al. (2006). On that regard, the use of regional data might offer a more reliable result than country level data.

Data analysis and results

Results for the ADF test shows that all the times series, except prices for Region III, were unitary root process, either with or without a constant and /or trend (Appendix B). As the estimated models consist on bivariate analysis for each of the six Mexican prices series with the maize prices in the US, for each pair it was performed the JTT (Appendix C). The results exhibit cointegration for all of them except for Regions IV and V, with and without trend. Despite this results it was decided to perform the VECM analysis, its results are shown in Table 1.

Table 1. Estimated long-run equilibrium (ECT) from the VECM

		Model 1 $LogP^{MX}$	Model 2 $LogP^{MX\ I}$	Model 3 $LogP^{MX\ II}$	Model 4 $LogP^{MX\ III}$	Model 5 $LogP^{MX\ IV}$	Model 6 $LogP^{MX\ V}$
$LogP^{US}$	β_1	-0.565***	-0.509***	-0.526***	-0.515***	-0.593***	-0.631***
	test statistics	-9.393	-9.586	-9.684	-7.889	-7.021	-7.943
	$\sigma_{\beta 1}$	0.06	0.053	0.054	0.065	0.084	0.079
Constant	*c*	0.215*	0.382**	0.287**	0.16	0.183	0.069
	test statistics	1.656	3.329	2.442	1.134	1.005	0.402
	$\sigma_{\beta 1}$	0.13	0.115	0.117	0.141	0.182	0.172

Source: own estimations using J-multi software developed by Lütkepohl & Krätzig (2004)

The results suggest that prices in the US share a common long run relationship with prices in Mexico at country and regional level since the estimated parameters are significant. The estimated β's, values less than one, are interpreted as Mexican prices being greater than US prices.

Table 2. Estimated loading parameters from the VECM

Model	Variable	Loading Parameters		
		α	*test statistics*	$\sigma_{\beta1}$
Model 1	$\Delta LogP^{MX}$	-0.061***	-4.198	0.015
	$\Delta LogP^{US}$	0.033**	2.160	0.015
Model 2	$\Delta LogP^{MX\_I}$	-0.159***	-5.910	0.027
	$\Delta LogP^{US}$	0.012	0.874	0.014
Model 3	$\Delta LogP^{MX\_II}$	-0.096***	-4.161	0.023
	$\Delta LogP^{US}$	0.042**	2.600	0.016
Model 4	$\Delta LogP^{MX\_III}$	-0.141***	-6.532	0.022
	$\Delta LogP^{US}$	0.021**	2.067	0.01
Model 5	$\Delta LogP^{MX\_IV}$	-0.040***	-3.233	0.012
	$\Delta LogP^{US}$	0.022	1.536	0.014
Model 6	$\Delta LogP^{MX\_V}$	-0.057***	-3.511	0.016
	$\Delta LogP^{US}$	0.023*	1.657	0.014

Source: own estimations using Jmulti software developed by Lütkepohl & Krätzig (2004)

The loading parameters and trend results (Table 2) suggest that prices for Mexico at country and regional level adjust to the equilibrium, while US prices in some cases do not adjust. With such evidence it might be plausible to say that US prices to some extend are exogenous and not determined by prices in Mexico.

With prices in Mexico as endogenous variable, and price in the US as exogenous variables, it is estimated the long run equilibrium with a VAR model. The results exhibit again prices in the US to be statistically significant, and that prices in Mexico are higher than in the US (Table 3).

Table 3. Estimated long-run equilibrium with VAR

		Model 1 $LogP^{MX}$	Model 2 $LogP^{MX\_I}$	Model 3 $LogP^{MX\_II}$	Model 4 $LogP^{MX\_III}$	Model 5 $LogP^{MX\_IV}$	Model 6 $LogP^{MX\_V}$
$LogP^{US}$	β_1	0.495***	0.49***	0.497***	0.444***	0.502***	0.554***
	test statistics	38.821	32.434	39.27	21.297	36.711	38.855
	$\sigma_{\beta1}$	0.013	0.015	0.013	0.021	0.014	0.014
Constant	*c*	-0.358***	-0.425***	-0.352***	-0.297***	-0.38***	-0.241***
	test statistics	-13.018	-13.015	-12.897	-6.595	-12.859	-7.823
	$\sigma_{\beta1}$	0.028	0.033	0.027	0.045	0.03	0.031

Source: own estimations using Jmulti software developed by Lütkepohl & Krätzig (2004)

In order to estimate the ATP, the residuals from the VAR models are split on positive and negative value. Using the model from equation (3), the new estimation shows the following (Table 4).

Table 4. Estimated loading parameters from the APT

	Variable	*ECT^{+}*		*ECT^{-}*	
		Φ^{+}	*Test statistic*	Φ^{-}	*Test statistic*
Model 1'	$\Delta LogP^{MX}$	-0.086***	-4.207	-0.037*	-1.654
Model 2'	$\Delta LogP^{MX\_I}$	-0.217***	-6.185	-0.083**	-2.07
Model 3'	$\Delta LogP^{MX\_II}$	-0.095***	-2.98	-0.098***	-3.051
Model 4'	$\Delta LogP^{MX\_III}$	-0.193***	-7.319	-0.038	-1.015
Model 5'	$\Delta LogP^{MX\_IV}$	-0.047***	-2.615	-0.035*	-1.937
Model 6'	$\Delta LogP^{MX\_V}$	-0.056**	-2.484	-0.061**	-2.475

Source: own estimations using Jmulti software developed by Lütkepohl & Krätzig (2004)

It is noticeable that the positive adjustment is always significant, while the negative adjustment is not. With such results it is not possible to assert that there is or not asymmetry. For doing so, it was performed an F test comparing the restricted model (VECM) with the unrestricted (APT). The null hypothesis states as "positive and negative adjustments are equal and jointly significant" (Table 5).

Table 5. F-tests for asymmetry

Models compared	*Test Statistics*	*5 % Critical F*
Model 1'(ATP) vs Model 1 (VECM)	2.51	3.84
Model 2'(ATP) vs Model2 (VECM)	6.39**	3.84
Model 3'(ATP) vs Model 3 (VECM)	0.17	3.84
Model 4'(ATP) vs Model 4 (VECM)	10.67**	3.84
Model 5'(ATP) vs Model 5 (VECM)	0.02	3.84
Model 6'(ATP) vs Model 6 (VECM)	-0.30	3.84

Source: own estimations

The results suggest the presence of asymmetries for Models 2 and 4; nonetheless for Model 4, due the fact that the negative adjustment is not significant (Table 4) also the asymmetry is rejected.

