Spatial Analysis of Market Power of Cassava Starch in Brazil
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The present study aimed to investigate the spatial price transmission of starch, addressing the major producing regions. The specific objectives were to identify their long-term behavior and to verify possible asymmetries on the price transmission. The analysis of price transmission among the markets indicates that prices cointegrated themselves in the long run, leading to the Vector Error Correction Model (VECM). Through the econometric regressions it was possible to verify the application of the Law of Price for only a region under analysis. This study concluded that the markets for starch were not spatially integrated. Thus, it was possible to infer that the market for starch showed a competitive inefficiency.

Keywords: starch, spatial price transmission and competitive efficiency.

JEL Classification: B23, Q13 e L11
1. Introduction

Agribusiness cassava stands out for its high starch marketing, due to the advantages of cultivation and its employment generation. Nigeria, Brazil, Indonesia and Thailand that have dominated the international production of cassava root in recent years. Even with its origin in the South America, currently the main producers are Africa and Asia. The main producing states of cassava root in Brazil are Pará, Paraná and Bahia. The states of the north and northeast are characterized by production for subsistence, of low tech and destined for the local market, however, it is already evidenced in some regions the presence of small starch-producing and the root culture for industrial use. In the south-central states of Brazil, highlighting the regions from Paranavaí (PR), Assis (SP) and Naviraí (MS), the culture of the root is primarily intended for industrial use, whether for the production of starch or flour.

The beginning of the cassava starch industry in Brazil happened in the mid 1950s, but its development was in fact in the 1990s, which was made possible by the insertion of the country in the international trade. A growing demand for the product appeared throughout the decade, causing some flour mill to become starch-producing. In the 2000s some units began to modify starch in natura attending other more specific niche markets such as the paper and cardboard, the chemical, the steel and other industries. (FELIPE, ALVES, CAMARGO, 2010).

The instabilities in the supply and starch prices mainly caused by the lack of raw material (root), have committed against its preference facing other types of starches. It is believed that the changes in the behavior of cassava root prices are the main justification for such behavior. The determinants of this behavior are the possible irregularities in the competitive market of starch, such as the action of intermediaries, the use of market power by some businesses, no barriers to entry and lack of coordination in the chain, among others. While prices change the main producing regions or producers of starch and/or root may present behaviors that distance themselves from the perfect competition, signaling some market power.
With respect to the performance of the starch chain as a whole, Cardoso (2003) showed that the segment is marginally competitive, because the revenues generated are not nearly sufficient to remunerate the specific factors of production. The author pointed out that there are other factors that can impair the competitiveness, which are conditioned to aspects of demand, for example, the technological limitations and the structural and the systemic factors. For the chain promotes competitive gains is interesting to have harmonious relationships that enhance the coordination among market levels.

The commercialization of starch has several constraints that limit their performance especially when it concerns the high perishability of the root, generating instabilities in its supply and the consequent disincentive for downstream industries in using the starch. Hence, it can be stated as research problem the possible existence of market power asymmetries between starch-producing regions.

Thus, the present study has as main objective to examine the market power, addressing starch price’s asymmetric transmission in the major producing regions of Brazil, which are in the states of Paraná, Mato Grosso do Sul and São Paulo. As specific objective we stand out: i) to verify long-term relationships among the variables addressed; ii) to study the asymmetric transmission among the starch prices to the main producing regions of Brazil.

2. **The Brazilian Cassava Starch Market**

As the Centro de Estudos Avançados em Economia Aplicada – CEPEA (Center for Advanced Studies on Applied Economics) (2013), the leading producer of starch in recent years was Paraná, and in 2012 its production reached about 70% (374,32 thousand tonnes) of the total. Among the regions of the state, the most representative is the northwest, also known as the Paranavaí region, with 42.2% of the national total, followed by the extreme western regions (18.30%) and Midwest (11, 50%). In the state of São Paulo the region of Assis stands out both for the production of cassava root as the starch occupying the position of the fourth largest producer of the starch in the country, with 9.2% of the national total in 2012. Other highlighted regions are the Mato Grosso do Sul extreme southern and
southeastern with, respectively, 8.90% and 8% of the national total. This regions are shown in Map 1.

It is emphasized the south coast of Santa Catarina and the upper valley of the Itajai, state of Santa Catarina with smaller representativeness. In 2011 the CEPEA began collecting information on starch producers from Pará and Bahia. The starch production currently focuses in the states of Paraná, Mato Grosso do Sul and São Paulo, where such regions totaling 98.20% of the Brazilian production of 2012, and those are the main producers in Brazil. Therefore, this study will address only the three regions of Paraná, the two regions of Mato Grosso do Sul and São Paulo region.

As regards the evolution of the production of starch and its dispersion by the Brazilian territory, GOEBEL (2005) pointed out that the transition of manioc cultivation in the recent years is also reflected in the production of starch. According to the author, the starch manufacturers initially emerged in the state of Santa Catarina later migrating to Paraná and Mato Grosso do Sul, "a way of changing the traditional existing production structure in the cassava chain that has always been linked, in almost all, to a subsistence crop and patterns of small farms." (GOEBEL, 2005, p. 148).

The study of Souza et al. (2005) confirmed this scenario. According to the authors, the incentives for the industrialization in Mato Grosso do Sul enabled changes of industrial plants to the state. This stimulus, when added to high productivity and mechanization of crops in the state, resulting in cost reduction of the cassava production, when compared with neighboring regions in Paraná. Thus, such event, discouraged cassava production in Paraná generating indolence in the largest starch producers in Paraná region, and an increase of starch producers in Mato Grosso do Sul.

The information asymmetry is a factor that affects the marketing of cassava and its derivatives. As Cardoso (2003), two levels of information asymmetry are identified in a market: firstly, related to the competitive strategy of companies (linked to prices, technologies and other) and secondly, characterized by the absence of information among the segments that make up the chain. The flow of information among the links of supply chain is important because it minimizes the constraints of information related to the limits and to the opportunities of generated products, i.e., reduces the asymmetries regarding the
applicability of starch. Thus, the consumers besides demanding the products, they also want their technical information (applicability) and the sale will build on these two factors. As a result, the companies which are not able to provide technical recommendations, as the case of the small ones, end up outside the most selective markets, selling only products with lower added value.

Goebel (2005) noted the existence of information asymmetric and of opportunistic actions in the agribusiness of cassava, where only the agroindustries have access to information, especially in relation to the marketing issues. Thus, the producers of cassava root shall be borne by the information passed by the undertakings.

