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Article

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Suggested Citation: da Cunha Amarante, Janaina Gabrielle Moreira Campos et al. (2018) : Econometric analysis of cointegration and causality between markets prices toward futures contracts: Evidence from the live cattle market in Brazil, Cogent Business & Management, ISSN 2331-1975, Taylor & Francis, Abingdon, Vol. 5, https://doi.org/10.1080/23311975.2018.1457861

This Version is available at:
https://hdl.handle.net/10419/206058

Amarante et al., *Cogent Business & Management* (2018), 5: 1457861
https://doi.org/10.1080/23311975.2018.1457861

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BANKING & FINANCE | RESEARCH ARTICLE

Econometric analysis of cointegration and causality between markets prices toward futures contracts: Evidence from the live cattle market in Brazil

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Received: 18 December 2017
Accepted: 12 March 2018
First Published: 04 April 2018

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Reviewing editor:
David McMillan, University of Stirling, UK

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Abstract: The objective of this study is to investigate evidence of cointegration and causality between the market price of the live cattle in Brazil and the prices of the respective derivatives traded on BM&FBOVESPA – São Paulo, Brazil. The Johansen test was used to analyze evidence of cointegration between markets. The cointegration of these markets and their bidirectional causality signal to decision-makers in this agribusiness that the variations in BM&FBOVESPA futures contracts cause changes in the prices of the spot prices, as well as the spot prices cause to the futures contracts of B&MFBOVESPA.

Subjects: Agriculture & Environmental Sciences; Economics, Finance, Business & Industry; Finance; Business, Management and Accounting

Keywords: futures markets; econometric tests; spot price; Brazil

JEL classifications: G10; G13; G14; G15; G17

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PUBLIC INTEREST STATEMENT

The agricultural activity, with emphasis on the production of cattle, is evidenced as a segment of relevance for the international economy, at the same time presents itself with potential risks due to its fragility of market unpredictability. The protection through the negotiation of futures contracts in the stock exchange consists of a mechanism that seeks to establish greater trust among the agents involved. Studies that address the market price and futures markets behavior are still under construction in the international literature, which led to the present research, whose objective is to investigate the existence of co-integration and causality in the transmission of price of the cattle. From this study, the reader is able to understand the mechanisms of co-integration and causality between markets, considering the risk profile of the livestock activity. In addition, the study can be used as a parameter for definitions of marketing strategies for future projections.

1. Introduction

The relevance of agricultural activity in the Brazilian economy, especially the production of bovine cattle, is characterized as a necessary and substantial niche with repercussions in the international market. This activity, as a whole, presents distinctive risks that are out of reach and control of the producer, such as: instability of supply and demand; price instability; foreign exchange risks; diseases in the herd during the productive process and seasonal climatic conditions (Abitante, 2008; Mueller & Mueller, 2016). Risks of this agribusiness permeate the entire production chain. Thus, more and more tools are needed in order to dilute these impacts and give support to the decision-making process of its main players: breeders; buyers and investors (Bressan & De Lima, 2002). According to BM&FBOVESPA (2015) the derivatives market can help reduce these risks. In this regard, futures markets stand out because of their considerable importance in determining commodity prices, as well as in credit guarantees to the economic agents involved (Bhaumik, Karanasos, & Kartsaklas, 2016; Soni, 2014).

Despite the characteristics that hamper estimates of the live cattle market, Brazil has presented annual representation for its productive capacity. According to the USDA Foreign Agricultural Service (2016), in Brazilian agribusiness cattle farming is one of the most important segments. Worldwide, Brazil has the largest commercial herd, standing out as the largest exporter, and also as the second largest producer, in addition to being sixth among the largest milk producers. According to data from the Ministry of Agriculture (2016) Brazil is the largest exporter and second largest producer in the world. The national technological level of production is considered low, a fact that can be verified by the low pasture occupation, as well as the low number of confined or supplemented animals slaughtered annually, compared to the final slaughter.

Studies on this field (Diakosavvas, 1995; Gaio, Castro Junior, & Oliveira, 2006; Mckenzie & Holt, 2002; Moraes, 2011; Yu, Han, He, & Liu, 2014) have been emerging in the academic community with the aim of investigating the relationship between the price of the live cattle in the spot market and the markets. In fact, there are few researches on the live cattle market in the international context, on the other hand, it is an area of extensive empirical research to investigate the relationship between present commodity markets and futures markets (Bekiros & Diks, 2008; Garbade & Silber, 1983; Kim & Kang, 2014; Sharma & Malhotra, 2015) as an example, the oil market (Bahloul & Bouri, 2016; Bekiros & Diks, 2008; Ratti & Vespignani, 2013; Sadorsky, 2000), the agricultural market (Soni, 2014), the regional commodity market (Sharma & Malhotra, 2015) and the electricity market (Kalantzis & Milonas, 2013).