Discussion

The results from the VECM and VAR/APT suggest that there is cointegration between maize markets in Mexico and the US. Nonetheless some issues should be regarded with more attention before drawing any conclusion.

The long run equilibrium estimated on the VECM and VAR suggest that either at country or regional level prices for Mexico share a common trend with US prices. Nonetheless it is unexpected that VECM suggest US prices also adjust to changes in the Mexican prices. Such event might be quite debatable; despite the fact that Mexico is the destination for 15% of the US maize total exports; the force that drives US maize prices is more likely to be the international markets rather than solely the Mexican market. For instance cointegration between both markets might have a non-linear performance. Furthermore as the estimated VECM is bivariate, it neglects the interaction among the five Mexican regions; therefore it is not possible to conclude that the adjustments measured are definitive. Regardless of the previous outcome is important to stress that the VECM suggest that both markets are integrated, either at regional or country level. As for that changes in the US prices will pass to the Mexican counterpart. The evidence for such argument is that adjustment parameters for prices changes in Mexico are significant, even using a level of confidence of one percent; furthermore the speed of adjustment for Mexican prices seems to be greater than adjustments in the US. In that regard the previous assumption of Mexican maize prices being affected or determined by the US markets might be suggested.

The APT results exhibit a weak evidence for asymmetry, only Model 2 can account for real asymmetry. These might be explained on the basis of the estimated VAR. From Table 3 is possible to see the high values of the t-statistics; such values exhibit estimation problems on the parameters, which although not biased might be misleading. Despite the outcome regarding asymmetry rejection, the results exhibit a plausible direction in future research. For instance the non-significance of negative adjustment might be read as Threshold cointegration, that is for some periods prices are co-integrated while in other periods not. Other possible limitation of the asymmetry might deal with the thriving parameter, which for the present research is not estimated but established as zero. There is the necessity to explore if asymmetries or non-linear price transmission occur with other values; on this regard the approach of Goetz & Cramon-Taubadel (2008) following Gonzalo & Pitarakis (2006) might be used to estimate a thriving parameter, furthermore such methodology allows for asymmetry in the ECT estimation as well.

Regarding the models in general, there is a main concern; they do not assume any structural break. Such assumption is clearly unrealistic given the results of the stability tests (Appendix E) which shows that both, the VECM and the ECT (VAR), are unstable. Such outcome stresses again the importance of accounting for some non-linearity in the long and short run equilibrium in order to improve the results.

Another limitation of the results has to do with data aggregation. As prices either at country level and regional level are the average of regional prices, the assumption of constant aggregation must be hold in order to get reliable results (Cramon-Taubadel, et al., 2006). Unfortunately for the data the cross sectional aggregation is not constant (Appendix F) therefore to some extend the average prices might not represent the performance of all the states compromising the Regions. As data aggregation causes loses of information, an alternative is modelling with the so called generalized autoregressive conditional heteroskedasticity (GARCH) models, which might capture volatility; nonetheless if the loss is concerning positive and negative changes of two prices averaging, the best option is the use of non-aggregated data.

A final word of caution has to be made regarding the present study. Despite the maize prices used here are at consumer level, maize is not consumed as a grain but as a processed good, mainly as “Tortilla”. Indeed more than 50% of the Mexican maize production is devoted for the “Tortilla” industry (Galarza Mercado, 2005). Weather such increases might have either a positive or negative effect on the consumers depends on the price transmission from maize to tortilla. The elasticities derived from the previous models might provide some insight of the effects at producers and processors levels, but not for consumers.

Conclusion

The present work provides a first insight on the way future research should develop in order to fill the gap in the current literature for maize markets cointegration between Mexico and the US. The relationship among US prices and Mexican prices at different levels is hard to capture by a simple linear model. The results exhibits that there is strong evidence that maize market in Mexico and the US are integrated, and that prices share a common relationship. An accurate measure of such relationship and its dynamics can be drawn with the help of advanced techniques such as thresholds, structural breaks, smoothness, or conditional heteroskedasticity. The advantage of such techniques lays on its non-linear nature.

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Appendix A. Acronyms

ADF. Augmented Dicked-Fuller Test

AIC. Akaike Info Criteria

ATP. Asymmetric Price Transmission

Banxico. Central Bank of Mexico

BLS. U.S. Berau of Labor Statistics.

CONASUPO. National Company of People´s Subsistence

ECT. Error Correction Term

HQC. Hannan-Quinn Criteria

JTT. Johancen Trace Test

NAFTA. North American Free Trade agreement

OLS. Ordinary Least Squares

SAGARPA. Mexican Ministry of Agriculture, Livestock, Rural Development, Fishery and Nourishment

SC. Schwarz Criteria

SNIIM. National System of Markets Information of the Mexican Ministry of Economy.

USDA. United States Department of Agriculture.

VECM. Vector Error correction Model.

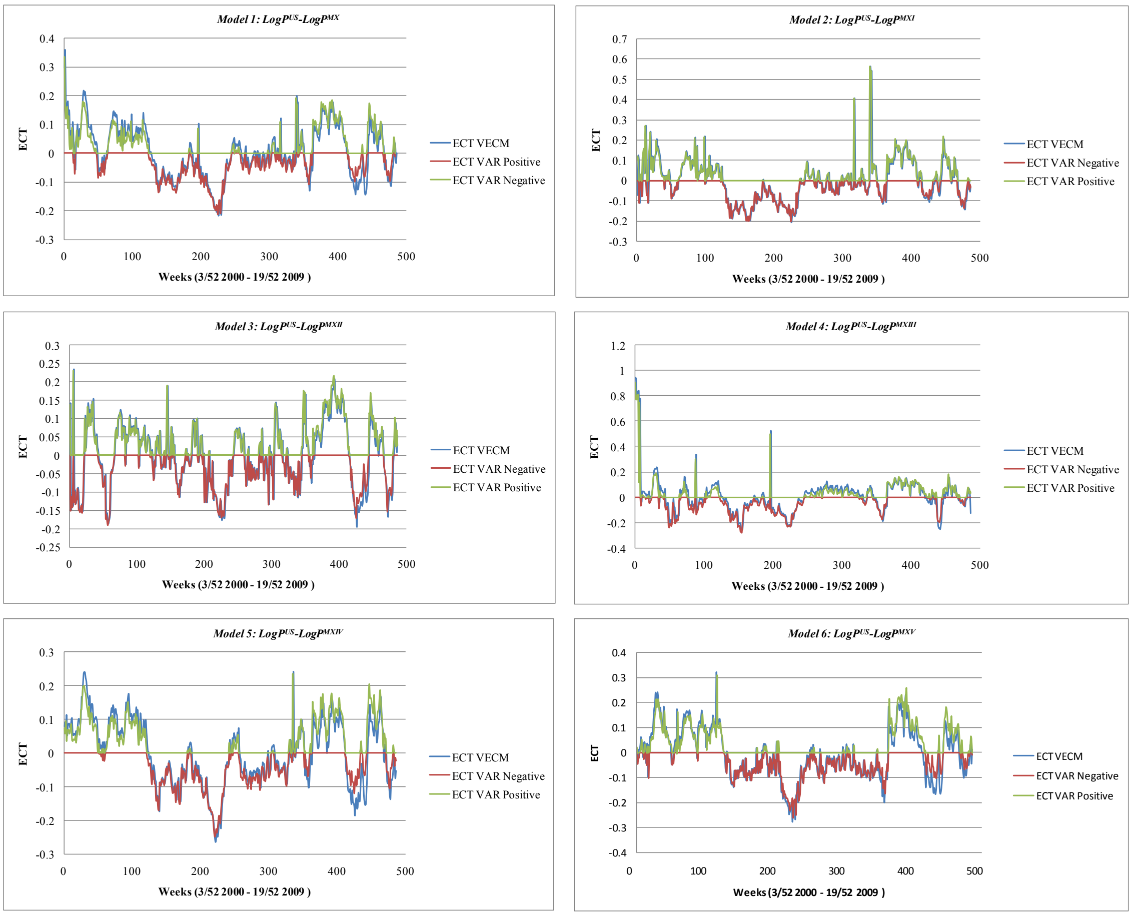
Appendix B. Unit root test results: Augmented Dicked-Fuller Test

