Convergence Clubs in the Brazilian Beef Market

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Abstract

The share of livestock in the Gross Domestic Product (GDP) of Brazilian agribusiness has considerable relevance in the country's economy. Specifically, the work tests the hypothesis of convergence and/or formation of price convergence clubs in each state, taking into account the possible technological differences existing among Brazil's different regions. Data from 12 Brazilian states, from 2004 to 2021, is used. The methodology is the time series analysis, as featured in Phillips & Sul (2007). In club convergence, it is observed that in economies with similar initial conditions and identical structural characteristics, prices converge to the same long-term level. And, in this specific case, it was possible to identify only one convergence club, where all states follow the same pattern.

Keywords: convergence clubs, Brazil, beef

1. Introduction

The share of livestock in the Gross Domestic Product (GDP) of Brazilian agribusiness has considerable relevance in the country's economy. The sector moves billions a year, in addition to generating employment for thousands of individuals. Specifically regarding the production of beef, it is worth noting that it is increasing in Brazil, and its exports have reached record levels since 2018, favoring the Brazilian trade balance, and allowing for the advancement of the continuous development of the sector, thus making the country the main beef exporter in the world in terms of tons (*Associação Brasileira das Indústrias Exportadoras de Carne*, 2018).

Due to its territorial extension, herd sizes, climate, fertile soil, and all the investments it has received during recent years in the cattle raising sector, Brazil occupies a prominent position in the international scenario. Exports from the meatpacking sector contribute to a surplus in the country's trade balance, collecting foreign currency, even with the existence of commercial and operational barriers that can make the process of exporting meat to foreign markets difficult. Competitiveness in international trade, it is worth mentioning, involves production volume, supply, production cost, product quality and export logistics, in relation to the beef sector.

Brazil is characterized by inequality, and this irregular distribution of its resources in the national territory covers many different issues, such as income, educational opportunities, infrastructure and technology. In this sense, for Porto Júnior and Ribeiro (2003), this scenario allows the existence of a tendency towards the formation of convergence clubs, with polarization among economic groups. Therefore, convergence among states with similar conditions can be better characterized by the club convergence method, which can be used as a basis for better policies and plans for the price of cattle in Brazil (Dias, Medeiros e Malafaia, 2021).

Due to the fact that in Brazil there are great climatic and soil differences, in addition to other particularities capable of differentially influencing the agricultural performance of states and regions, some authors, such as Penna and Linhares (2013), used the methodology proposed in Phillips and Sul (2007) to identify convergence clubs in agriculture in Brazilian states. Spohr & Freitas (2011), also, tested the hypothesis of convergence of agricultural GDP *per capita* in terms of σ and β absolute and conditional convergence.

Seeking to continue the analysis of the agricultural price convergence process, and also bringing to the debate the issue of the heterogeneity of technological progress, this work uses the methodology of time series analysis of Phillips & Sul (2007) to study the behavior of the price of beef cattle (known as *boi gordo*, in Brazil) in the Brazilian market. More

specifically, the work tests the hypothesis of convergence and/or formation of price convergence clubs in each state, taking into account the possible technological differences existing among regions.

As specific objectives, this work aims to: (i) investigate the existence of β and σ convergence (absolute and/or conditional), that is, test the hypothesis of convergence if initially lower agricultural prices of beef grow faster, and (ii) test the hypothesis of the existence of convergence clubs.

This methodology is particularly suitable for these types of variables, where the concepts of absolute convergence and random and/or deterministic convergence can be very demanding. Convergence tests are directly related to the integration of agricultural markets, aiming to measure the relationship in the behavior of the markets (Tabosa *et al.* 2020).

This work is organized as follows; after the introduction, the second section is dedicated to a brief literature review to serve as a basis for further discussion; the third section covers the database and methods suggested; the results are presented and discussed in the fourth section; and, lastly, the concluding remarks are featured.

2. Literature Review

2.1 Brazilian Beef Meat Market

According to Caleman and Cunha (2011), the Brazilian livestock sector can be considered as privileged, as the country has large territorial extensions, in addition to the favorable climate for cattle breeding, and a production cost considered lower than in other regions. All this suggests that the price of Brazilian beef is attractive to the international market, increasing the country's competitive advantages.