According to Alves and Vedovoto (2003), the information asymmetries may favor the action of intermediaries who act as determinants of prices, distancing its formation from a competitive structure to a process of asymmetric formation. Cardoso (2003) completes this idea stating that a worsening in relations between root and starch producers is the lack of mechanisms to deal with the information asymmetries on prices. The same author points out that there will always be agents who will benefit themselves from this condition, and he also highlights the lack of a suitable method for the compensation of the quality of the root; which explains the resistance toward the changes in the industry and justifies the absence of vertical integration, given the high dependence among the agricultural and processing sectors.

3. Theoretical Framework

It is not identified in the literature a consensus on what would be the most suitable quantitative model for the study of market power and, due to the difficulty of obtaining data in Brazil, the analyzes of the economy performance based on the Lerner index, as observed in international studies, become more difficult. National literature seeks to use methods that require minimal data, and easier to apply, as in the case of the price series. (AGUIAR; FIGUEIREDO, 2011; PITELLI, 2008). Thus, the method that was used in this present study will be the study of prices asymmetry, which proposes to detect the market
power among the producing regions of cassava starch and among the levels of producers' market of root and starch.

The importance of studying the prices asymmetry can be justified on two issues: the first relates to the fact that it fills gaps in the product literature as well as to identify which sector holds the market power (and influence prices). The second has implications and basis for policy decisions. Once assumed that the asymmetric price transmission is caused by the market power, the empirical evidences of asymmetry are often used to justify the state intervention. The main causes of the asymmetric price transmission are the presence of imperfect competition and the adjustment costs. Other causes may also be highlighted, as political intervention and asymmetric information. (Meyer, von CRAMON-TAUBADEL, 2004).

Aguiar (2011) stated that studies on price transmission among markets are widely discussed both in Brazil and in several parts of the world and the results differ according to the evaluated product, the period of analysis, the place and the method used. The explanations about the presence or absence of asymmetry in the price transmission process also vary according to the approach. The author defines as asymmetric the price transmission when price increases are transmitted unlike decreases. This difference occurs both in terms of intensity and in terms of speed, dividing the asymmetry in two dimensions: from the total elasticity and the short term elasticity. The total elasticity shows the asymmetries after a complete market adjustment; since the elasticity of short-term indicates whether the transmissions of increases may define not only the decreases in intensity but also in the terms of the transmit period.

Meyer and Von Cramon-Taubadel (2004) classified the asymmetric transmission prices according to three criteria. The first refers to the speed or magnitude of the asymmetric transmission; the second criterion, the classification of asymmetric transmission prices as positive or negative. Thus, if the output price reacts more rapidly with the increases in the prices than their respective falls, the asymmetry is regarded as positive, and otherwise it will be a negative one. Finally, the third criterion refers to the asymmetric transmission of prices among market levels (vertical) and among spatially separated markets (spatial). This study will address only the spatial asymmetries.
As Balcombe, Bailey and Brooks (2007), in the economic literature often is found a relationship among the prices of similar goods in spatially markets or vertically separated as a concept associated with the Law of One Price\(^1\) (SPL) and as a sign of competition and economic efficiency. The observation of relative prices can point oligopoly, collusion and cartel behavior. Inserted in this context, innumerous studies proposing to evaluate the spatial integration of markets and to measure the degree of transmission of shocks from one market on others spatially separated have been developed.

Pierce, Trebilcock, and Thomas (2006) pointed out that in integrated markets increases competition and improve profitability by creating incentives for achieving the best investments in the generation and in the transmission assets. Therefore, good market integration tends to potentially improve their performance in various ways, so that an increase in the market integration minimizes the market power and increases their competitive relationships. Meyer and von Cramon-Taubadel (2004) stated that the theory of prices is one of the foundations of the neoclassical school. Inserted in this context, the price flexibility is responsible for efficient resource allocation and the price transmission between vertically and horizontally integrated markets. Thus, when studying the efficiency of markets, it is investigated the process of price transmission.

According to Meyer (2004), the economists often use the integration among the markets, defining the degree of price transmission among them as a proxy of market efficiency. For this, it is necessary to use empirical methods that can answer questions about such integrations. The authors pointed out that econometric analysis on marketing interactions are becoming increasingly popular.

Fackler and Goodwin (2001) pointed out that in the literature, for sure, complete definition of market integration is not identified, and thus they indicated the proposition that the integration can be measured by the degree to which supply and demand shocks from one region are transmitted to another. The authors measured the expectation of the ratio of price transmission by the following formula:

\[ \text{Price Transmission} = \frac{\text{Price in Region A}}{\text{Price in Region B}} \]

\(^1\) The more perfect a market is, there will be a strong tendency for the same price that will be paid for the product and at the same time, and in all parts of the market. (Marshall, 1980). Thus, in the absence of transaction costs, the regional markets with the same trade submit a single price.
\[ R_{AB} = \frac{\varphi_{PB}/\varphi_{A}}{\varphi_{PA}/\varphi_{A}} \]  

where \( R_{AB} \) is the ratio of price transmission associated with a hypothetical shock \( \varepsilon_A \) amending the excess of demanding for a good in a region A, but not in B. Thus, perfectly integrated markets will show a price transmission ratio equal to one \( (R_{AB} = 1) \) and to a lower value as 1 their interactions among markets are smaller. The authors emphasized that these relationships may not be symmetric, i.e., it is possible for a region to be more integrated with other regions, than that with the first \( (R_{AB} \neq R_{BA}) \).

According to Balcombe, Bailey and Brooks (2007), the mechanism which maintains the SPL relationship is the space arbitration. Therefore, when prices of homogeneous products differentiate into two markets, then, in the absence of transportation costs, the arbitrators will shift part of the overproduction of a market to a scarcer one, where the product price will be higher, and such behavior will continue until the SPL is established. The authors pointed out that asymmetry in adjustments, lower transmission prices and deviations from SPL are justified by transportation or transaction costs\(^2\), protectionism, market barriers or some other form of imperfect competition.