Variable	Constant	Trend	Criterion	Lags	Test Statistics	Critical value
	No	No	AIC, HQC, SC	1	-0.9542	-1.94
$LogP^{US}$	Yes	No	AIC, HQC, SC	1	-1.1559	-2.86
	Yes	Yes	AIC, HQC, SC	1	-2.5690	-3.41
	No	No	AIC, HQC	4	-0.5277	-1.94
$LogP^{MX}$	Yes	No	AIC	4	-0.9586	-2.86
	Yes	Yes	AIC	4	-2.5126	-3.41
	No	No	AIK, HQC	6	-0.6562	-1.94
$LogP^{MXI}$	Yes	No	AIK, HQC	6	-1.5289	-2.86
	Yes	Yes	AIC	6	-2.5229	-3.41
	No	No	AIC	7	-0.5792	-1.94
$LogP^{MXII}$	Yes	No	AIC	7	-1.4127	-2.86
	Yes	Yes	AIC	7	-3.3358	-3.41
	No	No	AIC, HQC	3	-0.0309	-1.94
$LogP^{MXIII}$	Yes	No	AIC, HQC	3	-3.9758	-2.86
	Yes	Yes	AIC, HQC	3	-7.4070	-3.41
	No	No	AIC, HQC, SC	1	-0.6637	-1.94
$LogP^{MXIV}$	Yes	No	AIC, HQC, SC	1	-1.1661	-2.86
	Yes	Yes	AIC, HQC, SC	1	-2.0621	-3.41
	No	No	HQC	2	-0.9446	-1.94
$LogP^{MXV}$	Yes	No	AIC, HQC	2	-1.1246	-2.86
	Yes	Yes	AIC, HQC	2	-1.8952	-3.41

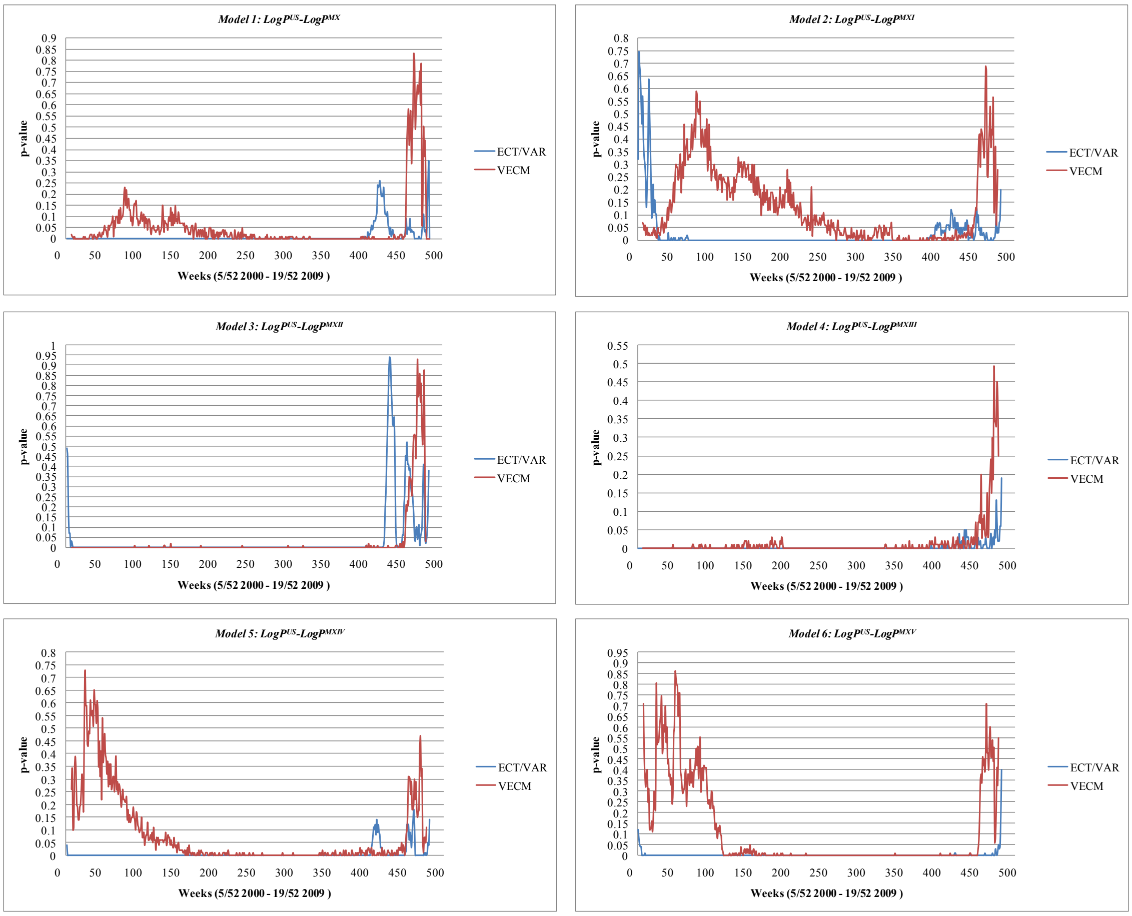
Appendix C. Cointegration test results: Johancen Trace test