In relation to meat consumption in the world, the most consumed meat on the planet is poultry, followed by pork and, third, beef. In Brazil, beef consumption is 24.4 kg/person. Still, in the context of consumption *per capita* of beef, the Brazilian population is the third largest consumer in the world, with Argentina (38.1 kg/person) in first place, followed by the United States (26.2 kg/person). However, compared to 2019, when 25.2 kg/person were ingested, there was, in Brazil, a 3.2% reduction in beef consumption (Organization for Economic Co-operation and Development, 2021).

In part because of these favorable aspects, Brazil occupies the first position in the number of herds, with more than 217 million heads of cattle, followed by India, with 190 million. In addition, it is the second largest producer of beef in the world, with 10 million tons, accounting for 14.8% of the total, being surpassed only by the United States, which accounts for 17.6% of world production. In addition, it is also the largest exporter with 2.2 million tons, accounting for 14.4% of the international market, followed by Australia, the United States and India (Aragon; Contini, 2020).

In terms of slaughter, the state of Mato Grosso had the highest number of animals slaughtered in the third quarter of 2021, with 1,136,062 heads that resulted in 328,870,199 kg of carcass; followed by São Paulo, with 760,077 heads slaughtered and 221,110,990 kg of carcass produced, and the state of Goiás, which slaughtered 751,599 heads and produced 211,243,563 kg of carcass (*Instituto Brasileiro de Geografia e Estatística*, 2021)

Although the herd and the production of Brazilian beef show considerable growth, Dias, Medeiros and Malafaia (2021) point out that the consumption of beef by the population of developed countries will decrease in the coming years due to price factors, as beef is still a more expensive option than pork and poultry; also due to the environment, and to growing discussions on sustainability, with, in Brazil, cattle raising being constantly linked to the deforestation of the Amazon, tarnishing the image of Brazilian meat for consumers both domestically and internationally. Furthermore, since the COVID-19 pandemic, there has been increased concern about the food quality and health, especially in developed countries.

2.2 Convergence

The concept of convergence originated from Solow's neoclassical growth model (Solow, 1956), followed by Baumol (1986), and later developed by Barro and Sala-i-Martin (1992). The convergence process, since then, has been used in different economic processes comprising groups of countries. Absolute convergence, conditional convergence and club convergence are the three that stand out although many hypotheses have been proposed in this context.

Absolute convergence, or β, implies that countries or units observed in the long run converge with each other, regardless of their initial conditions, while conditional convergence causes a convergence that is conditioned to countries with similar characteristics.

Furthermore, club convergence reveals that a set of economies with similar circumstances and structural characteristics (such as political systems, preferences and technology) will tend to converge towards the same steady state. Thus, as

proposed by Quah (1996, 1997), the club convergence test would result in testing absolute convergence in countries that, a priori, have common structural characteristics.

Thus, Durlauf and Johnson (2009), seeking to advance this analysis, used Classification and Regression Tree Analysis (CART) techniques to investigate the effects of initial income and schooling on the convergence method of economies and their packaging in so-called convergence clubs. The authors rejected the linear empirical version generally used in the literature in deference to econometric models that establish the feasibility of economies being grouped into multiple growth regimes. The argument presented by the authors for the formation of convergence clubs is the variability of the marginal product of capital in relation to the level of development of the economy.

Likewise, Durlauf, Kourtellos and Minkin (2001) also propose that the Solow growth model could be corroborated with an aggregate production function that integrates the structural distinctions present among economies. Furthermore, this characterization is influenced both by local characteristics and neighborhood effects, as well as regional developmental antecedents (DU *et al*., 2018).

Ferreira and Ellery Jr. (1996) sought to analyze the presence of convergence between income *per capita* in Brazilian states, between the years 1970 and 1985, using methodology based on the one featured in Barro and Sala-i-Martin (1992). The main results suggest a slower convergence process than the one found by Barro and Sala-i-Martin (1992) for the American states.

