Price convergence in Brazilian corn and wheat markets[1]

Francisco José Silva Tabosa[2]
Pablo Urano Castelar[3]

Abstract – This paper aims to verify the integration of markets, price convergence and the estimation of the half-life of the two main products of the Brazilian agribusiness: corn and wheat. For this purpose, the methodology used in this study is based on works by Choi et al. (2006), Mohsin & Gilbert (2010), Chin & Habibullah (2008) and Ucak (2012). Panel data from several Brazilian markets for corn and wheat is used, covering the period from January 2000 to June 2018. The results show that, according to the LLC and IPS unit root tests, both for the cases of corn and wheat, there is integration between these markets, thus indicating a convergence between the price series. This result is similar to the conclusions reached by works such as Barros et al. (2014) and Tabosa et al. (2014).

Keywords: Brazil, half-life, market integration.

Convergência de preços nos mercados brasileiros de milho e trigo

Resumo – Este trabalho visa verificar a integração dos mercados, a convergência de preços e a estimativa da meia-vida dos dois principais produtos do agronegócio brasileiro: milho e trigo. A metodologia neste estudo baseia-se em obras de Choi et al. (2006), Mohsin & Gilbert (2010), Chin & Habibullah (2008) e Ucak (2012). São usados os dados do painel de vários mercados brasileiros de milho e trigo, abrangendo o período de janeiro de 2000 a junho de 2018. Os resultados mostram que, de acordo com os testes de raiz unitária LLC e IPS, tanto para o milho quanto para o trigo, há integração entre esses mercados, indicando assim convergência entre a série de preços. Esse resultado é semelhante às conclusões de Barros et al. (2014) e Tabosa et al. (2014).

Palavras-chave: Brasil, meia-vida, integração de mercados.

Introduction

Empirical studies have shown that the price of a product can vary considerably between countries, regions, cities of the same country, and even adjacent commercial centers and retail outlets. According to these works[4], the forces of competitive markets and market pricing information tend to ensure price convergence.

Academic literature concerning price convergence has mostly focused on regional studies of commodity prices. This is due to the great advantage of the analysis of relative prices between

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[2] Economista, professor do Departamento de Economia Agrícola da UFC e do Mestrado Acadêmico em Economia Rural (Maer/UFC), bolsista de produtividade da Funcap. E-mail: franzetabosa@ufc.br

[3] Economista, professor do curso de Finanças da UFC. E-mail: pcastelar@gmail.com

[4] For example: Chin & Habibullah (2008), Mohsin & Gilbert (2010), Ucak (2012) and Ghauri et al. (2013).

regions or cities in one country, as one has certain advantages in estimating Purchasing Power Parity (PPP), such as the absence of trade barriers and non-tradable goods in a single country.

This line of work is also present in agribusiness, for one can assess the time of price transmission between markets, visualizing the presence of integration between these respective markets. First, the degree of market integration is identified with the level of price differences between different markets. In this case, if these differences are large (in relative terms), then the market is poorly integrated; if, on the contrary, they are small, the market would then be integrated (Chin & Habibullah, 2008).

Secondly, agriculture has rarely received attention as a testing ground for the hypothesis of economic convergence. However, there is substantial interest from public policies at all levels (local, regional, national and international) on productivity convergence in agriculture (Alexiadis, 2010).

Thus, this work aims to verify the integration of markets, price convergence and the estimation of the half-life of the two main products of the Brazilian agribusiness: corn and wheat. For this purpose, the methodology used in this research is based on the works by Choi et al. (2006), Chin & Habibullah (2008), Mohsin & Gilbert (2010) and Ucak (2012). Panel data from several Brazilian markets for corn and wheat is used, covering the period from January 2000 to June 2018.

This work is divided into six sections, besides this introduction. The following section presents information regarding the Brazilian markets for corn and wheat. Then, a literature review concerning the integration and convergence in markets is featured. Section 4 discusses the methodology used in this work. Section 5 presents and comments the results obtained. Lastly, the concluding remarks are presented.