Model	Constant	Trend	Criterion	Lags	Ho	Statistics	Critical value 5%	Critical value 10%
$LogP^{US}$-$LogP^{MXI}$	Yes	No	AIC, HQC, SC	2	r=0	36.62	20.16	17.98
			AIC, HQC, SC	2	r=1	1.96	9.14	7.60
	Yes	Yes	AIC, HQC, SC	2	r=0	41.10	25.73	23.32
			AIC, HQC, SC	2	r=1	6.46	12.45	10.68
$LogP^{US}$-$LogP^{MXII}$	Yes	No	AIC, HQC, SC	2	r=0	26.21	20.16	17.98
			AIC, HQC, SC	2	r=1	2.08	9.14	7.60
	Yes	Yes	AIC, HQC, SC	2	r=0	29.56	25.73	23.32
			AIC, HQC, SC	2	r=1	5.45	12.45	10.68
$LogP^{US}$-$LogP^{MXIII}$	Yes	No	AIC, HQC	3	r=0	54.51	20.16	17.98
			AIC, HQC	3	r=1	1.25	9.14	7.60
	Yes	Yes	AIC, HQC	3	r=0	67.77	25.73	23.32
			AIC, HQC	3	r=1	7.04	12.45	10.68
$LogP^{US}$-$LogP^{MXIV}$	Yes	No	AIC, HQC, SC	2	r=0	14.89	20.16	17.98
			AIC, HQC, SC	2	r=1	1.50	9.14	7.60
	Yes	Yes	AIC, HQC, SC	2	r=0	19.80	25.73	23.32
			AIC, HQC, SC	2	r=1	4.16	12.45	10.68
$LogP^{US}$-$LogP^{MXV}$	Yes	No	HQC, SC	2	r=0	17.59	20.16	17.98
			HQC, SC	2	r=1	1.76	9.14	7.60
	Yes	Yes	AIC, HQC, SC	2	r=0	22.99	25.73	23.32
			AIC, HQC, SC	2	r=1	3.98	12.45	10.68
$LogP^{US}$-$LogP^{MX}$	Yes	No	AIC, HQC, SC	2	r=0	23.21	20.16	17.98
			AIC, HQC, SC	2	r=1	1.17	9.14	7.60
	Yes	Yes	AIC, HQC, SC	2	r=0	28.79	25.73	23.32
			AIC, HQC, SC	2	r=1	6.82	12.45	10.68

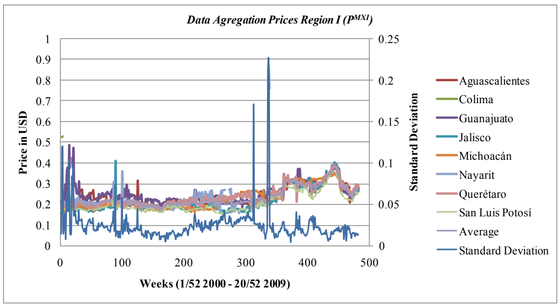
Appendix D. Estimated Error Correction Term (ECT) from the Vector Error Correction Model (VECM) and the Vector Autoregressive Model (VAR)/Asymmetric Price Transmission (APT) split in positive and negative values.

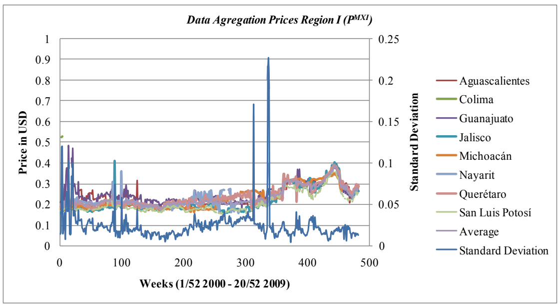


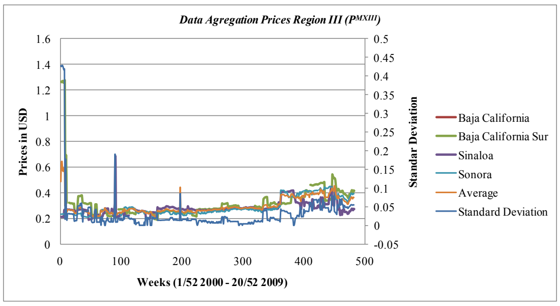
Appendix E. Stability tests for the long run equilibrium (ECT/VAR) and the VECM

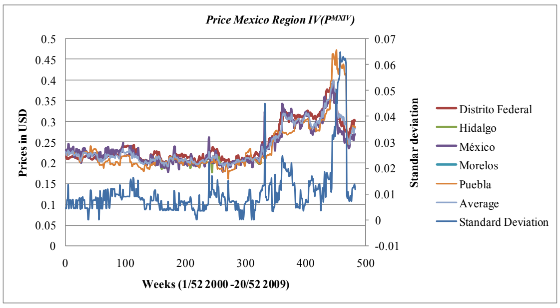


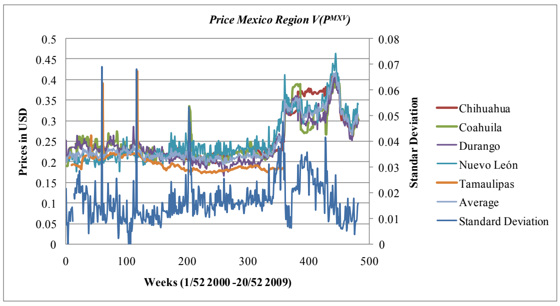
Appendix F. Cross-sectional data aggregation for calculating the average regional prices