Fackler and Goodwin (2001) complement this idea by claiming that there will only be arbitration when the difference in prices among the homogeneous product markets does not exceed the cost of moving the good from the region with lower prices to another with higher prices, as can be seen in the following equation:

\[ P_i - P_j \leq r_{ij} \]  

where \( r_{ij} \) represents the cost of moving the good from the market \( i \) to \( j \), and includes all relevant costs to transact among spatially separated regions. Mattos, Lima and Lily (2009) identified no consensus in the literature about the terminology of \( r_{ij} \) and they highlighted three most commonly used terms: transport costs, transfer costs and transaction costs, and the most used is the transaction cost.

Some studies confuse the transaction costs when analyzing them as the transaction costs as outlined by the New Institutional Economics. It is understood that transaction costs are related to all costs to transfer product from one market to another, plus shipping. The authors indicate no relationship with transaction costs as proposed by Williamson. Therefore, in order to better understand it, the concept will be more detailed subsequently.

\(^2\) In the literature on the integration of markets, it is not identify a consensus about the real meaning of the transaction costs. In the study of Balcombe, Bailey and Brooks (2007), the transaction costs are related to all costs to transfer product from one market to another, plus shipping. The authors indicate no relationship with transaction costs as proposed by Williamson. Therefore, in order to better understand it, the concept will be more detailed subsequently.
costs, addressed, for example, in Williamson (1985), can compose some of the costs $r_{ij}$ of equation 2. To contain this kind of problem from now on it will be used in this study, the term "transfer cost" which according to the definition of Barrett (2001), can be expressed as:

$$r_{ij} = f_{ij}(q_{ij}) + v_{ij}(p_{j}(2) - p_i - q_{ij} - z) + d_{ij}(p_{j} - p_i - q_{ij}) + \theta_{ij}$$

(3)

where $r_{ij}$ is the transfer cost of the equation 2, $f_{ij}$ are transportation costs (freight), $v_{ij}$ represents the variable cost related to insecurity, financing, hedging, contracts and the technical barriers to trade (health standards), $z$ is an exogenous vector of the components of cost (fees), $d_{ij}$ is the average taxes paid by the product and $\theta_{ij}$ captures unmeasured transaction costs such as the opportunity cost of the entrepreneur, costs for research and the risk premium associated to a bankruptcy contract or the variability in the exchange rate.

It is noteworthy that, over time, some studies of analysis about the prices transmission based on Granger causality and in cointegration models began to be criticized for neglecting the importance of transaction costs. Thus, Barrett (2001) states that, by ignoring the transfer costs ($r_{ij}$) in a regression of prices, these become a part of the error term. Therefore, the estimated parameters become biased and inconsistent and do not reflect the actual relationship among the markets.

So, it is expected that with the estimation of the price model and econometric tests, is possible to verify the spatial efficiency of cassava starch market and thus to identify possible relationships of market power among the addressed regions as well as the levels of producer and wholesale market

4. Materials and Methods

The empirical application of spatial analysis of the starch market power in its main producing regions of Brazil, began with the tests of the stationarity of the series to identify the orders of integration, followed by the cointegration. As long-term relationships were identified, we sought to adopt the best method to achieve the central objective of the study. The used tests and the estimated model will be detailed in the next topics.
4.1. Testing For Determination Of Integration Order

Harris and Sollis (2003) pointed out that there are several ways to test the presence of unit root, one of them is the Dickey-Fuller methodology (DF), proposed by Dickey and Fuller (1979) to test the null hypothesis that the series have unitary root, i.e., they are nonstationary. As authors, there are still other tests of the same null hypothesis as the Durbin-Watson test and the nonparametric test developed by Phillips and Perron, based on the Z test of Phillips (1987). The most popular is the ADF test due to its simplicity and more general nature. There are other tests which aim to test the null hypothesis that the series are stationary against the alternative hypothesis of nonstationarity assumption, as is the case of Kwiatkowski, Phillips, Schmidt and Shin test (1992) also known as KPSS.

According to Enders (2004), Dickey and Fuller test (1979) considers three different equations that can be used to test the presence of a unit root

\[ \Delta y_t = \gamma y_{t-1} + \epsilon_t \]  \hspace{1cm} (4)
\[ \Delta y_t = \alpha_0 + \gamma y_{t-1} + \epsilon_t \]  \hspace{1cm} (5)
\[ \Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \epsilon_t \]  \hspace{1cm} (6)

Enders (2004) states that the methodology of Augmented Dikey-Fuller test (ADF) consists in adding and subtracting \( \alpha_p y_{t-p+1} \), where \( p \) is the number of fundamental lags to make the uncorrelated error, until:

\[ y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \alpha_3 y_{t-3} + \cdots + \alpha_{p-2} y_{t-p+2} + (\alpha_{p-1} + \alpha_p) y_{t-p+1} - \alpha_p \Delta y_{t-p+1} + \epsilon_t \]  \hspace{1cm} (7)

Subsequently it is subtracted and added \( (\alpha_{p-1} - \alpha_p) y_{t-p+2} \) to obtain the following representation:

\[ \Delta y_t = \alpha_0 + \gamma y_{t-1} + \sum_{i=2}^{p} \beta_i \Delta y_{t-i+1} + \epsilon_t \]  \hspace{1cm} (8)

where

\[ \gamma = -(1 - \sum_{i=1}^{p} \alpha_i) \]  \hspace{1cm} (9)
and
\[ \beta_i = \sum_{j=1}^{p} \alpha_j \]  \hspace{1cm} (10)

The ADF test has the same hypothesis of the DF one using the same statistics of Dikey-Fuller table. Therefore, if the sum of coefficients of the differential equation is equal
to one, at least one characteristic root is unitary, if $\sum \alpha_j = 1, \gamma = 0$ and the system has a unit root.

According to Gurajati (2006), Phillips and Perron (1988) (PP) used nonparametric statistical methods to test the serial correlation in the error terms without adding lagged difference terms; and its asymptotic distribution is the same as the statistics of Augmented Dickey-Fuller test. In accordance with Aguiar and Figueiredo (2010), the PP method estimates the equation unexpanded from the Dickey Fuller test and modify the ratio \( t \) of the coefficient \( \alpha \) so that the serial correlation does not affect the asymptotic distribution of the test.

Thus, as stated by Enders (2004), Phillips and Peron (1988) developed a generalization of the DF model with the relaxation of assumptions about the error distribution. The author explains briefly the model as follows:

\[
y_t = \alpha_0^* + \alpha_1^* y_{t-1} + \mu_t
\]  \hspace{1cm} (11)

and

\[
y_t = \bar{\alpha}_0 + \bar{\alpha}_1 y_{t-1} + \bar{\alpha}_2 (t - T/2) + \mu_t
\]  \hspace{1cm} (12)

where \( T \) is the number of observations and \( \mu_t \) the error term, whose expected value is equal to zero, however, with a heterogeneous and autocorrelated distribution. So, unlike the DF test which assumes the independence and homogeneity the PP test allows weakly dependent errors and heteroscedastic distributed.