Due to the relevance of this context, and in line with this theoretical challenge, the present research focuses on the investigation of the existence of cointegration and causality in the transmission of live cattle price between the spot market price, according to the data of the Center for Advanced Studies in Applied Economics (CEPEA), and the BM&FBOVESPA derivatives markets. Although Brazil is the world's largest exporter of beef (Brazil, 2016) there is a lack of studies with the market cointegration approach. Thus, one of the objectives of this work is to bring more strength to the analysis approach and more contributory conclusions to the practice and to the existing theoretical framework. The expressiveness of the time series used in this study (2000 to 2014) and the methodological rigor in data collection and analysis, give more robustness to the research. In this study, cointegration was used as a convenient way to test the efficiency, equilibrium, relationships and degree of long-term interdependence between the markets investigated, enabling the market players and producers to analyze market behavior and future prospects for contracts. About causality, its importance consists in the presentation of evidence regarding the spot and futures markets and their representativeness as sources of information, as strategic tools for risk mitigation. Thus, the present research also aims to contribute with new information to the players of the markets under analysis, in order to broaden the outline of investment strategies aimed at risk hedging operations.

The present study is structured in six parts: introduction; Literature review containing the formation of market prices of live cattle, derivatives market and hedge; hypotheses and the research model; methodological procedures; results presentation and analysis; considerations on the found results in relation to the findings of other similar studies.

2. Literature review

2.1. Formation of market prices of live cattle

The formation and practice of market prices live cattle are shaped by instability and market volatility. For this price formation, Gaio et al. (2006) affirm that the price of cattle in the Brazilian market is muted due to some interferences such as variations in international demand and supply, seasonality of the market, climate and competition with other agricultural commodities. Due to these variations, the conduct of agricultural activities and their respective prices are marked by an irregular, cyclical and seasonal feature structure (Ferreira, Pereira, & Mattos, 2013).

According to Ferreira et al. (2013), this seasonality of the market is commonly inclined for the months of January to June, the period contemplated by the harvest. Theintercrop period, in turn, consubstantiates between the months of July and December. It is in the intercrop period that the cattle retention takes place, with the purpose of providing the weight gains (fattening) of the herd, which directs the consequence of the price increasing in the mentioned period. In this context, the valuation of live animals is influenced by the available situation of live cattle for slaughter, which is directly influenced by the pastures throughout the seasons, moreover, the livestock cycle establishes a pluriannual platform of oscillation of growth and decrease in supply and demand (Fournel, Rousseau, & Laberge, 2017; Sachs & Pinatti, 2007).

Regarding this question, the direction of the studies that seek to understand the instability of the agricultural market and its respective prices formation is understandable (Diakosavvas, 1995; Ferreira et al., 2013; Gaio et al., 2006; Mckenzie & Holt, 2002; Sachs & Pinatti, 2007; Singh & Shanmugam, 2007; Yu et al., 2014). In this aspect, the present research also seeks to understand the impact of this volatility of livestock activities in relation to the price risks, also substantiating the need for the composition of Futures Market contracts. This content is covered in more detail in the following section.

2.2. Derivatives market and hedge

According to Moraes (2011), the futures markets aim to make possible the protection (hedge) of the producers, through futures contracts, and to allow the opportunity of speculation to the market, through three main references: spot market of the merchandise; perspectives of the spot market; and economic trends (Moraes, 2011). Futures contracts are traded daily and large volumes allow the information to be transmitted quickly in the market (Joseph, Garcia, & Peterson, 2013). Moraes (2011) goes on to assert that the futures market captures information and advances prices to the market, ensuring the physical market of live cattle to minimize risks.

The literature on futures markets is supported by three different perspectives that support hedge theory, as Ederington (1979) argues: (1) A traditional hedge conceptualization suggests that futures prices and spot prices of a particular market move together over time; a possible loss in the spot market, would be sustained by a gain in its futures market and the contracts based on security / protection, guarantee the organization and facility of the futures market transactions, through a standardized contract, with the purpose of providing reliability to the parties involved (Chen, Lee, & Shrestha, 2003; Ederington, 1979; Telser & Higinbotham, 1977). In this perspective, the effect of the hedge on prices becomes zero and, consequently, the risks are reduced (Ederington, 1979); (2) This way of thinking about futures markets has been complemented by the theory of adaptive expectations, by proposing that changes in the prices of money in the future and in spot price do not occur in a harmonious way, since any variations that may occur in spot price may conduct to variations in the forward price, making contexts in which the hedgers could have earnings or losses of their

contracts (Ederington, 1979) and (3) Another perspective that integrates the traditional approach of the hedge to the theory of the adaptive expectations, is the one of the portfolios. For such an approach, the role played by the hedger is bound to maximize the expected returns base from a portfolio, which evidences the spot market and futures market contracts that present higher returns to the investor, considering a minimum or a lower possible risk (Ederington, 1979). Thus, the portfolios approach for Ederington (1979) suggests a method for measuring *hedge* effectiveness.

In adopting hedge strategies, companies and investors seek to reduce the risks incurred in the oscillations of the prices of a contract in the futures market (Ederington, 1979; Soni, 2014), especially in relation to instabilities in commodity prices (Revoredo-Giha & Zuppiroli, 2014). Although adopting a hedge strategy does not reduce the risk, it is possible to forecast the fluctuations that occur in the price of this type of market. A hedge is effective in reducing risk when futures prices are closer to spot prices. The participation of hedgers, who operate in this market, becomes essential for the development and liquidity of the market (Working, 1953).