Subsequently, Fochezatto and Stülp (2008), in an attempt to evaluate the hypothesis of convergence of labor productivity in the agricultural sector of Brazilian states, used the Markov chain technique, in order to compare the agricultural sector with other sectors, as well as how to gauge its behavior throughout the nineties. As a result, there was a rejection of the existence of convergence of labor productivity in the agricultural sector, suggesting that some states progress to a higher level of productivity, while others to a lower level.

Considering works which research convergence at the state level, Spohr & Freitas (2011) performed contingency tests of the convergence of agricultural GDP *per capita* in σ and β absolute and conditional convergence. The authors demonstrate that the β convergence tests, both absolute and conditional, support the convergence hypothesis, however, despite this, the test based on σ convergence refutes this hypothesis. It was concluded that the formation of convergence clubs may be resulting in these apparently contradictory results, and may lead to the existence of multiple stationary states.

Another work that identifies convergence clubs in agriculture in Brazilian states is that of Penna and Linhares (2013). In it, the authors used the methodology proposed in Phillips and Sul (2007), which allows identifying convergence clubs under the hypothesis of different types of heterogeneity. The authors' results suggest the formation of three groups, also validating the β-convergence hypothesis.

In view of the above, the neoclassical theory is the theoretical basis of convergence models, which entails technological progress, exogenous savings, decreasing rates of returns of factors of production and a propensity to a steady state (Tabosa et al., 2020). In line with the framework of theoretical and the empirical works, if the economies being analyzed have similar interests and technologies, the poorest tend to show faster GDP growth than the richest, thus reducing the development gap among them (Spohr & Freitas, 2011).

Over the last few years, several studies, thus, have analyzed the behavior of cattle prices in Brazil, whether among states, regions or even with neighboring countries. Considering that, in addition to being one of the main determinants of demand, it also limits profits earned by the agents, it therefore acts as an element of the exchange mechanism which is of great relevance for market participants, whether they are buyers, sellers, or those seeking to protect their profits.

Therefore, it is possible to question if different analysis periods and price-setting locations can lead to different results, confirming the importance of this research in testing the hypothesis of convergence and/or formation of convergence clubs of the prices of each state, taking into account possible technological differences between regions.

Lastly, it is worth noting that the literature did not contain many works focused on all of the Brazilian regions, most studies emphasize especially the states of the Center-west and Southeast regions, due to those states having the highest concentration of bovine production in the country. However, states of the North region, such as Pará, have shown continuous progress over the last few years, reinforcing the contribution of our work to the literature.

3. Methodology

3.1 Data

For this work, data from *Agrolink* (Note 1) was used, which provides prices for 12 states, or federation units (*Unidades Federativa*s, or UFs, as usually referenced in Brazil) in the database. These are: Bahia (BA), Goiás (GO), Maranhão (MA), Mato Grosso (MT), Mato Grosso do Sul (MS), Minas Gerais (MG), Pará(PA), Paraná(PR), Rio de Janeiro (RJ), Santa Catarina (SC), São Paulo (SP) and Tocantins (TO), and the period from March 2004 to June 2021, totaling 208 observations. These markets represent a large part of the national production, as they are the largest beef producers in Brazil. The quotation of the monthly price of fat cattle used was in *arrobas* (Note 2) (15 kg). The values were deflated by the IPCA index with the base period of June 2021.

Figure 1 shows the behavior of the state monthly series of beef prices (in *arrobas*) in Brazil. It can be observed that, as of September 2019, meat prices have shown exponential growth in all states. One of the main reasons is due to exchange rate increases, further stimulating exports in the sector. According to Nakabashi et al. (2008), when the exchange rate has an impact on a product, the relationship is inverse, that is, a variation in the exchange rate towards appreciation stimulates the growth rate of exports based on natural resources.

According to the Brazilian Association of Beef Exporting Industries (*Associação Brasileira das Indústrias Exportadoras de Carne*, 2019), the volume of beef exports to China increased by 54% from the year 2018 to 2019. In terms of revenue, the growth was 80%, with a total of $2.67 billion.