Until then, the unit root test presented as a null hypothesis the presence of a unit root, but Denis Kwiatkowski, Peter C.B. Phillips, Bert Schmidt and Yongcheol Shin presented a new representation for the unit root test, which became known by the initials of the authors (KPSS), and how the null hypothesis of the stationarity series encloses the deterministic trend. Kwiatkowski et al. (1992) presented the test with the decomposition of the dependent variable in function of the deterministic trend \( (t) \), a random walk \( (r_t) \), and a stationary error \( (\varepsilon_t) \):

\[
y_t = \xi t + r_t + \varepsilon_t
\]  \hspace{1cm} (13)

where \( r_t \) is a random walk:

\[
r_t = r_{t-1} + \mu_t
\]  \hspace{1cm} (14)
In that case, $\mu_t$ shows an average of zero and constant variance. The hypothesis of stationarity lies in $\sigma^2 = \sigma^2$, since the $\varepsilon_t$ error term is stationary. Starting from the assumption that the first term of the $r_t(=0)$ random walk is fixed, the series would be stationary around a trend, yet if $\xi=0$ the $y$ variable would be stationary around a constant $(r_0)$. To verify the hypothesis that $\sigma^2 = 0$, the authors considered that $\varepsilon_t$, $t=1, 2,...,T$ is the regression residuals of $y$ in function of the intercept and of a time trend and, in this case, the errors partial sum would be given by:

$$S_t = \sum_{i=1}^{T} e_i, \quad t = 1, 2, ..., T.$$  \hfill (15)

and a long-term variance defined as

$$\sigma^2 = \lim_{T \to \infty} T^{-1} E(S_T^2)$$  \hfill (16)

According to the authors, an efficient estimator of $\sigma^2$ would be $s^2(l)$ which is constructed by the $e_t$ residues and has the following form:

$$s^2(l) = T^{-1} \sum_{t=1}^{T} e_t^2 + 2T^{-1} \sum_{s=1}^{l} w(s, l) \sum_{t=s+1}^{T} e_t e_{t-s}$$  \hfill (17)

The test statistical begins as the sum of normalized errors for $T^2$:

$$\eta = T^{-2} \sum S_T^2$$  \hfill (18)

subsequently by dividing $\eta$ for a consistent estimation of $\sigma^2$ and thus, resulting the final statistic test:

$$KPSS = \frac{T^{-2} \sum S_T^2}{s^2(l)}$$  \hfill (19)

4.2. Cointegration Test

As Greene (2003), some macroeconomic empirical studies, most often, involve nonstationary variables and with trend, thus, the proper way of working with them is using the differentiation method or other mechanisms of differentiation, in other words, turning them into stationary and applying the VAR method, or Box and Jenkins. In recent studies, there is already a more appropriate way to analyze the behavior of the variables, assuming that the disturbances are stationary and the white noise, however, such behavior is seen only when the dependent variable is cointegrated with the explanatory. To verify the existence of cointegration, the present study used the approach of Johansen (1988), but there is also another approach to this test, the Engle and Granger (1987).
According to Harris and Sollis (2004), the Johansen technique (1988, 1995) is essential to the estimation models for time series, an implication of nonstationarity among variables can lead to spurious regressions step, unless there is a vector of cointegration, which makes the test a mandatory procedure. The authors present the model as follows:

$$z_t = A_1 z_{t-1} + \cdots + A_k z_{t-k} + u_t \quad u_t \sim IN(0, \Sigma) \quad (20)$$

Where $$z_t$$ is the vector $$(n \times 1)$$ of $$n$$ potential endogenous variables and each $$A_i$$ is a matrix of parameters $$(n \times n)$$, this being the type of VAR model which will be shown later, when rewriting the equation to the Model Error Correction (VECM) one comes in the following way:

$$\Delta z_t = \Gamma_1 \Delta z_{t-1} + \cdots + \Gamma_k \Delta z_{t-k+1} + \Pi z_{t-k} + u_t \quad (21)$$

Where $$\Gamma_i = -(I - A_1 - \cdots - A_i)$$ for $$i = 1, \ldots, k - 1$$ and $$\Pi = -(I - A_1 - \cdots - A_k)$$. In this case, it is assumed that the $$z_t$$ vector is nonstationary I (1) and I (0) at first difference, that $$\Pi z_{t-k}$$ must be stationary and the $$u_t$$ I(0) error term and white noise. Thus, if the rank of $$\Pi$$ matrix is null the model will not present cointegration vectors.

Harris and Sollis (2004) pointed out that there are three situations to the condition that $$\Pi z_{t-k} \sim I (0)$$ is to be identified. The first is when all the $$z_t$$ variables are stationary, in this case, it will not have the problem of spurious regressions and the best modeling strategy is to estimate the standard VAR model in level. The second scenario is when there is no cointegration, not implying any linear combination of $$z_t$$, consequently, the matrix $$\Pi$$ is null, due to the front specification the VAR model will be the most appropriate in first difference without involving long term element. In the third form, $$\Pi z_{t-k}$$ will be I(0) and there will be cointegration relationships up to n-1, in this case the VECM model will be the most appropriate. If $$\Pi$$ matrix has a full rank, that is, when $$r = n$$, then the rank of the matrix will be zero, in which case the most appropriate model is the VAR in level.

As proposed by Johansen model (1988, 1995), the number of characteristic roots ($$\lambda$$) different from zero in $$\Pi$$ matrix, which correspond to the number of cointegration vectors ($$r$$) may be identified by the trace and maximum eigenvalue tests, which are respectively specified as follows:

$$\lambda_{trace} = -T \sum_{i=r+1}^{k} \ln(1 - \hat{\lambda}_i) \quad (22)$$

$$\lambda_{max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (23)$$
where \( T \) is the number of observations and \( \lambda_i \) the \( i^{th} \) characteristic root of \( \Pi \). The trace statistics tests the null hypothesis that the number of cointegration vectors should be less or equal to \( r \) and the farther from zero were the values of \( \lambda_i \), the higher will be the statistic value. The max null hypothesis tests the number of cointegration vectors which are \( r \) and the alternative hypothesis of \( r+1 \).