It is based on an efficient market in relation to the futures markets, directing safe signals to interested parties, enabling solidified planning regarding production efficiency, storage, marketing, rationalization of transaction costs and profitability to producers (Sahoo & Kumar, 2009). The market is effectively efficient when all available information at any given moment is reflected in current prices (Natcher & Weaver, 1999). In this scenario, one can observe in the literature the search for the understanding of futures markets regarding an efficient price discovery mechanism (Bekiros & Diks, 2008). In the seminal study by Garbade and Silber (1983), there is interest in developing a model centered on research-centric of the main function of futures prices markets and the effects of arbitrage on local price and commodity futures markets. This model was replicated by other authors, but was not limited to the bovine market (Joseph et al., 2013; Moraes, 2011; Oellermann, Brorsen, & Farris, 1989).

In the configuration for the construction of scientific knowledge, futures markets for agricultural contracts have become the target of investigation, even regarding the performance of private information in relation to the discovery of price in the futures markets of the live cattle, when it is still in the fattening phase, (Schaefer, Myers, & Koontz, 2004). This is one of the main obstacles to such research in the absence of availability of private information, which is managed by only a few market participants. In the configuration of this approach, futures markets have also been analyzed, mainly regarding the security provided and their respective mechanisms of efficiency (Soni, 2014). The results of this study are presented in Table 1, which shows the relationship between the futures market and the spot market (Kumar, Singh, & Pandey, 2008; Soni, 2014), linked with the purposes of this research.

2.3. Relevant prior studies

From the theoretical basis of the understanding of how the market prices of live cattle are formed, as well as the functionality of futures markets, it is necessary to highlight the demand for studies that investigate the relationship between these markets and their respective rise in the scientific community. In this respect, different studies, although still few, discuss and investigate the proposed relationship.

Diakosavvas (1995) identified that, although not fully presented, Australian and US beef prices are cointegrated and that the degree of convergence between the various price pairs did not increase significantly. Through the Johansen cointegration test, Neto and Garcia (2013) investigate the relationship between the efficiency of the future Brazilian beef market and the spot market of Argentine steers. The authors identify an 80% efficiency of the Brazilian beef cattle market in relation to the Argentinean market, providing assistance in the prediction of steer prices. In a similar way, other studies conclude that the spot price of the live cattle and futured prices are interlinked, pointing out that the price of futures markets influences the movement of the spot price (Joseph et al., 2013; Koontz, Garcia, & Hudson, 1990; Oellermann et al., 1989; Weiber Junior et al., 2016).

Table 1. Summary of previous studies

Authors	Title	Object of investigation	Tests realized	Research results
Soni (2014)	Cointegration, linear and nonlinear causality: Analysis using Indian agriculture futures contracts	It analyses the efficiency of the Indian futures markets, with four agricultural commodities (corn, chickpeas, soybean and wheat), for a forecast horizon of 28 days, 56 days, and 84 days.	ADF test; Non-parametric Philips-Perron test; Johansen Cointegration	There is no long-term relationship in three of the four futures contracts, indicating markets as inefficient and biased; The spot and futures markets do not present consistent results of causality
Joseph et al. (2013)	Price discovery in the U.S. fed cattle market	Investigate price discovery in the United States livestock market and its interactions between future prices, spot price and beef price, taking into account prices negotiated weekly between 2001 and 2012.	ADF test; Model of Garbade and Silber (1983); Cointegration test; Granger causality test	Live cattle spot prices are in line with future prices
Neto and Garcia (2013)	The efficiency of the future market for Brazilian live cattle	To verify the efficiency of the future Brazilian live cattle market on BM&FBOVESPA, as a predictor of the prices of beef steers in the Argentine spot market in the presence of risk premium—Period: 2002 to 2011.	ADF test; Johansen cointegration; Error Correction Vector Template	It has been identified that the future Brazilian live cattle market is efficient, and that in the long run the future prices of the beef cattle are unbiased estimators of the spot prices of Argentine steers
Moraes (2011)	Cattle pricing and Cointegration between physical prices and future markets: the case of Itapetinga, BA, Brazil	To examine the behavior of the price discovery and the cointegration between the futures markets for live cattle in BM&F (São Paulo) and the Itapetinga/Bahia square—Period: 2002 to 2010	Model adapted by Oellermann et al. (1989), from Garbade and Silber (1983); Causality of Granger	The discovery of the price occurs in the futures market, which absorbs information first and transmits it to the spot market; For four of the six years studied, the cointegrating relationship was not evidenced
Abitante (2008)	Cointegration between spot and future markets: evidence from the Cattle and Soybean Markets	Statistical linkage between the spot market and the future of the live cattle market traded on the BM&F and between the spot and future soybean markets traded on the BM&F and the Chicago Board of Trade (CBOT)—Period: 2005 daily prices	ADF Test; Johansen cointegration; Short-term efficiency test	Evidence of cointegration was found for both the live cattle and soybeans in relation to the future contract; The efficiency indicator of the live cattle future contract was shown to be high, indicating that it may help to discover the price of this commodity
Gaio et al. (2006)	Causality and elasticity in the transmission of beef prices between regions of Brazil and the Commodities & Futures Exchange, SP, Brazil	Elasticity of transmission and price causality of live cattle, between BM&F and important localities in Brazil—Period Daily prices from 2000 to 2004	ADF test; Johanm cointegration; Granger causality test	Markets are spatially ingrained; All series are cointegrated; BM&F causes, in the Granger sense, the prices of the regions
Diakosavvas (1995)	How integrated are world beef markets? The case of Australian and U.S. beef markets	To examine the integration of the Australian and US markets between the levels of live cattle prices. Period: 1962: 1-1979: 12; 1980: 1-1985: 12; 1986: 1-1993: 2	Cointegration analysis and a procedure for estimating time-varying parameters based on the Kalman filter model	Although not fully presented, beef prices from Australia and the United States are cointegrated; The degree of convergence between the various price pairs did not increase significantly