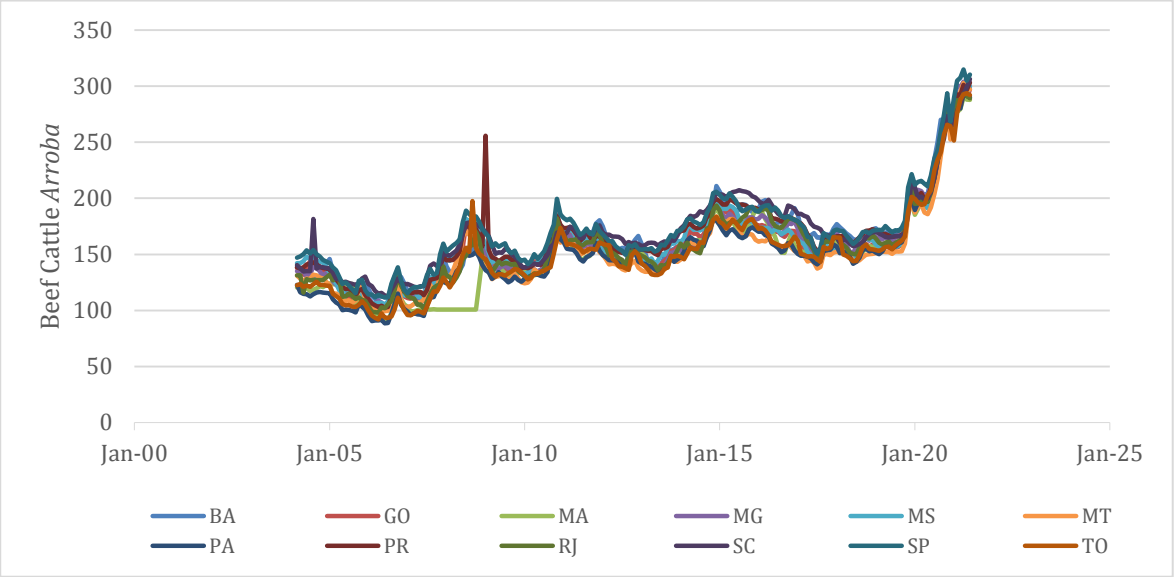

Figure 1. Behavior of the state series of the price (in arrobas) of beef

Source: Prepared by the authors using data from *Agrolink*.

As for the decrease in the supply of animals, the number of females has been reduced in recent years because of the slaughter. According to the Brazilian Institute of Geography and Statistics (2020), from January to June 2020, 14.55 million animals (heads of cattle) in Brazil were slaughtered, that is, 8.63% less than in the same period in 2019, and the lowest amount since 2011. The replacement of cows intended for breeding (known in Brazil as *vaca matriz*) became expensive, and thus, breeders reduced the supply of these cows and held back heifers to rebuild the herd.

In addition to the aforementioned factors, the reduction of stocks in the meatpacking industry to supply the domestic market during the Covid-19 pandemic also contributed to the increase in this product. This occurred both because of restrictions on the operation of slaughterhouses, and because industries believed that domestic demand would decrease significantly during the pandemic, which did not happen (Carvalho; Felema, 2020).

Next, the regression-based convergence test developed by Phillips and Sul (2007) will be presented, initially discussing the $log\ t$ test. The test is based on the cross section variation of the cattle price over time. The unique point

of this methodology is the non-requirement of cointegrated time series, thus allowing individual behavior to be transitionally divergent (Note 3). This method endogenously allows the observation of a wide spectrum of transition behavior among the Brazilian states, such as convergence to a common steady state, divergence and club convergence.

3.2 The Log t Test

Phillips and Sul (2007) developed the *log t* test methodology, which allows the identification of convergence clubs in the Brazilian beef markets among the Federation Units, or states, of Brazil, in the period from March 2004 to June 2021 (Note 4), under the hypothesis of different types of heterogeneity.