### 4.3. Vector Autoregression Models (Var) and Vector Error Correction Models (VECM)

Judge et al. (1988) showed that, in a model composed of endogenous variables, it is possible to use the feature of simultaneous equations to specify the intertemporal relationships and the dynamics of these variables. At times it is possible to include more than one lag for each model variable, coming to the following reduced form:

\[
y_t = \nu + \Theta_1 y_{t-1} + \ldots + \Theta_p y_{t-p} + v_t
\]  

(24)

Where for a model with two variables \( c_t \) and \( y_t \), we have:

\[
y_t = \begin{bmatrix} c_t \\ y_t \end{bmatrix}, \quad v = \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}, \quad \Theta_i = \begin{bmatrix} \theta_i \\ \psi_i \\ \delta_i \end{bmatrix}, \quad e = \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix}
\]

(25)

According to authors, the relationship exhibited in (24) is very close to the Autoregression Traditional model (AR) added to a \( \nu \) vector of intercept. Thus, when the vectors of \( y_t \) variables are related to the \( y_{t-1}, y_{t-2}, \ldots \) lagged vectors there is a Vector Autoregression Model (VAR) of \( p \) order.

When the system has \( M \) variables, the specification is as follows:

\[
y_t = (y_{1t}, \ldots, y_{Mt})' = (v_t, \ldots, v_M)' \Theta_i = \begin{bmatrix} \theta_{11,i} & \ldots & \theta_{1M,i} \\ \vdots & \ddots & \vdots \\ \theta_{M1,i} & \ldots & \theta_{MM,i} \end{bmatrix} \text{ and the error vector } v_t = (v_{1t}, \ldots, v_{Mt})' v_t \sim \text{IN}(0, \Sigma)
\]

In this case, the errors have the same stochastic properties of the AR model \( (v_t \sim \text{IN}(0, \Sigma)) \), i.e., white noise.

According to Harris (1995), the VAR model has become more notorious by Sims (1980) with a dynamic way of estimating the joint relationships of endogenous variables without imposing restrictions. Harris (1995) highlighted that when reformulating the equation (24) one arrives at the Vector Error Correction Model (VECM).
\[
\Delta y_t = v + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + \Pi y_{t-p} + v_t
\]  
(26)

where \( \Gamma_i = -(I - \Theta_i - \cdots - \Theta_i), (i = 1, \ldots, p - 1) \) and \( \Pi = -(I - \Theta_1 - \cdots - \Theta_p) \). This form of specification provides information on the short and long-term adjustments of \( y_t \) changes, through estimates of \( \Gamma_i \) and \( \Pi \), respectively. Harris (1995), by defining \( \Pi = \alpha \beta' \), stated that \( \alpha \) represents the speed of adjustment of short-term imbalances and \( \beta \) the coefficient matrix of long-term, such that the \( \beta' y_{t-p} \) term indicates the number of cointegrations relationships in a multivariate model, ensuring that \( y_t \) converges to its steady state in the long run.

4.4. The model of price transmission among Regions

The methodology adopted for testing the hypothesis of price transmission among regions was sustained on the model mentioned by Goodwin (2001). As the author, in studies on the interaction between spatially separated markets prices should not be omitted the transfers\(^3\) costs, which means that these markets are linked by a spatial arbitrage. The basic form of the regression among the relations proposed price Goodwin (2001) is expressed as:

\[
P_t^1 = \alpha + P_t^2
\]  
(27)

where \( P_t^i \) is the product prices in the \( i \) region in the \( t \) period and the \( \alpha \) parameter represents the transfers costs. The author highlights that this relationship is flawed since the exchange flows among the markets are not continuous which becomes impossible that the differences in expected prices were equal to the transport costs. Thus, it is up to the inequality equation:

\[
P_t^1 \leq \alpha + P_t^2
\]  
(28)

Silva and Margarido (2009) pointed out that in this case the prices can differ only in the short term, because the actions of the arbitrageurs tend to balance the long-term prices leading to an equality of transaction costs. Therefore, for long-term analysis, the initial equation is valid.

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\(^3\) Concept defined by Barret (2001) in the theoretical framework.
In this way, Silva and Margarido (2009) presented a model in the logarithmic form, where the product prices in a specified region are function of the prices of the same good in another region added an error term:

\[ p_t^1 = \alpha + \beta p_t^2 \]  \hspace{1cm} (29)

In that case, the \( \alpha \) parameter behaves as the error term for capturing the deviations among the prices, it soon becomes necessary that \( \alpha \sim \text{iid} (\mu, \sigma^2) \) and \( \mathbb{E}[p_t^2, \alpha] = 0 \). For the same authors the \( \beta \) coefficient will present value to 1 under the hypothesis of perfect integration among the markets, confirming the Law of One Price. The parameter can also be considered as the elasticity of price transmission in the region 1. However, the null value of \( \beta \) shows that the markets do not have relationships in the product prices, where both regions would be completely closed. In cases where \( \beta \) results in values between zero and one, some kind of restriction is imposed on the market.

5. Data and Results

5.1. Source and Nature of Data

The data were provided by CEPEA-ESALQ in their monthly averages, in the period from February 2002 to February 2013, totaling 133 observations. The prices have been fixed for February 2013 by Índice Geral de Preços Disponibilidade Interna - IGP-DI / FGV (General Price Index Domestic) for behavioral (descriptive) prices analysis. However, the results exploited in the research are related to the nominal series only, since the actual data lead to increased autocorrelation and reduce the explanatory power of the model. We also emphasize that in some of the studies reviewed we did not identify treatments for the correction of inflation, as is the case of Balcombe, Bailey and Brooks (2007), Azevedo and Politi (2008), Souza and Campos (2008) and Silva and Margarido (2009).

The database constitutes six variables divided into six distinct regions located in the Midwest, Southeast and South. The series were worked with their values in natural logarithm (ln), to submit a near normal distribution and for elasticities analysis. In this
study, we chose the period according to the availability of data for the analyzed markets, and the regions according to their representation in the Brazilian production.

Note that the seasonal behaviors of the series have been corrected. According to Hoffmann (2006), there are many causes for the variability in the prices of agricultural products, and these are related to the duration of the considered period. The long-term variations are induced by the currency devaluations, the population growth, the urbanization, the technological development, the variations in per capita income and income distribution, in the tastes and the customs. The short-term variations are bounded by the seasonality of production, by crop losses due to weather conditions and the incidence of pests or diseases etc.