Brazilian corn and wheat market

In this section, data and overall information on the corn and wheat markets are presented, both for the international and Brazilian contexts.

Table 1 presents a ranking of the world's leading producers of corn in 2012. As can be seen, Brazil occupies the 4th place with a harvest of 62 million tons (7.2% of world production). The United States is the world's largest producer, with an output of 313,918 million tons, representing 36.3% of world production in 2012.

Table 1. World's leading producers of corn in 2012.

Ranking	Country	Production (in millions of tons)	%
1	United States	313,918	36.3
2	China	191,75	22.2
3	EU-27	64,524	7.5
4	**Brazil**	**62**	**7.2**
5	Ukraine	22,5	2.6
6	India	21,5	2.5
7	Argentina	21,5	2.5
8	Mexico	19	2.2
9	South Africa	11,5	1.3

Source: adapted from Abimilho (2014).

Corn has great relevance in the Brazilian agribusiness, since it supplies for both human consumption and animal feeding, where more than 68% is destined to supply poultry and pork, and only 1.44% for human consumption, according to the Brazilian Association of Corn Industries. It should be noted that due to its low market cost, transportation costs can considerably affect the remuneration of the output in distant regions of the points of consumption, reducing interest in the shift of production at greater distances or in conditions where the transportation logistics are unfavorable. These are some of the factors that explain the increased consumption of corn only in the domestic market, although it a significant increase in Brazilian exports of cereal is estimated for the second decade of the 2000s (Abimilho, 2014).

Table 2 presents the production in the major corn producing states in Brazil in 2012. It can be observed that the states of Paraná and Mato Grosso are the largest corn producers in Brazil, where both are responsible for 45.30% of national production. The states of Goiás (11.58%), Minas Gerais (10.73%), Mato Grosso do Sul (9.11%), São Paulo (6.30%), Rio Grande do Sul (4 44%) and Santa Catarina (4.04%) come next. These markets account for over 90% of national production.

Table 2. Main corn producing states in Brazil in 2012.

State	Quantity produced (in tonnes)	%
Paraná	16,555	23.29
Mato Grosso	15,646	22.01
Goiás	8,23	11.58
Minas Gerais	7,625	10.73
Mato Grosso do Sul	6,477	9.11
São Paulo	4,478	6.30
Rio Grande do Sul	3,155	4.44
Santa Catarina	2,87	4.04
Brazil	**71,073**	**100**

Source: adapted from IBGE (2014).

It should also be noted that this culture is especially produced in the South, Southeast and Midwest regions of Brazil, where corn is geared primarily to meet the needs of the domestic market, thus raising the hypothesis that markets tend to integrate (Tabosa et al., 2014).

The Brazilian wheat market has immense importance for the Brazilian economy, since Brazilian production is insufficient to meet domestic demand, due to particular climate conditions. Thus, as local demand has to resort to imports of grain (Margarido et al., 2006; Barros et al., 2014).

Table 3 presents a ranking of the largest producers of wheat in 2012. We can see that the EU is responsible for 20% of world production, followed by China, Russia, India and the United States. Brazil is the 12th largest producer, with an output of 6 million tons.

Table 3. Main producers of wheat in 2012.

Ranking	Country	Production (in millions de tons)	%
1	EU	133	20
2	China	118	18
3	Russia	89	13
4	India	91	14
5	USA	61	9
6	Canada	27	4
7	Pakistan	23	3
8	Australia	26	4
9	North Africa	17	3
10	Middle East	38	6
11	Argentina	12	2
12	**Brazil**	**5**	**1**
13	Others	27	4

Source: adapted from Safras & Mercados (2018).

Table 4 presents the main wheat producing states in Brazil in 2012. It can be observed that the states of Paraná and Rio Grande do Sul account for over 90% of national production. This implies that there is a high concentration of domestic production of wheat in these two states.