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On the other hand, Soni (2014) analyzes the efficiency of Indian futures markets, consubstantiating their study in four agricultural commodities (corn, chickpeas, soybeans and wheat) traded in India for a prediction horizon of 28 days, 56 days and 84 days. Through cointegration and causality tests, the author noted that between the futures markets and the spot prices of agricultural commodities selected for the study, there is no long-term relationship in three of the four futures contracts, indicating that markets are inefficient and biased. The causality test did not yield consistent results, indicating that results may vary. In addition, although reduced, the studies with such configuration form a broad field for the development of future researches. Thus, Table 1 summarizes the main previous studies that contemplate the approach.

2.4. Conceptual development of the hypotheses

As guidelines for the search of solution of the research problem we highlight the search for evidences that prove, support or refute the affirmative statements presented in the hypotheses of further research.

Abitante (2008) notes statistical evidence of cointegration between spot prices and BM&FBOVESPA futures contracts. In addition, Gaio et al. (2006) sought to verify the existing relationships between this price in some regions of Brazil and the Brazilian Mercantile & Future Exchange (BM&F), analyzing the elasticity of transmission and causality, considering the time horizon of 2000 to 2004, we found that markets are spatially integrated, explaining that a supply or demand shock on the BM & F results in the impact on prices as well as on other markets. In this study, the authors argue that the Brazilian beef market is efficient, since the information has occurred quickly among those involved in this market, making it possible for the arbitrage mechanisms and the LoP (law of one price) satisfactory. On the same horizon, Joseph et al. (2013) also found cointegration between these markets. Although there are studies that suggest cointegration evidence between the spot markets and the futures markets, there is also research (Kudlawicz, Bach, Veiga, Senff, & Silva, 2016; Moraes, 2011; Soni, 2014) that opposes the positioning of cointegration among the markets studied, asserting that there is no long-term relationship. These authors provide subsidies for the construction of the following research hypothesis:

> ***H1**: The Spot price of the live cattle market and the futures contracts of BM&FBOVESPA **are cointegrated**, that is, there is evidence of the equilibrium relationship in the long term*

Gaio et al. (2006), using Granger's causality test (1969), conclude that BM&FBOVESPA causes prices in other regions. In some of the raised studies, such as Soni (2014), pointed out that the spot markets and futures markets do not present consistent results of causality. To corroborate, or not, the assertion of these authors, it became necessary to propose the following research hypothesis:

> *H_2: The spot price of the live cattle market and the futures contracts of BM& FBOVESPA **have causal relations***

3. Methodological procedures

The present research was initially based on a systematic literature review aiming to identify convergences and divergences on the topic addressed. In a second moment, we tried to identify the models used and the conceptual bases that founded them. These phases allowed delineating the entire research process. It is applied research as to its nature; descriptive/explanatory as to its purpose; econometric modeling on an already existing database regarding to the strategy problem approach the use of secondary data regarding the procedure of data collection and longitudinal cutting as to the amplitude of analysis.

3.1. Data collection

The 3,091 observations of the time series (10 January 2000 to 30 December 2014) on the prices of physical beef cattle traded on the market were collected from the Center for Advanced Studies in Applied Economics (CEPEA) website and data on futures market quotes were collected from the

BM&FBOVESPA website. The choice of sample period is justified initially by the year 2000, as it is considered the first year that the data of the derivative prices became openly made available by BM&FBOVESPA. The year 2014 was defined as the fact that it is the last year with data availability until the completion of the present research. The study strategy consisted in capturing as many data as possible, allowing a more accurate long-term analysis.

The futures contracts of live cattle considered for this research is related to 330 net arrobas, configuring as male—castrated cattle; alive; convex carcass; fed in confinement, maximum time of 42 months; weight centered between 450 and 550 k (Bolsa de Valores, Mercadorias e Futuros - BM&FBOVESPA, 2015; Neto & Garcia, 2013).

3.2. Data analysis

The initial analysis of the data, through the software GRETL—version. 1.9.91 (GNU Regression, Econometric and Time-series Library), consisted in some tests antecedent to the estimation of cointegration and causality. Also, through graphs, it was possible to identify, a priori, non-stationarity characteristics of the series. Confirmation of the non-stationarity occurred after the procedure of identification of the lowest lag of the econometric model, when the Stakeout Extended Dickey Fuller (ADF) test was estimated and the presence of unit root was confirmed. The Johansen (1988) cointegration test was performed based on the results of the Trace and Maximum Value (LMax) tests, following the assumption that the series are non-stationary and using the level variables. Considering that without a dynamic specification of the model, it is not possible to determine how the short-term and long-term deviations of the variables will be adjusted, we applied the error correction model (ECM) of this problem and a more accurate analysis of the short and long-term asymmetries.The Granger causality test, which assumes that the series have stationary characteristics, was thus used and the smallest lag was chosen to estimate the cointegration model. The protocol adopted by this research followed the script proposed in Table 2.