Such application has become necessary due to the production of cassava root being fully connected to climatic impact behavior and the incidence of pests. The correction method was the X12-ARIMA Version 0.2.7 developed by US Census Bureau (2011).

Firstly, a descriptive analysis of the data was realized with the purpose of understanding the series. As shown as in Table 1, the region with the highest average price was Paranaense Midwest (R$ 1,428.76/t), and the one with lowest price was Paranaense Northwest (R$ 1,376.73/t). The top price of cassava starch was identified in the South of Mato Grosso do Sul region (R$ 3,182.76/t) and the least in Southeast Mato Grosso do Sul region. This difference between the maximum and minimum prices was approximately R$ 2,474.18/t (a gap of 77.74%). Comparing the contrast between the maximum and minimum prices in each analyzed regions the gap was about 74.58% in mean. Therefore, these performances confirm the elevated starch price variability. Also, high standard deviations were identified, having Far South of Mato Grosso do Sul pointed the top one, and Paranaense Northwest the lower one.

The price time series, according to Graph 1, reported similar prices behavior to the regions (even increases and decreases). Thereby it’s possible to infer that the regions prices are correlated, suggesting a possible causality relation between them. It should be noticed that this graphical analysis confirmed the unstable behavior of the prices.
5.2. Results

For the analysis of price transmission model among the regions, it becomes necessary to identify the pricing center. Many studies use as a pricing center the region with the highest production. In the present study the Paranaense Northwest, which in 2012 produced about 42% of the national total is taking as pricing center.

Another way of detection is by Base Price Theory. As stated by Mattos (2008) that interconnected markets establish and maintain a non-competitive pricing system, usually, in the form of organized oligopoly. In this case, the base price is defined in a specific market (base market) and the price paid by buyers from other regions arises from the sum of the base price plus the costs that incurred to transfer the merchandise from the base market to the final destination. It means, businesses located in other regions take price from the base market and add transportation costs until they get their prices. Thus, as the base price changes, in other interconnected markets they will also change. Adding the Base Price Theory and the Law of One Price, you arrive at the consensus that the differences in prices, except for transfer costs, will be eliminated over time through the spatial arbitrage.

In the Base Price Theory, it is expected that the price is set at the central market, while others markets, that are far from it, will have a higher final prices. Thus, the lowest price must, necessarily, take place in the base market and the highest at the distal region thereof. In order to verify this relationship, it is suggested that the base market is the Paranaense Northwest, due to the highest production and the lowest average price for starch.

To assume that the more distant region is from the base market, the more will be their prices, we tried to measure the distances of each in relation to the Paranaense Northwest. The results are shown in Board 1.

The region with the highest average price for starch was the Paranaense Midwest, followed by the Paranaense Far West, Assis, and the Southeast and the Far South from Mato Grosso do Sul. Analyzing the physical distances of each in relation to the base market the farthest region is the Paranaense Far West, then the region of Assis, the Far South from Mato Grosso do Sul, the Southeast from Mato Grosso do Sul and, finally, the Paranaense

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4 Understood in this study as transfer cost.
Midwest. Therefore, with the exception of the Paranaense Midwest, the regions exhibit increases in the average prices as they get farther from the base market.

As the descriptive analysis of the data signaled possible relationship among the markets it becomes necessary to identify the long-term relationships among them. However, to this end, the series stationarity tests are applied.

The Table 2 presents the results of the Augmented Dickey-Fuller and Phillips-Perron for detecting the unit roots, in their specifications for the addressed series: full model, without trend and without trend and intercept.

The analysis of Table 2 for Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, pointed out that the series are nonstationary in levels but stationary in the first differences. It means that they are integrated of order 1, i.e. $I(1)$. However, the ADF test showed that the series from the Paranaense Midwest with seasonal correction is not stationary in the first difference in the complete model. Therefore, to complete the obtained results we opted for the KPSS test, whose methodology differs from the previous ones. The Table 3 shows the results of KPSS tests probabilities.

The KPSS test rejected the null hypothesis that the series are stationary in level and did not reject the null hypothesis of stationarity for the series in the first difference, including for the prices of the Paranaense Midwest region. Therefore, the tests allow us to conclude that the series are stationary in the first difference. After identifying the order of integration of the variables the cointegration test was realized, in order to find the pricing region. The Table 4 presents the results of the Johansen cointegration test and their applicability: Trace and $\lambda$ maximum.

The values obtained for the Trace and $\lambda$ maximum statistics rejected the null hypothesis of no cointegration, indicating more than four cointegrations to the trace statistics, and five cointegrations for the $\lambda$ maximum statistic. For the regions cointegrated themselves in the long run (belong to the same market) it is necessary to find the number of cointegration equal to the number of variables minus one, i.e., the exact number of five cointegrations confirmed by the statistics. It is noteworthy that for both the model with

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5 We chose not run causality test before asymmetry tests, as in the baseline Silva and Margarido (2009) study.
seasonal adjustment and without seasonal adjustments, the results were the same. Therefore, it is evident that the cointegration is not due to seasonal cycles.

As noticed in Table 4 all the squares must belong to the same market and follow the same direction in price formation, i.e., there is a tendency that governs the behavior of prices in all regions analyzed over time. Adopting the Base Price Theory and the Law of One Price hypothesis it is assumed that this trend is governed by the price of the base market.

After detection of the integration order we go to identify the long-term behavior among the regions. For this purpose we used the Johansen test in its tracks of Trace and \( \lambda \) max, in order to get better models specifications. These were tested for the specification where there is an intercept in the Vector Error Correction Model and an implied constant in the Error Correction Term (1) and the specification where there is an intercept in the VECM and a linear trend in the Error Correction Term (2). The results are shown in the Table 5.

The Trace and \( \lambda \) maximum statistics for the model (1) rejected the null hypothesis of no cointegration, pointing to a cointegration relationship for the Trace statistic and another in favor of no cointegration for the \( \lambda \) maximum statistics and the specification with (2) showed the same results. However, it was not possible to reject the null hypothesis of a cointegration in favor of two for both statistics.