Literature review: integration and market convergence

In this section we present some international and national references, focusing on works related to the integration of markets and convergence of agricultural commodity prices.

Stigler & Sherwin (1985) approach the concept of the market as being a facilitating environment where buyers and sellers can make exchanges and that the comprehension of the rate of exchange is fundamental in understanding

Table 4. Main wheat producing states in Brazil in 2012.

State	Quantity produced (in tons)	%
Paraná	2,138	48.39
Rio Grande do Sul	1,866	42.24
Santa Catarina	139	3.14
São Paulo	122	2.76
Minas Gerais	80	1.81
Goiás	43	0.97
Mato Grosso do Sul	24	0.54
Distrito Federal	5	0.11
Brazil	**4,418**	**100**

Source: adapted from IBGE (2014).

the terms of such trade. As such, the existence of integrated markets leads to small fluctuations in their respective prices. Furthermore, the higher the levels of competition in markets, and the more the transport facilities, the better the flow of goods in a given market to another will be. The physical movement of goods, or even buyers, assert the authors, is a potential source of information on the geographic extent of a market and would, supposedly, play a fundamental role in explaining price uniformity between markets.

Balke & Fomby (1997) and Goodwin & Holt (1999) investigated the integration of markets through convergence tests between prices. If the prices of different markets are converging to the same level of long-term prices, then there is evidence that the market is integrated in the long run. Moreover, the existence of a conditional convergence implies price differences resulting from transaction costs, measured as the percentage of the price difference (Goldberg & Verboven, 2005).

According to Zhou et al. (2000), Park et al. (2002), Huang & Rozelle (2006), and Awokuse (2007) and Fan & Wei (2006), who carried out tests investigating the convergence of grain prices in China among 96 products, prices have converged to a "law of One Price "in China for an overwhelming majority of goods and services.

Solakoglu & Civan (2006), through unit root tests for panel data and the estimation of "beta" convergence, study the convergence of wheat prices in transition economies to world markets, with special emphasis on the effect of the perspective of becoming a member of the European Union. The results show that the countries of Central Europe were about twice as fast in terms of integration to world markets than the countries in the Commonwealth of Independent States.

Choi et al. (2006) present three complications for the panel data estimation of the half-life of Purchasing Power Parity: the polarization induced by the improper cross aggregation of coefficients, small sample bias estimation of dynamic latency coefficients and the induced polarization by adding time commodity prices. Using an annual set of panel data in real exchange rates based on the CPI for 21 OECD countries from 1973 to 1998, the authors obtained an estimate of the half-life point of approximately 3 years, with a 95% confidence interval of 2.3-4.2 years.

In this sense, Susanto et al. (2007), using the convergence model, test the integration of the fruit and vegetable market, including tomatoes, in the NAFTA countries (US, Canada and Mexico). The results reported by the authors are in favor of a process of absolute convergence, indicating an integration of the markets for the products analyzed.

Chin & Habibullah (2008) aimed to evaluate the integration of markets in Malaysia, looking at price convergence across Peninsular Malaysia, Sabah and Sarawak; through price convergence methodology and using Purchasing Power Parity (PPP), as well as unit root tests in panel data, the empirical evidence suggests that there is a convergence of prices in Malaysia, where there is an increase in the degree of market integration between Peninsular Malaysia, Sabah and Sarawak.

Alexiadis (2010) used convergence testing of agricultural productivity among 26 regions in the EU during the period of 1995 to 2004. The results showed a low convergence rate estimated

for the period 1995-2004, while the evidence of the existence of a convergence club is apparent. A similar study was developed by Ucak (2012), which examined the issue of price differences in the EU commodity markets and investigated the convergence of agricultural price disparities between Member States. The results show the existence of convergence of agricultural prices between EU member states since 1991, including even some countries which were not members of the EU.