Table 2. Protocol conducting this research

Step	Procedure	Method	Objective
Method of collecting secondary data	Data collection at CEPEA and BOVESPA	Variables referring to live cattle: spot price with Funrural and the values of the BM&FBOVESPA futures contracts	Elaboration of the database with balanced panel for analysis of time series with 3,091 observations (2000 to 2014)
Preparation of data for analysis	Estimation of econometric tests in Gretl software version 1.9.91	Time series plot graph and Tests Dickey-Fuller Magnified (ADF) to check the stationarity of the series and the presence of a unit root	Assumptions prior to the cointegration and causality tests to be performed.
		Confirmation of the non-stationary assumption of the time series and the presence of unit root	
Data analysis		Johansen Cointegration Test, based on Trace Testing and Maximum Value Testing—Error-correction model (ECM)	To check if the series are cointegrated
		Granger causality test	To verify causal relationships between series

Source: Research data.

4. Results and discussions

This research aimed to verify if there are long-term equilibrium relationships in the Brazilian live cattle market between spot prices and those practiced in BM&FBOVESPA futures contracts. Figure 1 was used for the visualization of non-stationarity characteristics between the series under analysis. It was also noticed that the series show an increasing trend as a function of time. The non-stationary characteristics of the series were evaluated, and the ADF (Dickey Fuller Extended) test was performed to confirm and verify the presence of the root unit.

An antecedent to the ADF test is the identification of the best number of lags for the two variables of the model, following the Akaike (AIC), Schwarz Bayesian (BIC) and Hannan-Quinn (HQC) criteria. The smallest number of lags for the variable "spot price" was five, while for the variable "Bovespa Futures Contracts" was six. The criteria with the lowest lag were BIC and HQC, respectively. The results of this procedure are shown in Table 3.

For the variables "Spot price" and "Bovespa Futures Contracts", the values presented non-stationary characteristics and unit root presence considering that p-asymptotic value > 0.05. The values obtained confirm the non-stationarity suggested in Figure 1. After identifying the smallest gap (criterion BIC = 6) for the model composed by both variables, we sought to estimate the existence of long-term equilibrium relationships between them by means of Johansen Cointegration Test.

The data in Table 4 indicate that, for the trace test and the LMax test, there exists a cointegration vector between the variables "Spot price" and Futures Contracts zeroorder vector, indicating that there are equilibrium relations in the long term between these two variables. This occurred because their values remained significant (p-value < 0.05).The cointegrating parameter is able to define a linear combination between the two prices, which follow a common trend and without deviations. Therefore, in this study, from a long-term perspective, the parameter was normalized, so that the parameter should be considered in its standardized version. The results of the cointegration test suggest that, over time, these variables remain in equilibrium, confirming H1, that is, there is no enough statistical evidence to reject the market cointegration hypothesis.

In the light of the evidence presented in Table 4, we can see the cointegration between spot and futures prices in the Brazilian live cattle market. In observing that the two time series are cointegrated, there is a long-run equilibrium relationship between both, but short-term imbalance may occur. To do so, the error correction model (ECM), associated with the cointegration test, was estimated as an adequate reparameterization of the linear autoregressive distribution model, since a time series of an economic variable can be widely moving and may also not manifest, in the long run, significant deviations (Table 5).

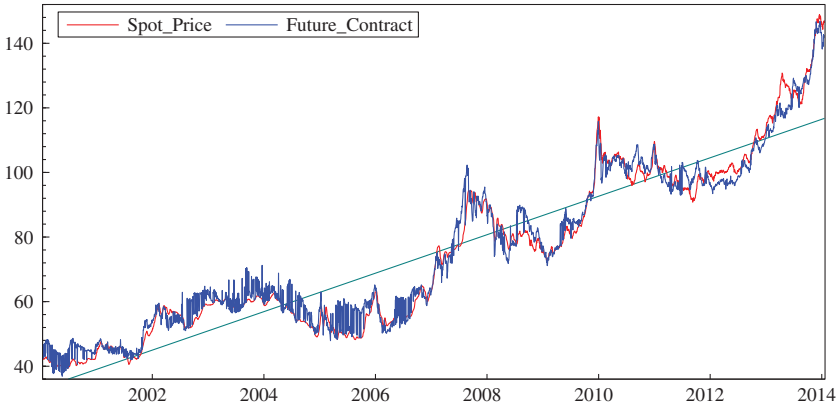

Figure 1. Non-stationarity characteristics of the time series.

The model estimates corroborate the cointegration of the series and show that the parameter values of the analyzed variables are statistically significant. The coefficient of the error correction term presents statistical significance as to the probability of error, indicating that short-term imbalances between the two series of spot and future market prices should disappear in the exact condition of the long-run equilibrium. The effect of the error term coefficient implies that the long-term deviation is adjusted in installments of each day.