Aiming to find the best specification it was tested the both cases by means of Akaike and Schwarz's Criterion. The results showed that the model (1)\(^6\) would be statistically the most appropriated, it made possible long-term analysis among the series via the Vector Error Correction Model (VECM). The Table 6 presents the coefficients estimated for short and long-term to the relationships among the Paranaense Northwest region and the other regions.

Estimates of long-run parameters of the VECM model indicated that changes in the prices of cassava starch in the Paranaense Northwest are transferred less than proportionally, around 95% for all regions in both series, with the exception of the Southeast of the Mato Grosso do Sul, where the transfers are more than proportionals. Such

\( ^6 \) Where there is an intercept in the Vector Error Correction Model and an implied constant in the Term Error Correction.
transmission relations denoted an inelastic relationship, in which the pricing of starch in covered regions are strongly influenced by the changes in the starch prices in the Paranaense Northwest, confirming what was expected.

As for short-term behavior, the relationship between the Paranaense Northwest and the Paranaense Midwest indicated that short-term imbalances tend to be corrected with an adjustment speed of 73.38% in each period for the Paranaense Midwest and of 14.12% for the Paranaense Northwest, pointing out that the imbalances would be eliminated slowly in the last place.

In the Far West Parana region, the adjustment speed of transitional imbalances in the price of starch was 65.48% while for the base market was 11.07%. For the Assis region its adjust speed was 66.24% and the base market was 25.59%. The regions belonging to the Mato Grosso do Sul showed high speeds both on the secondary market as the pricing market.

Thus, the behaviors highlighted that in the short-term the imbalances would be eliminated more quickly in the secondary markets than in the base market. In order to test the Law of One Price and the degree of interaction among the markets, a long-term restriction was imposed making the β parameters of both variables equal to 1. The results are shown in the Table 7.

The imposition of restrictions on the coefficients, as shown in the Table 7, showed changes in both adjustment speed in the base market and in the secondary markets. For the relationships between the Paranaense Northwest and the Southeast of the Mato Grosso do Sul the values of both speeds were reduced. The adjustment speed of transitional imbalances in the starch price of the base market is reduced and the secondary market rose in relation to the Far West Paranaense. In the other relationships, there was an increase in the adjustment speed for all the markets. Thus, the increases in short-term coefficients of the Paranaense Northwest reinforced the dynamic behavior of the market.

To confirm if the impositions of restrictions were significant and if the Law of One Price is applicable to explain the interactions among the markets, it is necessary to test statistically through the $\chi^2$ test the constraint that β assumes a value equal to 1 to the base market ($\beta_{11} = \beta_{21} = 1$). The results can be seen in the Table 8.
The results in the Table 8 show that the probabilities of committing a Type I error were high for the relationships with the Far South of the Mato Grosso do Sul (51%) and the Central West of Paraná (45%) and in lower intensities with the Southeast of the Mato Grosso do Sul (24%). For the other regions, it was not possible to reject the null hypothesis that the restricted parameters are not significant ($\beta_{11} \neq \beta_{21} \neq 1$) in both series specifications. Therefore, to the regions of the Far West Paranaense and Assis the Law of One Price was proven, in a way that the long-term variations in the base market prices (Paranaense Northwest) are fully transferred to the same ones confirming the interaction among these markets.

6. Conclusion

The present study aimed to analyze the asymmetric transmission in the starch prices, addressing the main Brazilian regions, seeking to identify what region holds the greater market power. Specifically we sought to verify their long-term relationships and possible asymmetries in price transmission for the major producing regions of Brazil.

As Johansen methodology, the Trace and $\lambda$ max statistics showed that the variables in the long run cointegrated themselves for the addressed series, establishing as the best methodology for analyzing the Vector Error Correction Model (VECM). The estimates of long-run parameters of the VECM model showed that the changes in the prices of cassava starch in the Paranaense Northwest were transferred less than proportionally, except for the Southeast of the Mato Grosso do Sul, denoting an inelastic relationship among its peers. Thus, the determination of starch prices in the covered regions would be influenced by the changes in the starch prices in the Paranaense Northwest, confirming what was expected. The speeds in the short-term adjustments highlighted that the imbalances dissipated faster in the secondary market for all the relationships.

In order to test the Law of One Price and the degree of interaction among the markets, it was imposed a long-term restriction making the $\beta$ parameters of both variables

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7 Rejecting the null hypothesis that the coefficients of the restricted parameters are not jointly significant, when they are different of one, when in fact they are so.
equal to one. The imposition of restrictions on the coefficients indicated that for most of the relationships tested the adjustments speeds rose in both markets, reinforcing the dynamic behavior of the market.

The result showed that for the Far West Paranaense the Law of One Price is valid, i.e., that the changes in the base market prices are fully transferred to the same ones confirming the interaction among the markets. Thus, we can conclude that mostly of the market peers showed no integration, indicating that the competitive market performance may be compromised, stimulating the market power.

Then, in the light of the results, this study concluded that the starch markets are not spatially integrated, since it can transmit the increases in prices unlikely the decreases, enunciating inefficiency competitive for the market in analysis. So another aspect is identified, aside from those mentioned in the introduction to the study, which commits the preference of cassava starch among other ones, indicating that some policies would be necessary to encourage cassava starch competitiveness.

REFERENCES


Table 1 – Descriptive Statistics

<table>
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<th>Assis Paranaense</th>
<th>Centro Oeste Paranaense</th>
<th>Extremo Oeste Paranaense</th>
<th>Noroeste Paranaense</th>
<th>Extremo Sul Mato Grossense do Sul</th>
<th>Sudeste Mato Grossense do Sul</th>
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<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
<td>133</td>
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</table>

Source: Research results.