Mohsin & Gilbert (2010) estimated a relative convergence of 35 Pakistani cities prices, as well as the half-life of price shocks, in the period of July 2001 to June 2008. The authors find that the average half-life of a price shock is of at least 5 months, but it varies from 1.3 to 6.8 months, in the case of individual cities.

Brazilian literature still lacks works using the price convergence methodology aimed at agribusiness. However, some relevant studies are mentioned below.

Cunha et al. (2013) analyzed the causality and the transmission of corn prices for a municipality of the state of Goiás and cereal prices on the Bovespa. The authors use the Threshold Autoregressive Model (TAR) to measure costs of transaction, and the estimated results show a weak convergence between market prices and suggest that producers are more concerned with private hedging transactions in the physical market, not seeking the stock market for protection against price fluctuations.

Barros et al. (2014) verified the convergence of prices in the Brazil, Argentina and the United States wheat markets. For this, the authors used unit root tests for the time series analyzed, aiming to calculate the beta convergence (β) and half-life. The results indicate that there is a high degree of convergence between wheat prices and also the presence of transaction costs, except between prices in Argentina and the Brazilian state of Porto Alegre.

Methodology

Data

The data used in this work for the Brazilian market of wheat and corn were obtained from the Safras e Mercados[5] consulting firm, and it consists of real monthly price series of corn (in bags of 60 kg) and wheat (in tons), from January 2000 to June 2018, being a total of 222 observations.

For the wheat market, the wholesale markets analyzed were those of Curitiba/PR, Porto Alegre/RS (abbreviated as POA), Maringá/PR and Cascavel/PR. As for the corn market, information was gathered from the wholesale markets of Campinas/SP, Mogiana/SP, Campo Grande/MS, Uberlandia/MG, Maringa/PR, Cascavel/PR, Ponta Grossa/PR, Chapecó/SC, Carazinho/RS, Campo Verde/MT, Rio Verde/GO and São Paulo/SP (abbreviated as SAMPA). It is noteworthy that all price series were deflated by the IGP-DI based on June 2018.

Figure 1 presents the behavior of the price series in the Brazilian wheat market. It can be observed that in all of the analyzed series, there is a peak in growth in 2008, a period related to the global crisis, which directly affected the prices of several agricultural commodities, including wheat (Barros et al., 2014). Figure 2 shows the behavior of the price series in the Brazilian corn market.

Analysis of integration and price convergence

The first step in performing a market integration and price convergence analysis is the realization of the unit root test for panel data. These tests are similar to those used in individual time series. These tests consider the same equation in differences used in as the basis for Augmented Dickey Fuller test (ADF), which is shown below.