The value of DW discards the possibility of non-normality of the residues, with significance of 1%. Therefore, from the results presented, it is verified that the short-term imbalances of the two series studied will be adjusted daily at a fixed rate until they disappear at the time of long-term equilibrium. This result is in line with those obtained by Gaio et al. (2006) for a time horizon from 2000 to 2004. This result is also justified by the study by Abitante (2008), which found evidence of cointegration for both cattle and Soybean in relation to futures contracts, in line with the findings of Joseph et al. (2013).

It can be argued that on occasions when spot market prices and futures markets prices show equilibrium over time, their underlying risk, represented by the difference between the spot price and the futures prices of the live cattle, tends to be low. Therefore, the presence of cointegration is one of the main efficiency assumptions of the futures markets, since it focuses on their integrated

Table 3. ADF stationarity test

Spot price with constant		**Spot price with constant and tendency**
Model	(1 − L)y = b0 + (a − 1)*y(− 1) + ... + ε	(1 − L)y = b0 + b1*t + (a − 1)*y(− 1) + ... + ε
Coef. 1st order for ε	0.001	−0.078
Lagged differences	*F*(4.3085) = 174.784 [0.0000]	–
Estimated value of (a − 1)	0.000149094	−0.00029082
Statistical test	$\tau_c(1) = 0.565921$	$\tau_{ct}(1) = -0.386774$
P-asymptotic value	0.9889	0.9881
Futures contracts with constant		Futures contracts with constant and tendency
Model	(1 − L)y = b0 + (a − 1)*y(− 1) + ... + ε	(1 − L)y = b0 + b1*t + (a − 1)*y(− 1) + ... + ε
Coef. 1st order for "ε"	−0.002	−0.001
Lagged differences	*F*(5.3083) = 187.213 [0.0000]	*F*(6.3080) = 148.031 [0.0000]
Estimated value of (a − 1)	0.000430955	−0.00914547
Test statistics	$\tau_c(1) = 0.284476$	$\tau_{ct}(1) = -2.19211$
P-asymptotic value	0.9776	0.4935

Table 4. Johansen cointegration test

Order	**Self-worth**	**Trace test**	***p*-value**	**Lmax test**	***p*-value**
0	0.018279	57.286	[0.0000]	57.005	[0.0000]
1	9.0774e-005	0.28050	[0.5964]	0.28050	[0.5964]
Variables	**β**	**α**	Normalized **β**	Normalized **α**	
Spot price wth Funrural	0.31603	−0.035907	1.0000	−0.011348	
	0.054931	0.0024405	−3.2463	−4.1295e-005	
Futures Contracts	−0.33748	0.15239	−1.0678	0.048161	
	−0.016921	0.016037	1.0000	−0.00027135	

Notes: Number of equations = 2; Lag order = 6; Estimation period: 1:07–172: 18 (T = 3,090).

Case 3: Constant without restrictions; Likelihood Log = 976,849 (including a constant: −7792.19).

Table 5. Error-correction model (ECM)

Variable	Coefficient	*t*-value	*t*-prob
DLSPO	1.235	2.4658	0.0000
DLFUT	−0.0078	−0.0042	0.0124
Residuals_1	−0.4452	−3.3562	0.0000
Residuals_2	−0.2345	−2.0871	0.0120
R^2 = 0.7223	DW 2.01	Sigma = 0.1682	RSS= 0.7351263

relationship with the spot market. This finding suggests to economic agents the adoption of investment strategies for hedge operations, because over time the futures price of the live cattle could approach the spot price of the live cattle, which would tend to reduce the risks between these two series over time. According to Working (1953), hedge formalization does not guarantee a complete reduction of risk, forecasts of price fluctuations can contribute to predict futures market behavior and the hedge will be effective in reducing risks when futures prices are closer to the spot prices. The benefits and options of hedging provided by the hedge become an interesting security feature against the relative volatility of exchange rates and interest rates, since markets are cointegrated, permitting long-term delivery and settlement with the same available configuration of the assets presented in the spot markets.

To estimate the Granger Causality Test between the time series, it is necessary that the variables be stationary and has no unit root. Thus, considering that the variables presented non-stationarity characteristics, it was decided to transform the values into the first difference level. This procedure can be visualized in Figure 2.

After the transformation of the variables in first difference, the graphs presented stationarity characteristics. However, to confirm the information obtained in Graphs 2, it is necessary to perform the ADF test that indicates the absence of unit root and the stationarity of the series. Initially, it was verified that the smallest number of lags for the variables in their difference and later, the ADF test procedure was performed, which can be visualized in Table 6.

After confirming the stationarity of the series, the smallest discrepancy (BIC = 5) was identified for both series in order to conduct the Granger Causality Test. Table 7 shows the obtained results.