Appendix E. Descriptive statistics of the prices series

Region	Variable	Mean	Min	Max	Standard Deviation
Region I	$P^{MX\ I}$	0.233436	0.177525	0.394806	0.047012
	$LogP^{MX\ I}$	-1.472630	-1.728640	-0.929362	0.182679
	$\Delta LogP^{MX\ I}$	0.000764	-0.498360	0.565100	0.062081
Region II	$P^{MX\ II}$	0.247339	0.178377	0.393163	0.046624
	$LogP^{MX\ II}$	-1.413630	-1.723860	-0.933531	0.175514
	$\Delta LogP^{MX\ II}$	0.001021	-0.353978	0.357573	0.045809
Region III	$P^{MX\ III}$	0.293320	0.207142	0.642614	0.065026
	$LogP^{MX\ III}$	-1.246090	-1.574350	-0.442211	0.196975
	$\Delta LogP^{MX\ III}$	-0.000611	-0.729380	0.632768	0.077808
Region IV	$P^{MX\ IV}$	0.238138	0.189239	0.400493	0.047241
	$LogP^{MX\ IV}$	-1.452320	-1.664750	-0.915060	0.180416
	$\Delta LogP^{MX\ IV}$	0.000458	-0.212727	0.251179	0.026766
Region V	$P^{MX\ V}$	0.245684	0.191933	0.417436	0.053752
	$LogP^{MX\ V}$	-1.424700	-1.650610	-0.873624	0.196265
	$\Delta LogP^{MX\ V}$	0.000807	-0.214443	0.244306	0.038054
Mexico country level	P^{MX}	0.246581	0.197613	0.396189	0.047441
	$LogP^{MX}$	-1.416440	-1.621450	-0.925865	0.175431
	$\Delta LogP^{MX}$	0.000422	-0.178157	0.200119	0.029819
US	P^{US}	0.124393	0.073032	0.304528	0.045003
	$LogP^{US}$	-2.137400	-2.616860	-1.188990	0.308191
	$\Delta LogP^{US}$	0.001448	-0.143548	0.111435	0.030886

Appendix F. Regions within Mexico

Region	States	Region	States
1- West	Aguascalientes	3 -Northwest	Baja California
	Colima		Baja California Sur
	Guanajuato		Sinaloa
	Jalisco		Sonora
	Michoacán	4 -Centre	Distrito Federal
	Nayarit		Hidalgo
	Querétaro		México
	San Luis Potosí		Morelos
	Zacatecas		Puebla
2 -South	Campeche	5 - Northeast	Tlaxcala
	Chiapas		Chihuahua
	Guerrero		Coahuila
	Oaxaca		Durango
	Quintana Roo		Nuevo León
	Tabasco		Tamaulipas
	Veracruz		
	Yucatán		

Source: taken from Galarza Mercado (2005)

APPENDIX III: THE RELATIONSHIP BETWEEN TRADE AND PRICE VOLATILITY IN THE MEXICAN AND US MAIZE MARKETS

This paper originated with the idea of including information about trade in the price transmission analysis. It was presented at the 123th EAAE Seminar "Price Volatility and Farm Income Stabilisation Modelling Outcomes and Assessing Market and Policy Based Responses" held in Dublin, Ireland in February 23-24, 2012. The current version, which is included is still under development.

Abstract

The supply of maize in the Mexican market depends to a large extent from the US imports which represent a large share of the domestic consumption. Furthermore imports exhibit a seasonal pattern, and peaks are often found close to low levels of domestic production and stocks. The present research suggests that there is a link between imports and prices volatility. Below a threshold value, imports and volatility are not related, but beyond the threshold it is volatility the variable driving imports. From the results one can argue that imports have served as a measure to stabilize prices when the domestic supply is scarce.

Keywords: Volatility, Maize, Imports, Mexico

JEL classification: Q11, Q17.

Introduction

Albeit price variation has been a characteristic of the agricultural markets, the dramatic increases for many commodities during the 2007-2008 food crisis has made researchers, policy makers, NGO's and other stakeholders to pay attention to the issue. The discussion in the academia has not only been centered on the consequences of high volatility, but also in the causes for it.

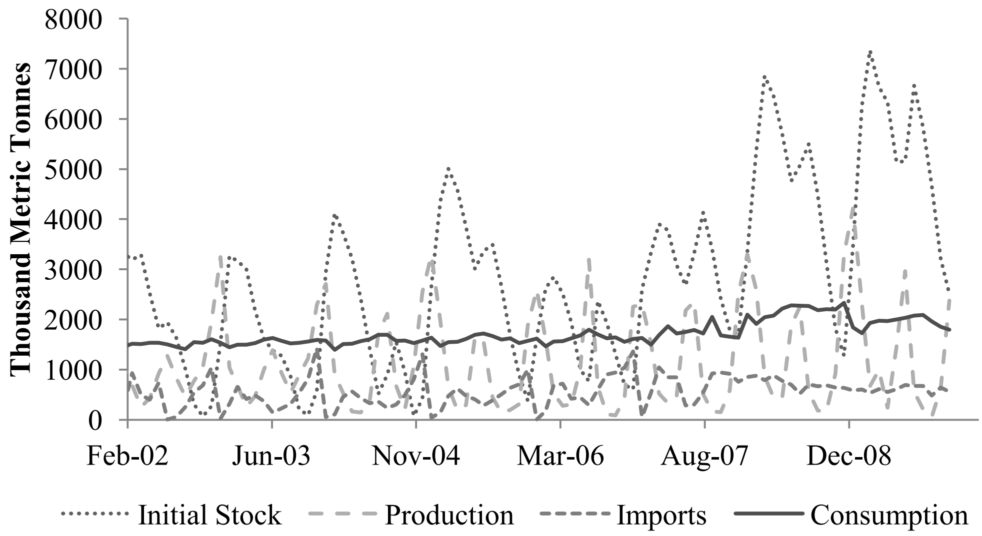
Unlike other type of goods, agricultural commodities are demand inelastic, thus large changes in the prices lead to short changes in the demand; on the contrary agricultural commodities prices are quite sensible to shocks in the supply (Gilbert, 2006), thus weather shocks have a large impact on prices behavior (Gilbert & Morgan, 2011). The current literature offers several explanations for volatility and variables affecting it. For instance Balcombe (2011) and Tothova (2011) summarizes some factors which are likely to affect volatility such as past volatility, trends, yields, stock levels, weather, speculation, policy, exchange rates, oil and energy prices, investment, interest rate and structural change. Those factors and their relation with volatility have been studied more in detail by other authors, being much of the research done between volatility and biofuel linkages. Recent research suggests that there is evidence that the increasing amount of agricultural goods devoted to the produce biofuel, i.e. maize and rapeseed has created a link between energy and food prices. For instance Baffes (2011), Buse, et al. (2011), Du, et al. (2011), and Ji & Fan (2012) found that for some agricultural commodities the relationship between agricultural goods and energy prices has increased in the last years. The problem is not such a link itself, it is rather that energy markets exhibit higher volatilities than other commodities (Plourde & Watkins, 1998), thus volatility spillovers are passed through the agricultural markets. Other research has centered on how policy instruments serve to prevent excessive volatility. Specifically in the European case O'Connor & Keane (2011) and Velazquez (2011) argue that the current CAP instruments which have served to stabilize prices should be revised and improved; this should be done properly in order to avoid volatility peaks in international markets. Concerning developing countries, policy instruments to ensure price stabilization have been the reduction of the tariffs and custom fees (Demeke, et al., 2011), which has lead to an increase in trade. This exposure to international markets, although might serve to alleviate high prices and volatility, exposes regional markets in developing countries to international shocks. Using information from the international markets Stigler & Prakash (2011) found that volatility is linked to low levels of stocks. Indeed for many developing countries such stocks depend on imports. From this perspective trade might serve to understand volatility in the agricultural markets. To the knowledge of the author no study had found empirical evidence that relates trade and volatility. Knowing if international trade serves either to alleviate or increase volatility can serve to implement the adequate policies. The question turns more interesting when one of the markets is a developing country with an open economy, for instance Mexico.