[5] http://www2.safras.com.br

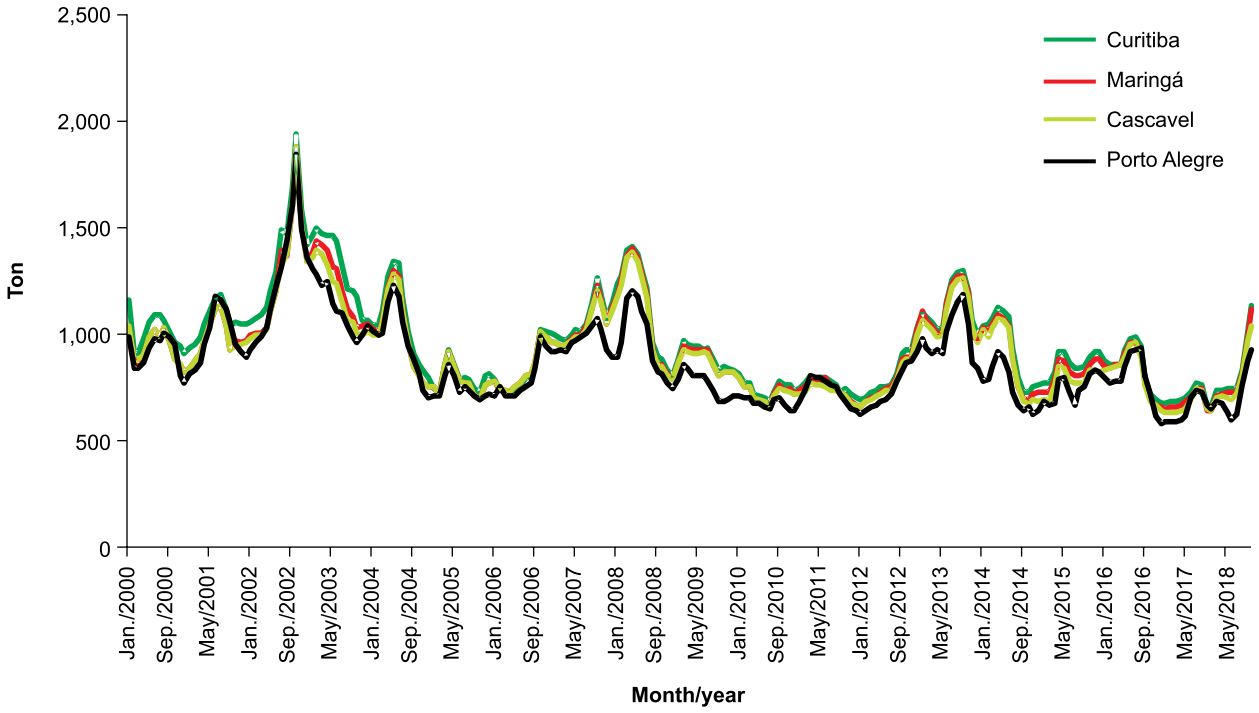

Figure 1. Behavior of the monthly Brazilian wheat market real prices series (in tons): January 2000 to June 2018.

Source: adapted from Safras & Mercados (2018).

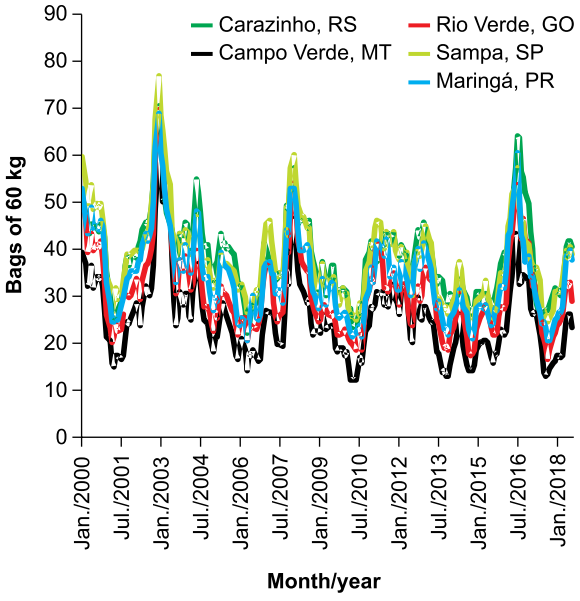

Figure 2. Behavior of the monthly Brazilian corn market real prices series (in bags of 60 kg): January 2000 to June 2018.

Source: adapted from Safras & Mercados (2018).

$$\Delta y_{it} = \alpha_t + \delta_{it}\, y_{it\text{-}1} + \sum_{j=1}^{p} \lambda_{ij} \Delta y_{it\text{-}j} + u_{it} \qquad (1)$$

where: $y_{it} = ln\ P_{it} - ln\ P_{zt}$ denotes the natural logarithm of relative prices between the wholesale markets of wheat and corn; $i = 1, 2,..., N$ wholesale markets; $j = 1,...,J$ wholesale markets, with $i \neq j$; $t = 1,..., T$ periods (months); $\Delta y_{it} = y_{it} - y_{it\text{-}1}$.