The results of the Granger Causality test suggest causality between the two variables. The F test values were statistically significant (F = 0.000), that is, they were less than 0.05. Thus, it can be said that changes in spot prices cause variations in the BOVESPA Futures Contract Amounts. An inverse relationship also exists, that is, the values of the BOVESPA Futures Contracts also cause variations in

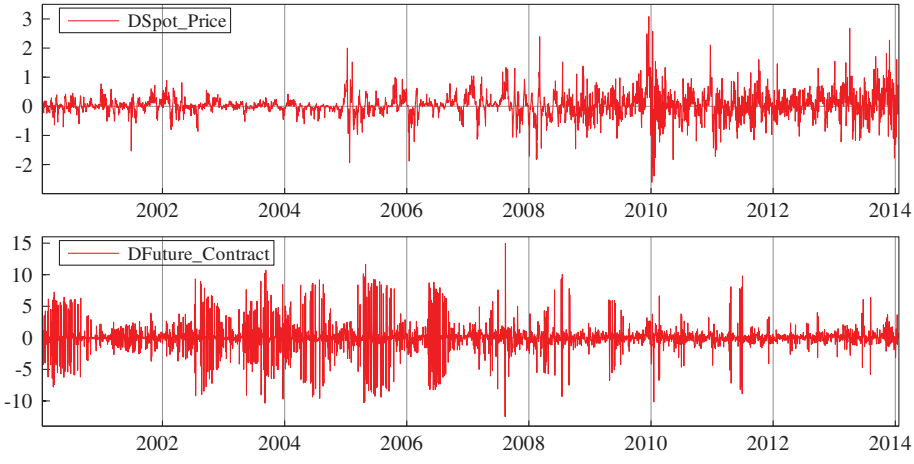

Figure 2. Transformation of the series spot price with funrural and transformation of the series Bovespa futures contracts in their difference.

Table 6. ADF stationarity test with the variables in their difference

	Spot price with constant	Spot price with constant and tendency
Model	(1 − L)y = b0 + (a − 1)*y(− 1) + ... + ε	(1 − L)y = b0+ b1*t + (a − 1)*y(− 1) +...+ ε
Coef. 1st order for ε	0.001	0.001
Lagged differences	*F*(3, 3086) = 82.075 [0.0000]	*F*(3, 3085) = 81.156 [0.0000]
Estimated value of (a − 1)	−0.398572	−0.40087
Statistical test	$\tau_c(1) = -17.2099$	$\tau_{ct}(1) = -17.2635$
P-asymptotic value	2.69e-041	8.067e-055
	Futures contracts with constant	Futures contracts with constant and tendency
Model	(1 − L)y = b0 + (a − 1)*y(− 1) + ... + ε	(1 − L)y = b0 + b1*t + (a − 1)*y(− 1) + ... + ε
Coef. 1st order for "e"	−0.031	−0.031
Lagged differences	–	–
Estimated value of (a − 1)	−1.70561	−1.70603
Statistical test	$\tau_c(1) = -57.468$	$\tau_{ct}(1) = -57.4726$
P-asymptotic value	1	4.007e-100

spot prices. These results support H3, that is, there is no statistical evidence to reject the hypothesis that BM&FBOVESPA's spot prices and Futures Contracts have causal relations. As a result, when the Brazilian market increases the value of live cattle, its value in the form of contracts by BM&FBOVESPA also suffers positive variations in its increase, and, in the same way, the opposite may also occur, allowing to assert that the causality consists of a bidirectional characteristic. This confirmed causal relationship in H3 is not confirmed in Soni (2014) and Gaio et al. (2006) who showed unidirectional causality from BM&FBOVESPA to the studied regions.

Considering the longitudinal consistency of the series involved, bidirectional causality, found in the transmission of the live cattle prices between the spot price and futures markets, allows one to understand the variations and meanings that they are directed in the long run, that is, as these two markets promote price changes between them. This finding leads to market behavior, allowing comparative analysis over the years, yet in a daily behavior. Thus, it is possible to assert that the spot prices (future) provide directions in the forecast of the future price (spot).

The results of this study show that, as a rule, the transmission of price information, both spot and futures, to market players, results from the view of these agents on the prices of these markets and their respective cointegration. This assignment of signage, training and price discovery is considered appropriate if it reflects quickly all the information received by its participants. It should be noted that the information contained in the prices are preponderant for the proper functioning of the beef market in the Brazilian context, which is the subject of investigation of the present study.

The results also allow us to state that price discovery in futures markets can be defined as the use of future prices to determine price expectations for the spot market, giving the producer the opportunity to secure a given price in exchange for the risk of oscillation of the base, with lower volatility. Thus, the greater the degree of correlation between the markets investigated, the greater the assertiveness in price discovery for those involved in this market, allowing greater confidence for the futures market to predict the spot market and the spot market to predict future markets.