Maize production in Mexico

For Mexico one of the most, if not the most, important agricultural commodity is maize. Between 1996 and 2006, 51% of the agricultural land in Mexico was used for producing maize, it accounted for 7.6% of the total agricultural production volume and 30% of the total agricultural production value (Galarza Mercado, 2005). The importance of the maize is not only from the production/supply side perspective, but from the consumer perspective as well. In rural areas for 2006 on average 5.9% of the total expenditures are made on cereals (Urzúa, 2008), from which maize represents more than 50%. Another important consumer of maize is the feed industry which share of the total domestic demand is 50%. Nevertheless feed industry and human consumption require different types of maize; for human consumption the main product is white maize, for the feed industry the main product is yellow maize. From the labour markets perspective maize is also important. For 2005 it was required more than 20 millions of workers for producing maize (Galarza Mercado, 2005). Also in the same year the maize processing industry occupied nearly 150,000 workers. Indeed maize production value is close to one percent of the national GDP.

Despite being in the top five maize producers in the world, Mexico is also in the top maize importers in the world; being most of the imports from the neighbour US. Indeed yellow maize accounts for more than 90% of maize imports in Mexico. Figure 1 shows the development of monthly production, stocks, imports and demand for maize between 2002 and 2009.

Figure 1.Development of monthly maize stocks, production, imports and demand for the period 2002-2009



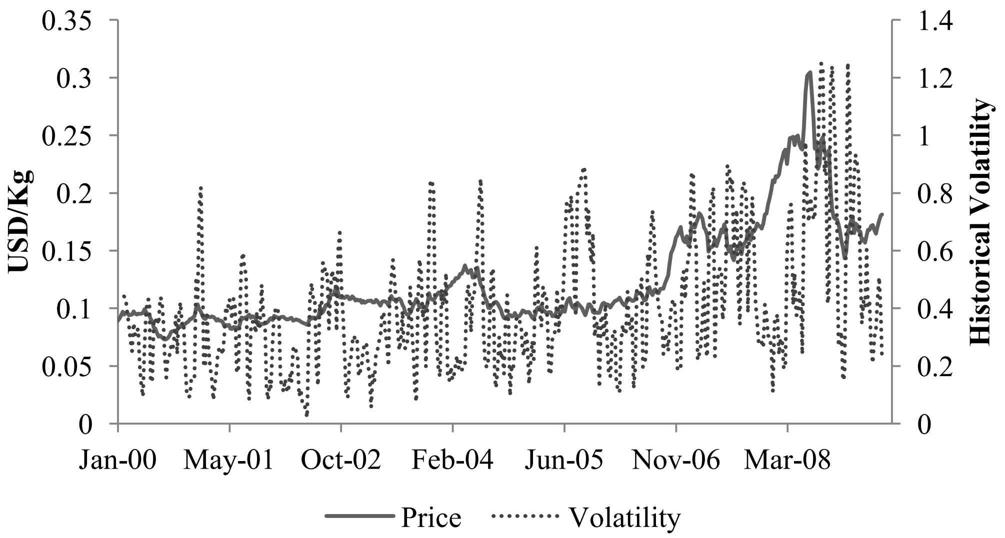
Source: Own elaboration with data from the Mexican Ministry of Agriculture

For the period 2002-2009 imports represented 48% of the domestic production, 33% of the domestic demand, and 20% of the initial stocks. Being the imports from the US relevant for the domestic supply in the Mexican market, one can expect that the volatility of the US markets prices will influence volatility in the Mexican markets prices.

Volatility and Trade in the Mexican and US maize markets

The agricultural commodities prices, as many other commodities, are characterized by price fluctuations which if big lead to periods of high volatility. In 2007-2008 the so called food crises was characterized by large increases in food prices, having as a consequence high volatility periods. The maize markets were exposed to such crises as well as Figure 2 shows.

Figure 2. Prices in USD per kilogram and four-week period volatility for yellow maize at the Lousiana Gulf port (Period January 2000 – May 2009)

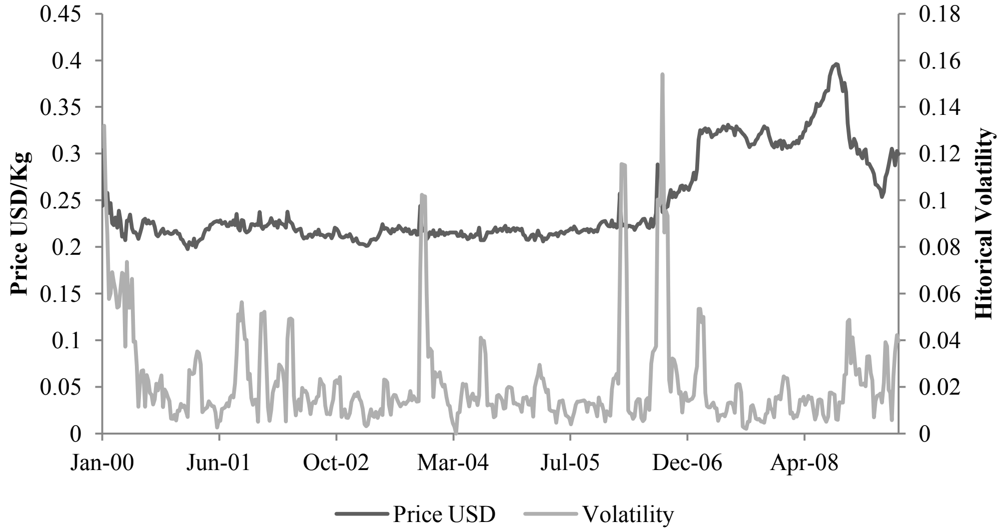


Source: Own elaboration with data from the USDA

Thus from figure 2 it is clear that the increases in maize prices in 2008 are also linked to the highest volatility values; nevertheless other periods of high fluctuations before the food crisis can be observed. The question is to what extend the volatility in the US markets affect the prices in Mexico.