Regarding hypothesis tests on the δ parameter to be estimated, two assumptions can be made. The first considers common parameters between the transverse cross sections, such that $\delta = \delta_i$ for all $i = 1, ..., N$ (Levin et al., 2002). The second considers that the parameter δ may vary freely between the cross section cuts (Im et al., 2003).

The Levin et al. (2002) panel unit root test, or simply LLC, considers the existence of a common unit root process between cross-sections. However, the LLC test is subject to two limitations. The first limitation is that the test depends

fundamentally on the assumption of independence between individuals or cross-sections, no matter the presence of serial correlation between them. But the main limitation is that the autoregressive parameters are considered identical across the panel.

Im et al. (2003), or simply IPS, correct these limitations, to present a unit root test that allows variation in the autoregressive parameters between the cross-sectional units and the existence of autocorrelated residue. The test proposed by IPS individually calculates the unit root tests for each cross section. The null and alternative hypotheses for both tests are, respectively, $H_0 = \delta_i = 0$ against the $H_0 = \delta_i < 0$ hypothesis, for all $i = 1, ..., N$ markets.

The rejection of the null hypothesis indicates that the difference between the market price series is stationary, thus indicating the convergence between the markets for an equilibrium value in the long run (Solakoglu & Civan, 2006; Chin & Habibullah, 2008; Mohsin & Gilbert, 2010; Ucak, 2012).

If relative prices between markets converge, we are now interested in determining the convergence speed parameter, the β convergence (Choi et al., 2006; Mohsin & Gilbert, 2010). This can be obtained from equation (2) below:

$$y_{it} = \alpha_i + \beta_i y_{it-1} + u_{it} \quad (2)$$

The relative prices between markets will be convergent if $\beta_i < 0$ where β is the autoregressive coefficient. The coefficient was estimated using fixed and random effects, where the Hausman test was used to determine which is the more appropriate model. The half-life estimation is performed using the following expression:

$$H(\beta) = log(0.5) / log(\beta) \quad (3)$$

Results

In this section, we present the results obtained with the unit root tests for panel data proposed by Levin et al. (2002) and Im et al. (2003); as well as the estimation of the β coefficient of the speed of convergence and the half-life for the Brazilian markets for corn and wheat.

Table 5 shows the results of the panel data unit root tests, as well as the β convergence and the half-life estimation -*H*(β)- for the markets of corn and wheat. The results of the Levin et al. (2002) and Im et al. (2003) - tests presented in columns 2 and 3 - indicate that the series of relative prices of corn markets and wheat are stationary. Thus, it can be stated that these markets are integrated, which is in accordance to Solakoglu & Civan (2006), Chin & Habibullah (2008), Mohsin & Gilbert (2010), Ucak (2012) and Tabosa et al. (2014).

Columns 4 and 5 of Table 5 show the coefficient values for β convergence and the half-life for the corn and wheat markets in Brazil. For the Brazilian corn market, the value of the convergence β coefficient was equal to 0.9193, with a half-life equal to 8.2377.

Thus, the series of the Brazilian corn market converge in about eight months. It is noteworthy that the estimated model for calculating these estimates was the fixed effects model, as the χ^2 Hausman test showed a value of 26.75, being

Table 5. Results of the LLC and IPS panel data unit root tests, β convergence and half-life *H*(β) of the Brazilian wheat and corn markets: January 2000 to June 2018.

Product	LLC	IPS	β	H(β)
Corn	-6.5023*	-3.1649*	0.9193*+	8.2377
Wheat	-8.6128*	-2.3496**	0.9535*++	14.5570

* Statistically significant at 1%; ** Statistically significant at 5%; + Coefficient estimated through fixed effects; ++ Coeficient estimated through random effects.

statistically significant at 1%, indicating that this would be the appropriate model.