As Brazil has a great socioeconomic disparity among its regions, in addition to other particularities capable of differentially influencing the agricultural performance of states, this method is considered adequate for the investigation of the convergence of the country's beef market. It is worth mentioning that, before applying the test, the data were filtered to remove the business cycle using the Hodrick-Prescott smoothing filter (Hodrick and Prescott, 1997), as suggested by Phillips and Sul (2007). Typically, panel data is broken down as:

$$log\ y_{it} = \varphi_i \mu_t + \varepsilon_{it} \quad (1)$$

where φ_i represents the characteristic component unit, μ_t the common factor and ε_{it} the error term.

Convergently, the specifications applied here, in this case, the price of beef cattle (15kg), $log\ y_{it}$ has a variable time representation factor that can be derived from the conventional panel data representation.

According to Phillips and Sul (2007), this new method of research operates under the assumption that technological learning may differ over time and across economies, and is based on the formulation of a model of nonlinear factors composed of a time variant idiosyncratic element, suitable for measuring individual steady-state transition effects, and a common stochastic trend factor, which captures the effects of common technology. Thus:

$$log\ y_{it} = \left(\varphi_i + \frac{\varepsilon_{it}}{\mu_t}\right)\mu_t = \delta_{it}\mu_t \quad (2)$$

Where δ_{it} absorbs the error term and the unit-specific component, thus representing the idiosyncratic part that varies over time. This second approach aims to describe the price of live cattle (15kg) measuring from δ_{it} from the common growth path μ_t, which i goes through. In order to model the transition coefficients δ, a relative transition coefficient, h_{it}, is constructed as;

$$h_{it} = \frac{logy_{it}}{N^{-1}\sum_{i=1}^{N} logy_{it}} = \frac{\delta_{it}}{N^{-1}\sum_{i=1}^{N}\delta_{it}} \quad (3)$$

Thus, h_{it} represents the transition path of the cattle price of state i in relation to the average of the cross section, having two interpretations: first, it measures the individual behavior in relation to the other states, and second, it describes the relative outputs of state i of the common growth path μ_t. In the case of convergence, that is, when the price of cattle (15kg) of all federative units moves to the same transition path, $h_{it} \to 1$ for all i with $t \to \infty$. Thus, the cross section variation of h_{it}, denoted by $V_t^2 = N^{-1}\sum_i (h_{it} - 1)^2$, converges to zero. In the presence of non-convergence, there are several possible outcomes. For example, V_t may converge to a positive number, typical of convergence clubs, or remain bounded above zero and not converge, or diverge.

However, in order to specify the null hypothesis of convergence, Phillips and Sul (2007) model δ_{it} in a semiparametric way to model the transition coefficients assuming they are linear stochastic trends and allowing heterogeneity between the price over time:

$$\delta_{it} = \delta_i + \frac{\sigma_i \xi_{it}}{L(t)t^{\alpha}} \quad (4)$$

In which δ_i is fixed, σ_i is an idiosyncratic scalar parameter, ξ_{it} is iid (0,1), $L(t)$ is a slowly varying function (such that $L(t) \to \infty$ when $t \to \infty$) and is the decay rate (Note 5). The null and alternative hypothesis of convergence can be written as:

$$H_0: \delta_i = \delta\ and\ \alpha \geq 0$$

$$H_A: \delta_i \neq \delta\ and\ \alpha < 0 \quad (5)$$

In the null hypothesis of convergence, several patterns of transition of the price of live cattle in states and *j* are possible, including temporal divergence, which refers to the period of $\delta_i \neq \delta_j$. It is worth noting that the method proposed by Phillips and Sul (2007) allows detecting convergence even in the case of divergence in the transition, where other methods, such as the stationarity tests applied by Hobijn and Franses (2000), were not effective.