Table 7. Granger causality test values

Spot price	Coefficient	Default error	Reason-t	*p*-value
Const	−0.00205892	0.0133404	−0.1543	0.87735
d_SpotwithFunrural_1	0.192128	0.0182619	10.5207	<0.00001***
d_ SpotwithFunrural _2	0.140681	0.0184809	7.6122	<0.00001***
d_ SpotwithFunrural _3	0.0573207	0.0184918	3.0998	0.00195***
d_ SpotwithFunrural _4	0.12104	0.0181522	6.6680	<0.00001***
d_ SpotwithFunrural _5	0.00590535	0.0178228	0.3313	0.74041
d_FuturesContractsBMFBovesp_1	0.0263852	0.00330409	7.9856	<0.00001***
d_FuturesContractsBMFBovesp_2	0.0355654	0.00386306	9.2066	<0.00001***
d_FuturesContractsBMFBovesp_3	0.0301762	0.00399638	7.5509	<0.00001***
d_FuturesContractsBMFBovesp_4	0.0191177	0.00389694	4.9058	<0.00001***
d_FuturesContractsBMFBovesp_5	0.0105507	0.00333867	3.1601	0.00159***
Time	9.50976e^{-06}	7.47692e-06	1.2719	0.20351
All lags of d_spotwithFunrural *F*(5.3078)				88.183 [0.0000]
All lags of d_FuturesContractsBMFBovesp *F*(5.3078)				21.387 [0.0000]
All variables, lag 5 *F*(2.3078)				5.0481 [0.0065]
BM&FBOVESPA futures contracts	Coefficient	Default error	Reason-t	*p*-value
Const	−0.00389105	0.0732509	−0.0531	0.95764
d_AvistacomFunrural_1	0.829765	0.100274	8.2750	<0.00001***
d_AvistacomFunrural_2	0.425209	0.101477	4.1902	0.00003***
d_AvistacomFunrural_3	0.0414071	0.101537	0.4078	0.68345
d_AvistacomFunrural_4	−0.124733	0.099672	−1.2514	0.21087
d_AvistacomFunrural_5	−0.265331	0.0978633	−2.7112	0.00674
d_FuturesContractsBMFBovesp_1	−0.588021	0.0181424	−32.4114	<0.00001***
d_FuturesContractsBMFBovesp_2	−0.371803	0.0212116	−17.5283	<0.00001***
d_FuturesContractsBMFBovesp_3	−0.269775	0.0219437	−12.2940	<0.00001***
d_FuturesContractsBMFBovesp_4	−0.146134	0.0213977	−6.8294	<0.00001***
d_FuturesContractsBMFBovesp_5	−0.114109	0.0183323	−6.2245	<0.00001***
Time	3.30616e^{-05}	4.1055e-05	0.8053	0.42071
All lags of d_spotwithFunrural *F*(5.3078)				21.849 [0.0000]
All lags of d_FuturesContractsBMFBovesp *F*(5.3078)				215.12 [0.0000]
All variable, lag 5 *F*(2.3078)				23.047 [0.0000]

***Significance at 1% level.

5. Final considerations

This paper aimed to investigate evidence of cointegration and causality between spot prices and future prices in the Brazilian live cattle market. For this, 3,091 observations were collected over a 14-year time horizon (2000 to 2014). The spot price data were collected from CEPEA's website while prices in the futures markets (derivatives) were collected from the BM&FBOVESPA website and then organized as a balanced panel. Next, the Amplified Dickey-Fuller (ADF) tests were used to verify the stationarity of the series and the presence of unit root. From the lower lag of the econometric model we conclude by the non-stationarity of the series, indicating that these presented variations over time with increasing trends over the years.

The Johansen test was used to analyze evidence of cointegration between markets. This test concluded that there was no statistical evidence to reject H1 (market cointegration hypothesis). This result is in line with Gaio et al. (2006), Abitante (2008), Joseph et al. (2013), Oellermann et al. (1989), and Koontz et al. (1990) who also identified cointegration between these markets. In an opposite

direction are Soni (2014) and Moraes (2011) who concluded by the non-cointegration between these markets.

When using the Granger causality test, bidirectional causality was evidenced, supporting H3 of existence of bidirectional causality between the series. Thus, it is possible to assert that when the Brazilian market increases the cash values of the live cattle, their value in the form of futures contracts by the BM&FBOVESPA also undergoes positive variations in their increase and the opposite may also occur. These conclusions are in conflict with Soni (2014) and partially counteracted with Gaio et al. (2006) who, when analyzing this market in the period 2000 to 2004, identified only unidirectional causality of BM&FBOVESPA for the regions studied. Abdallah, Belloumi, and De Wolf (2013) argue that there are many controversies in studies that verify causal relationships, since they can be configured as unidirectional, bidirectional or absent. For these authors the plurality of results is attributed, above all, to the several empirical methods employed, as well as to the considered study period.

The cointegration of these markets and their bidirectional causality signal to decision makers in this agribusiness that the variations in BM&FBOVESPA futures contracts cause changes in the prices of the spot prices, as well as the spot prices cause to the futures contracts of B&MFBOVESPA. Risk mitigation strategies derive from this information. Hedge is then presented as a risk hedging mechanism to guarantee the economic agents of this market. The benefits and options of hedging provided by the hedge become a security feature against the relative volatility of exchange rates and interest rates since markets are cointegrated. It can be traded with long-term deliveries and settlement with the same available configuration of the assets presented in the spot markets.

Funding
The authors received no direct funding for this research.

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Citation information
Cite this article as: Econometric analysis of cointegration and causality between markets prices toward futures contracts: Evidence from the live cattle market in Brazil, Janaina Gabrielle Moreira Campos da Cunha Amarante, Tatiana Marceda Bach, Wesley Vieira da Silva, Daniela Matiollo, Alceu Souza & Claudimar Pereira da Veiga, *Cogent Business & Management* (2018), 5: 1457861.

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Cogent Business & Management **(ISSN: 2331-1975) is published by Cogent OA, part of Taylor & Francis Group.**