In theory, perfectly cointegrated markets in equilibrium exhibit the same volatility as their changes over the time are proportionally the same. Although in the long run markets should reach equilibrium, in the short run it can be violated. Nevertheless arbitrage brings markets to the equilibrium. In the case of Mexican and US maize markets the violations of its equilibrium relationship are corrected by means of the trade among them. Thus as trade occurs prices in the markets adjust following the same path, hence exhibiting similar volatility. Figure 3 shows the historical volatility for the Mexican maize markets.

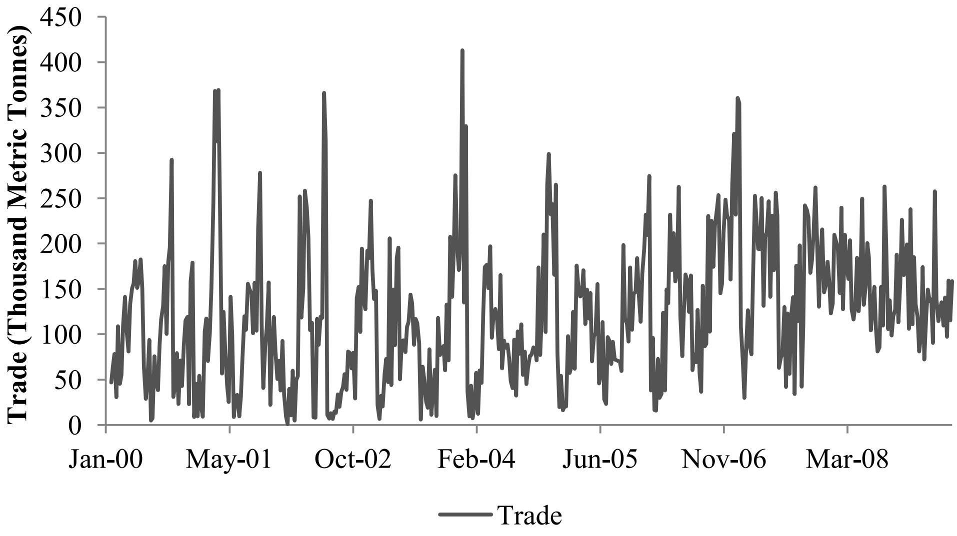
Figure 3.Maize prices and four-week period historical volatility in Mexico (Period January 2000 – May 2009)



Source: Own elaboration with data from the Mexican Ministry of Economy

From Figure 3 one can see that Mexican markets are characterized by larger fluctuations than in the US. This is perhaps linked to the production systems in both countries. For instance in Mexico a large share of the domestic supply comes from small farmers (non-irrigation production) which depend on the weather conditions. Thus by comparing figures 2 and 3 one can observe that volatility in Mexico and the US is quite different. This outcome is closely related to the markets cointegration. For instance Araujo-Enciso (2011) found Mexican markets to have mixed degrees of cointegration with the US markets ranging from 0.27 to 0.93, with a value close to 0.5 at national level. An approach suggested to evaluate the relationship between volatility spillovers was suggested by Zhao & Goodwin (2011); their approach is to find volatility spillovers with a VAR model rather than with the typical GARCH models. Their research is done for soybeans and maize markets, for which there is evidence of spillovers. Nevertheless both products are likely to have a strong cointegration, for instance Marsh (2007) considers an effect on the maize prices by the soybeans supply in the livestock and poultry industries; also Zhang, et al. (2009) found Granger causality between soybean and maize prices. As it was mentioned before, the evidence of cointegrated prices between Mexico and the US is not strong, hence an analysis of volatility spillover is not really promising. Instead of doing that an alternative approach is to evaluate the impact of imports on the volatility by means of a VAR model. Figure 4 depicts the maize imports from the US on a weekly basis.

Figure 4. Mexican yellow maize imports (Period January 2000 – May 2009)



Source: Own elaboration with data from the USDA

The weekly maize imports serve to capture seasonality changes in the supply, which are assumed to be one plausible source of volatility in the Mexican maize markets.

Methods and Results

Methods

Let considered a Vector Autoregressive Model (VAR) of order p whit K endogenous variables $y_{t=}(y_{1t}, y_{2t}, \dots y_{Kt})$. The VAR(p) process is defined as

$$y_{t=}A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + \epsilon_t \ (1)$$

where A_i are $(K \times K)$ coefficient matrices for $i = 1, \dots, p$ and ϵ_t is a K-dimensional white noise process.

For instance one can consider the vector $y_{t=}(v_{MX,t}, \tau_t)$, with $v_{MX,t}$ denoting the maize prices volatility in the Mexico, and τ_t the maize imports between Mexico and the US at national level. Such a model would serve to understand a linear relationship between volatility and trade. Nevertheless one can consider a non-linear approach such as the so called Threshold Vector Autoregressive Model (TVAR). The TVAR(p) process can be written as

$$y_{t=} \begin{cases} A_1^U y_{t-1} + A_2^U y_{t-2} + \cdots + A_p^U y_{t-p} + \epsilon_t \ if \ y_{kt-l} > \theta \\ A_1^L y_{t-1} + A_2^L y_{t-2} + \cdots + A_p^2 y_{t-p} + \epsilon_t \ if \ y_{kt-l} \leq \theta \end{cases} (2)$$

where $l \leq p$ is the selected lagged value for the threshold variable, θ is the threshold value and the superscripts U and L denote the upper and lower regimes respectively. The idea behind a threshold model is to consider different relationships between the variables depending on a threshold value.

In order to estimate a TVAR model one needs to set up a variable which will serve as the threshold which for this research are the imports. The reason is that imports are a source of shifts on the supply, nonetheless they are not the unique source as domestic production and stocks also play a role, hence it is only when the imports are beyond a certain threshold value that the shift in the supply becomes large enough to cause fluctuations in prices (volatility).

The selection of a TVAR versus a VAR can be done by using the sup-LR statistics proposed by Lo & Zivot (2001) which can be written as

$$LR_{jm} = T\left(ln\left(\left|\hat{\Sigma}_j\right|\right) - ln\left(\left|\hat{\Sigma}_m\right|\right)\right) \ (3)$$

where $\hat{\Sigma}_j$ and $\hat{\Sigma}_m$ denote the estimated residual covariance matrix from the restricted (linear) and unrestricted (threshold) models respectively. The previous test can be extended to test models with more than one threshold, for instance two threshold and three regimes. Three criterions are done in order to select the number of lags: Akaike Info Criterion (AIC), Hannan-

Quinn Criterion (HQC) and the Schwarz Criterion (SC). The selected value is the one that serves to estimate the most parsimonious model.