Graph 1 – Graph of price behavior of the regions in Feb 2002 to Feb 2013


Source: Research results.
Map 1 – Cassava Starch Industrial Units in Brazil

Board 1 - Distances of the main municipalities of the addressed regions in relation to the Paranavaí municipality

<table>
<thead>
<tr>
<th>Regiões</th>
<th>Northwest Paranaense: Paranavaí region</th>
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</thead>
<tbody>
<tr>
<td>Center West Paranaense: Araruna region</td>
<td>149 km</td>
</tr>
<tr>
<td>Southeast Mato-grossense-do-sul: Ivinhema region</td>
<td>226 km</td>
</tr>
<tr>
<td>Far South Mato-grossense-do-sul: Naviraí region</td>
<td>229 km</td>
</tr>
<tr>
<td>Assis in São Paulo State: Assis region</td>
<td>293 km</td>
</tr>
<tr>
<td>Far West Paranaense: Marechal Cândido Rondon region</td>
<td>331 km</td>
</tr>
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</table>

Source: Google Maps (2012),

Table 2 – Augmented Dickey-Fuller and Phillips-Perron Unit Roots tests

<table>
<thead>
<tr>
<th>Variables</th>
<th>La</th>
<th></th>
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<th></th>
<th>PP</th>
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<td>τ</td>
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Table 3 - KPSS Unit Root Test for the Starch Prices

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<th>τµ</th>
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Primeira diferença

<table>
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<tr>
<th>Variables</th>
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τµ = 10%: 0,347 5% : 0,463 2,5%: 0,574 1% : 0,739 and ττ = 10%: 0,119 5% : 0,146 2,5%: 0,176 1% : 0,216; ns don’t reject the hull hypothesis of unit root with 1% significance and * reject the hull hypothesis of unit root with 1% significance, a Akaike and Schwartz Criterion, EOP: Far West of Paraná, COP: Center West of Paraná, NOP: Northwest of Paraná, ESM: Far South of Mato Grosso do Sul, SSM: Southeast of Mato Grosso do Sul ASS: São Paulo

Source: Research results.

Table 4 – Cointegration test to identify deterministic parameters

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<td>r &lt;= 5</td>
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<table>
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<tr>
<td>r &lt; = 3</td>
<td>r = 3 r = 4 31,3718*</td>
</tr>
<tr>
<td>r &lt; = 4</td>
<td>r = 4 r = 5 25,3093*</td>
</tr>
<tr>
<td>r &lt; = 5</td>
<td>r = 5 r = 6 3,7460ns</td>
</tr>
</tbody>
</table>

ns don’t reject the hull hypothesis of unit root with 1% significance and ** reject the hull hypothesis of unit root with 1% significance

Source: Research results.

Table 5 - Johansen test for cointegration among starch producing regions from the models with constant and linear trend for the series with and without seasonal adjustments

<table>
<thead>
<tr>
<th>Test - Northwest Paranaense and Far West Paranaense</th>
<th>λ Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consnt(1) Trace</td>
<td>λ Maximum</td>
</tr>
<tr>
<td>H0</td>
<td>H1</td>
</tr>
<tr>
<td>Trend(2) Trace</td>
<td>λ Maximum</td>
</tr>
<tr>
<td>H0</td>
<td>H1</td>
</tr>
</tbody>
</table>
Table 6 - Estimates of the short and long-term coefficients from the Vector Error Correction Model (VECM)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Short-run parameters estimated(α)</th>
<th>Long-run parameters estimated (β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>InF_Nop</td>
<td>-0.141233</td>
<td>0.984981</td>
</tr>
<tr>
<td></td>
<td>0.3536693</td>
<td>0.0113028</td>
</tr>
<tr>
<td>InF_Cop</td>
<td>-0.7338</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.3422172</td>
<td></td>
</tr>
<tr>
<td>InF_Nop</td>
<td>-0.1107716</td>
<td>-0.9413292</td>
</tr>
<tr>
<td></td>
<td>0.2074513</td>
<td>0.0198154</td>
</tr>
<tr>
<td>InF_Eop</td>
<td>-0.4454993</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1962772</td>
<td></td>
</tr>
<tr>
<td>InF_Nop</td>
<td>-0.4835721</td>
<td>-0.988905</td>
</tr>
<tr>
<td></td>
<td>0.2709714</td>
<td>0.0155887</td>
</tr>
<tr>
<td>InF_Esm</td>
<td>-0.8323794</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.2632134</td>
<td></td>
</tr>
</tbody>
</table>

* don’t reject the null hypothesis of unit root with 5% significance and ** reject the null hypothesis of unit root with 5% significance

Source: Research results.
### Table 7 - Estimates of the short and long-term coefficients from the Vector Error Correction Model (VECM) with restrictions

<table>
<thead>
<tr>
<th>Variables</th>
<th>Short-run parameters estimated (α)</th>
<th>Long-run parameters estimated (β)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln F_{Nop} )</td>
<td>0,079208 0,34282</td>
<td>-1 0,34282</td>
</tr>
<tr>
<td>( \ln F_{Cop} )</td>
<td>-0,51454 0,34282</td>
<td>1 0,34282</td>
</tr>
<tr>
<td>( \ln F_{Eop} )</td>
<td>0,127952 0,18293</td>
<td>-1 0,17628</td>
</tr>
<tr>
<td>( \ln F_{Esm} )</td>
<td>-0,41233 0,2784</td>
<td>1 0,27097</td>
</tr>
<tr>
<td>( \ln F_{Ssm} )</td>
<td>-0,40514 0,31686</td>
<td>-1 0,32833</td>
</tr>
<tr>
<td>( \ln F_{Ass} )</td>
<td>-0,04189 0,23435</td>
<td>1 0,21765</td>
</tr>
</tbody>
</table>

EOP: Far West of Paraná, COP: Center West of Paraná, NOP: Northwest of Paraná, ESM: Far South of Mato Grosso do Sul, SSM: Southeast of Mato Grosso do Sul, ASS: São Paulo

Source: Research results.

### Table 8 - Test of restriction significance on the long-term parameters of the cointegration vectors for the relations with the base market

<table>
<thead>
<tr>
<th>Variável</th>
<th>( \chi^2 )</th>
<th>Graus de liberdade</th>
<th>Valor da probabilidade</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln F_{Cop} )</td>
<td>1,355243</td>
<td>1</td>
<td>0,244364</td>
</tr>
<tr>
<td>( \ln F_{Eop} )</td>
<td>5,36165</td>
<td>1</td>
<td>0,020584</td>
</tr>
<tr>
<td>( \ln F_{Esm} )</td>
<td>0,421027</td>
<td>1</td>
<td>0,516425</td>
</tr>
<tr>
<td>( \ln F_{Ssm} )</td>
<td>0,559747</td>
<td>1</td>
<td>0,454362</td>
</tr>
<tr>
<td>( \ln F_{Ass} )</td>
<td>5,250342</td>
<td>1</td>
<td>0,021942</td>
</tr>
</tbody>
</table>

EOP: Far West of Paraná, COP: Center West of Paraná, NOP: Northwest of Paraná, ESM: Far South of Mato Grosso do Sul, SSM: Southeast of Mato Grosso do Sul, ASS: São Paulo

Source: Research results.