In the wheat market, the value of the β convergence coefficient was equal to 0.9535, with a half-life equal to 14.5570. Thus, the series of the Brazilian wheat market converges in approximately fourteen months. Again, the estimated model for calculating these estimates was random effects, as the χ^2 Hausman test showed a value of 0.75.

It would be appropriate to highlight some of these results. Firstly, according to the results of the LLC and IPS unit root tests, the corn and wheat markets are integrated. Thus, the price series between markets converge over time. Secondly, the corn market has a lower convergence time (8 months) than the wheat market (14 months), while the wheat market has a lower spatial area (only the states of Rio Grande do Sul and Paraná), while in the corn market, wholesale markets were analyzed for the South, Southeast and Midwest regions.

One important explanation is that in the wheat market, these prices are directly affected by the prices in Argentina and in the US (more precisely prices in Kansas / USA and Chicago / USA). In other words, these prices are marketed according to the international wheat market, where the Brazilian market has little influence, as the country is importing more than exporting (Margarido et al., 2006; Barros et al., 2014).

As for the corn market, that market is focused on domestic consumption, where more than 68% of production is for feeding poultry and pork, and only 1.44% for human consumption (Abimilho, 2014). Thus, this type of market tends to have a higher degree of integration and a shorter convergence rate than other markets which are targeted at foreign countries (Ravallion, 1986; Gonzáles-Rivera & Helfand, 2001).

Concluding remarks

This work aimed to verify the integration of markets, convergence and estimation of the half-life of the two main products of the Brazilian agribusiness: corn and wheat. For that purpose, unit root tests for panel data were used, and the estimation of β convergence and the half-life of the prices for these products, following the methodology developed by Choi et al. (2006), Chin & Habibullah (2008), Mohsin & Gilbert (2010) and Ucak (2012).

The results show that, according to the LLC and IPS unit root tests, both for the cases of corn and wheat, there is integration between these markets, thus indicating a convergence between the price series. This result is similar to the conclusions reached by works such as Barros et al. (2014) and Tabosa et al. (2014).

Another important result was that the convergence time for the corn market is of approximately 8 months, whereas this convergence for the wheat market occurs in approximately 14 months. One explanation for this result is that in the case of the corn market, its production is mostly for domestic consumption. Thus, this type of market tends to have a higher degree of integration and a shorter convergence than other markets which target foreign countries, such as the wheat market, where prices are formed according to the international wheat market, where the Brazilian market has little influence, as the country is importing more than exporting.

These results are important in the sense that, as discussed by Hufbauer et al. (2002), lower barriers in an economy (global or local) should bring greater price convergence, as would freer investment and more advanced technology. Therefore, open and competitive markets, which eliminate trade barriers and foment investment, should improve price convergence.

Another aspect worth mentioning is that of rural credit and insurance. As discussed by authors such as Moraes (2014) and Castro & Teixeira (2012), federal subsidies and various support programs are available in Brazil, and are an important tool in aiding the sector.

Programs like the Medium Size Farmers Support Program (PRONAMP) and Low Carbon

Agricultural Program (ABC), investment programs such as PRONAMP and Agricultural Cooperatives Capitalization Program (PROCAP-AGRO), and recent developments, such as the Technological Innovation Program (INOVAGRO) and PSI Cerealista, all protect and subsidize, in some manner, whether directly transferring funds or performing the equalization of the interest rates, the economic activities of the agricultural sector.

Moraes (2014), for instance, argues that strategic investments for agricultural development should be preserved, as in the case of infrastructure and fertilizer production, to maintain stability when facing exogenous shocks. Likewise, Castro & Texeira (2012), present evidence which shows that farmers face budget restrictions to purchase inputs, thus, government credit programs might increase the agricultural supply.

Thus, the results of this work, which discusses price convergence in important goods for a developing economy, can be of assistance to policy makers in providing the appropriate environment for the markets to better integrate and achieve further convergence in the price of its goods, whether through long-term policies, such as opening markets, or creating (or expanding) rural credit to facilitate production.

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