The analyses consist on pair-wise models for the volatility data in the five regions in Mexico and at national level, and the maize imports.

Criterion results

The first step consists on determining the number of lags to include in the models. Table 1 summarizes the results of the three criterions for the six models.

Table 1: Lags to include suggested by the criterions results for the six VAR models

Criterion	Lags
AIC	9
HQC	9
SC	5

Source: own elaboration

The results suggest that in order to estimate the most parsimonious model the choice is 5 lags for all the models.

Testing for linear and threshold models results

In order to test if the model is linear or non-linear first one has to select the threshold variable, which on this set up is the imports variable τ_t, nevertheless as the model includes five lags one has to select which of the lags is the threshold. The imports used on the analysis have a delivery time of 30 days; hence one expects that the shock in the supply will occur with 30 days of delay, which in weeks is approximately four. Nonetheless that is the delivery time at the port of entry. There is also a time for carrying out the maize to the final destination which has to be accounted for. Following this idea the lagged selected for the threshold was of five weeks, which is also the maximum number of lags considered for the models.

After selecting the threshold variable one has to test for the threshold models, for doing so it is used the Lo & Zivot (2001) test implemented in the tsDyn package by Di Narzo, et al. (2009). Testing threshold models consider more than one null hypothesis. The following sets of hypothesis are tested: the null H_0^1*:linearity* versus the alternative H_a^1*: one threshold with two regimes*; the H_0^2*:linearity* versus the alternative H_a^2*: two thresholds with three regimes*; and the null H_0^3*: one threshold with two regimes* versus the alternative H_a^3*: two thresholds with three* *regimes*. The results are summarized in table 2. For the entire test 250 bootstraps were performed to get the distribution.

Table 2: P-values for the Lo & Zivot (2011) test

Threshold variable	Hypotheses	P-value
τ_{t-5}	H_0^1 vs. H_a^1	0.02
	H_0^2 vs. H_a^2	0.01
	H_0^3 vs. H_a^3	0.10

Source: own elaboration

Following the results the model to estimate is a TVAR(5) with one threshold and two regimes

Estimations from the TVAR model

The estimation is done using the package tsDyn implemented in R by Di Narzo, et al. (2009). The estimated threshold value is $\widehat{\tau_{t-5}} = 252.66$. The percentage of observations in the lower regime is 94.8, and 5.2 for the upper regime. The estimated coefficients are summarized in Table 3.

The results suggest that in the Lower Regime, where most of the observations belong, the lagged terms of the volatility doe not have en effect on the imports, on the same way the lagged terms of imports do not have an effect on the volatility. Therefore in the lower regime, both variables are unrelated. Nevertheless in the Upper Regime, which accounts for nearly five percent of the observations, the lagged terms of the volatility have a significant impact on trade, on the contrary only one lagged term of the imports has a significant impact on volatility at 10% level. Hence one can conclude that when the amount of trade is lower than 252.66 thousand metric tonnes, the variables volatility and trade do not have an effect each on other, nevertheless when the trade amounts goes beyond the lagged terms of the volatility drive the performance of the imports. This is to some extent contrary to what was assumed, one could assume that imports by means of shifts on the supply curve causes prices to fluctuate, hence causing volatility. Nonetheless the fact that volatility is driven imports is plausible. The figure 1 shows that between 2002 and 2007, peaks on the amount of imports are close to low levels of stock and low level of production. On this regard one can argue that low production and low stocks shifts the supply down causing prices to fluctuate (increase), as a measure to alleviate such a fluctuation and in order to stabilize prices imports increase. Following this idea, on average, exposure of the Mexican markets to the world markets by means of trade (imports) seems to have served as tool not only to drop the domestic prices, but also to stabilize them when production and stocks levels are low.

Table 3: Estimated parameters from the TVAR(5) model

Variables	Lower Regime		Upper Regime	
	v_{MX}	τ	v_{MX}	τ
Intercept	0.0354	31.3763	0.0925	-113.4385
	(0.0096)***	(7.7721)***	(0.1715)	(139.3942)
$v_{MX,t-1}$	1.0182	-30.2241	0.4694	-2072.3451
	(0.0437)***	(35.5191)	(0.5671)	(461.0869)***
τ_{t-1}	-0.00002	0.4884	-0.0002	1.2725
	(6.3e-05)	(0.0511)***	(0.0005)	(0.4177)**
$v_{MX,t-2}$	-0.1817	80.8839	0.1784	1722.7369
	(0.0596)**	(48.4743)	(0.6641)	(539.8975)**
τ_{t-2}	-0.000082	0.2326	-0.0001	-0.2603
	(6.1e-05)	(0.0496)***	(0.0002)	(0.1754)
$v_{MX,t-3}$	0.1652	-57.1883	-0.0604	-799.1242
	(0.0601)**	(48.8404)	(0.6789)	(551.9462)
τ_{t-3}	0.0000036	0.0679	-0.0002	0.2958
	(6.2e-05)	(0.0503)	(0.0002)	(0.1923)
$v_{MX,t-4}$	-0.4976	11.4253	-0.1282	1789.8152
	(0.0597)***	(48.5445)	(0.5826)	(473.6871)***
τ_{t-4}	-0.00005	-0.01	0.0008	0.1266
	(5.9e-05)	(0.0482)	(0.0003)*	(0.2576)
$v_{MX,t-5}$	0.3339	29.9835	0.0839	-1536.6734
	(0.0424)***	(34.4909)	(0.4947)	(402.2132)***
τ_{t-5}	0.000056	-0.0586	-0.0002	-0.0952
	(5.5e-05)	(0.0447)	(0.0003)	(0.2345)

Source: own elaboration

Note: standard errors are in parentheses, ***, **, and * denote the significance levels at 1%, 5% and 10% respectively.

The measurement of impact of the volatility on imports cannot be analyzed by simply looking at individual estimated coefficients; it has to be done by looking at the impulse response functions which is left for future research.

Besides it could be interesting to perform the analysis not only with imports, but also with the stocks and production variables. Nonetheless there is data limitation, as for those two later variables the data frequency is in months. Hence the time horizon of the analysis should be extended in order to allow estimating a TVAR model with monthly data.

Concluding Remarks

The maize imports of maize in Mexico from the US have served as a tool to stabilize prices. Import peaks are often found close to low levels of production and stocks, hence when the low supply causes prices to fluctuate, the imports increase. Furthermore such mechanism is not frequently observed as it accounts roughly five percentage of the observations.

Further research has to be done by including more variables affecting the supply, additionally the impulse response functions can provide a better understanding on how imports and volatility are related.

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