Considering equation (4), Phillips and Sul (2007) show that, under the convergence of the cross-sectional variation of the h_{it} has the limiting form:

$$V_t^2 \sim \frac{A}{L(t)^2 t^{2\alpha}}, \text{ where } t \to \infty \; \forall \; A > 0 \tag{6}$$

from which the regression-based convergence test can be deduced:

$$log\left(\frac{V_1^2}{V_t^2}\right) - 2logL(t) = a + b\, logt + u_t\,,$$
$$\forall\, t = [rT], [rT]+1, \ldots, T \tag{7}$$

Where in general $r \in (0,1)$ and $L(t)$ are slowly varying the function. Therefore, Phillips and Sul (2007) suggest the use of $L(t) = log\, t$ and $r = 0{,}3$ for sample sizes below $T = 50$. Lastly, using $\hat{b} = 2\hat{a}$, a one-sided *t* test robust to heteroscedasticity and autocorrelation (HAC) is applied to test the null hypothesis inequality $a \geq 0$. The null hypothesis of convergence is to reject if $t_{\hat{b}} < -1.65$ (5% significance level). If convergence is rejected for the general sample, the test procedure will be replicated to the subgroups, following a test procedure of the clustering mechanism suggested in Phillips and Sul (2007).

4. Results

From the data collected, it is possible to present the descriptive statistics in Table 1, which shows the scenario observed in 208 observations from each state. It is observed that the price in São Paulo (SP) had the highest average (R$170.29), while Pará had the lowest average (R$148.81). Another relevant information is that the series presented a positive average monthly growth rate, indicating overall growth in the bovine sector. This growth was very homogeneous among markets, ranging from 0.24% in Mato Grosso do Sul and 0.33% in Maranhão (MA) and Pará(PA), as a result of the expansion of the area for cattle herds in the south of Maranhão and south of Pará(MATOPIBA region).

Table 1. Descriptive Statistics and Average Monthly Growth Rate of the price series (in *arrobas*) of beef - 2004-2021

State	Observations	Mean	Std. Dev.	Min	Max	Average monthly growth rate (%)
BA	208	165.59	37.78	109.13	295.47	0.30
GO	208	157.93	36.56	102.00	297.87	0.26
MA	208	149.87	39.72	91.28	289.9	0.33
MG	208	159.24	38.13	103.61	303.93	0.28
MS	208	160.05	35.61	105.13	299.84	0.24
MT	208	150.65	36.37	99.24	302.82	0.27
PA	208	148.81	39.08	88.47	293.05	0.33
PR	208	165.05	37.51	102.63	303.29	0.28
RJ	208	157.04	37.52	98.08	293.29	0.30
SC	208	168.59	34.99	112.46	306.29	0.25
SP	208	170.29	37.55	111.65	314.88	0.25
TO	208	150.9	38.08	91.93	293.79	0.31

Source: Prepared by the authors using data from *Agrolink*.

When analyzing the price of cattle using the t log test, the hypothesis of general convergence was accepted at a significance level of 5%, with the estimate of $\beta = 0.313$, with$\tau = 0.452$. Thus, this suggests that in all analyzed markets, prices converge to the same steady state. In other words, prices are converging in a single club.

Analyzing the result in terms of agricultural economics, one could say that these markets are integrated, where they are well informed and show the same behaviors. These results corroborate the results of the average monthly growth rates of the states, which showed low variation among them.

Following the procedures presented by Phillips and Sul (2007), it was possible to identify only one grouping of Brazilian beef markets, composed of the 12 states (or markets). The results of the t log test are presented with the club formation in Table 2, where the estimated parameters and corresponding standard errors for the period 2004-2021 are also featured.

Table 2. Formation of the Convergence Clubs

Club	**Federation Unit (State)**	$\hat{b}$	$t-stat.$	$P-value$	$s.e.$
	Price of beet cattle (*boi gordo*)				
Club 1	SP, MG, PR, MT, GO, MS, SC, BA, RJ, PA, TO, MA	0.259	0.382	0.703	0.679

Source: Prepared by the authors.

Furthermore, for better visualization, an illustration is presented in the form of a map featuring the members of these clubs, in relation to the country as a whole in Figure 2 below. These correspond to 2 states in the North region, 3 in the Northeast region, 3 in the Midwest region, 3 from the Southeast Region and 2 from the South Region.

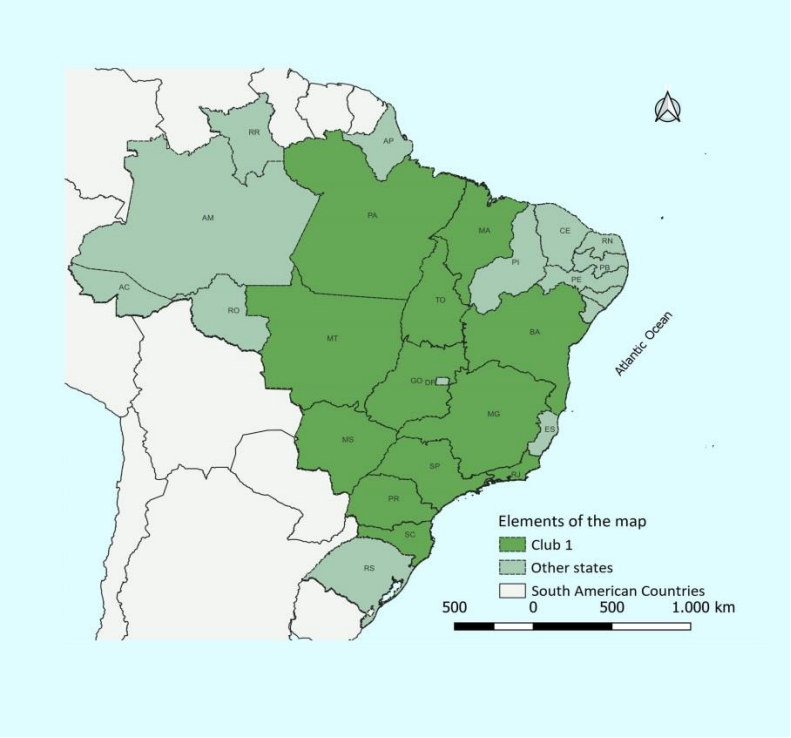

Figure 2. Convergence Clubs

Source: Prepared by the authors.

5. Concluding Remarks

The objective of this work was to verify the existence of the formation of convergence clubs in the Brazilian beef market. For this purpose, time series of beef prices from 12 Brazilian states were used, as well as the methodology of Phillips and Sul (2007).

Especially in recent years, there has been a growing need for empirical research on the club convergence hypothesis, especially to determine convergence clubs among Brazilian states, or federation units, driven by the high demand for the product both in the domestic and foreign markets. A part of the literature focuses on the endogenous decisions of groups that converge to the same steady state level.

In this work, a one-step procedure is used to empirically test the hypothesis of global convergence of 12 Brazilian states from 2004 to 2021. Through the log *t* test (Phillips and Sul, 2007), it was possible to analyze the price behavior of beef in the Brazilian market under the hypothesis of convergence and/or formation of price convergence clubs in each state and it was possible to conclude that the null hypothesis of global convergence was accepted, indicating the existence of a convergence club.

In club convergence, it is observed that in economies with similar initial conditions and identical structural characteristics, prices converge to the same long-term level. And, in this specific case, it was possible to identify only one convergence club, where all states follow the same pattern.

This is one of the few markets where this type of convergence occurs, as in most cases, more clubs are formed, as is the case with corn, as discussed by Tabosa *et al.* (2014). The formation of these clubs can be explained by the annual growth rate of prices practiced by the respective markets. In addition, the strong integration among the markets corroborates the results obtained. This indicates that public policies aimed at encouraging the Brazilian beef market, such as access to credit and rural insurance, for example, can act homogeneously across Brazilian regions.

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Notes

Note 1. Available at: www.agrolink.com.br. Accessed on Sept. 21st, 2022.

Note 2. *Arroba* is a unit of measure used in the agriculture sector in Brazil. It is defined as 15 kilograms, or 33 pounds.

Note 3. Rejecting co-integration does not necessarily imply the absence of approval or convergence. For more, see Phillips and Sul (2007), p.1779.

Note 4. The series begns in 2004, as that is when data starts to become available on the platform.

Note 5. More details on regularity conditions relative to i and it can be found in Phillips and Sul (2007), p. 1786-1787.