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MARKET EFFICIENCY: APPLICATION OF THE CONCEPT TO THE SUCROALCOOLEIRO SECTOR OF PARAÍBA

EFICIÊNCIA DE MERCADO: UMA APLICAÇÃO NO SETOR SUCROALCOOLEIRO DA PARAÍBA

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ABSTRACT

Purpose – This article has as main objective to analyze the efficiency of the sugar and ethanol market in Paraíba, through the cointegration test.
Design/methodology/approach – To this end, historical series of sugar and ethanol from the Paraíba market were used, collected at BM&FBOVESPA and CEPEA. As for the methods, the Descriptive Statistics metrics were applied to describe the series' behaviors, the Dickey-Fuller Increased Unit Root Test to verify stationarity, and finally the Cointegration Test, to analyze the long-term relationship.
Findings – The results indicated a behavior with several oscillatory movements in the series prices. Regarding the stationarity of the series, the variables in sight and future of the Paraíba market, a non-stationary process was presented. Finally, the series were estimated to have no cointegration. Thus, we can conclude that the sugar and alcohol sector in the Paraiba market is inefficient, that is, commodities deviate from the real market value.
Research limitations/implications – In the unfolding of this research, a limitation was evident during the exploratory phase, such as: Restrictions on the period of data on sugar and hydrated ethanol available at CEPEA and BM & FBOVESPA, mainly with regard to the cash price and future variables of the Paraiba market.
Practical implications – In this research, it can be seen that the Paraíba market would be considered efficient if it reflected the information available in commodity prices, making abnormal gains impossible.
Originality/value – A study on market efficiency is relevant, as it makes it possible to identify patterns of behavior of asset prices in the market. That is, they can assess whether asset prices are being overvalued and how it affects the investor and the Brazilian economy.

Keywords - Market efficiency; Cointegration; Sucroalcooleiro Sector.

RESUMO

Objetivo – Este artigo tem como principal objetivo analisar a eficiência do mercado de açúcar e etanol da Paraíba, mediante o teste de cointegração.
Design/metodologia/abordagem – Para tanto, utilizaram-se séries históricas do açúcar e etanol do mercado paraibano, coletados na BM&FBOVESPA e na CEPEA. Quanto aos métodos, aplicaram-se as métricas de Estatísticas Descritiva para descrever os comportamentos das séries, o Teste Raiz Unitária Aumentado de Dickey-Fuller para verificar a estacionariedade, e por fim o Teste de Cointegração, para analisar a relação a longo prazo.
Resultados – Os resultados indicaram um comportamento com diversos movimentos oscilatórios nos preços das séries. Quanto a estacionariedade das séries, as variáveis à vista e futuro do mercado paraibano, apresentou-se processo não estacionário. Por fim, as séries estimaram-se que não há cointegração. Podendo assim, concluir que o setor sucroalcooleiro do mercado paraibano é ineficiente, ou seja, as commodities desviar o valor real de mercado.
Implicações/limitações da pesquisa – No desdobramento desta pesquisa, ficou evidente uma limitação no decorrer da fase exploratória, como: Restrições no período dos dados do açúcar e etanol hidratado disponíveis na CEPEA e BM&FBOVESPA, principalmente no que se refere as variáveis de preço à vista e futuro do mercado paraibano.
Implicações práticas – Nesta pesquisa, podem-se constatar que o mercado paraibano seria considerado eficiente se refletisse as informações disponíveis nos preços das commodities, impossibilitando ganhos anormais.
Originalidade/valor – Estudo sobre eficiência de mercado é relevante, pois possibilita identificar padrões de comportamento dos preços de ativos no mercado. Isto é, podem avaliar se os preços dos ativos sendo supervalorizadas e como isso afeta o investidor e a economia brasileira.

Palavras-chave - Eficiência de mercado; Cointegração; Setor Sucroalcooleiro

1 INTRODUCTION

The culture of sugarcane production has historical importance in the world economy, especially in Brazil. This culture and its commercialization can be found in more than 70 countries, among which Brazil, India, and China stand out as the largest producers, according to the National Supply Company (CONAB) (2018). In Brazil, the sugar and ethanol sectors in Paraíba contributed directly to the development of the national economy. In Paraíba, these sectors comprise 1,800 small, medium, and large sugarcane producers, which are responsible for supplying 30% of the sugarcane milled by the plants in the state (CONAB, 2018).

In relation to commercialization, the sector revolves around the import and export of sugar and ethanol, which expose it to a commodity market risk factor. Although the sugar and alcohol sectors are subject to the market's uncertainties, it is possible to analyze the risk factors through the protection mechanism to eliminate losses in purchase/sale transactions in the derivatives market (Harzer et al., 2012).

The market risks that are involved in the sugar and ethanol sectors are related to the production process and the price formation factor (Hull, 2016). Thus, such risks can be caused by market uncertainties, resulting from price formation or events inherent in the activity of production itself, such as droughts, excessive rainfall, changes in the external environment, issues with the exchange rate, hedge fund actions, and bad weather (Fraga & Silva Neto, 2011).

However, it is possible to commercialize sales and purchase transactions involving sugar and alcohol commodities in the futures market as a mechanism through which agents can eliminate price risks in negotiations, provided that the market is efficient (Alves, Duarte, & Lima, 2008). Market efficiency reflects all available information about the market prices of assets (Harzer et al., 2012; Melo, Lima, & Moraes, 2009; Fama, 1970).

In this context, market efficiency acts as a mechanism in the futures and spot markets to bring the price fluctuation of a commodity to the level of efficiency with the purpose of verifying all the possible avenues for producers to mitigate their inefficiencies and exploit their capacity to evaluate the information available on the market (Domingues, 2014) before making a decision to sell or buy commodities.

Considering the studies related to market efficiency and cointegration in agricultural commodities (Rodrigues & Martines Filho, 2015; Harzer et al., 2012; Fraga & Silva Neto, 2011), this research was conducted with the goal of analyzing the efficiency of sugar and ethanol from the Paraíban market through the cointegration test. Another aim was to contribute to the strengthening of the literature regarding research related to market efficiency when applied to Brazilian agricultural commodities, and, above all, to consolidate the cointegration techniques developed by Johansen and Juselius (1990) when applied to the sugar and alcohol markets.

In this context, to achieve the proposed objective, it was necessary to conduct this research as follows: apply descriptive statistics to depict the behavior of sugar and ethanol in the Paraíba state market; perform the ADF unit root test (Dickey and Fuller, 1981) to verify the stationarity of the spot and futures price variables; and, finally, apply the Johansen and Juselius cointegration test (1990) to analyze whether there was a long-term relationship between the variables studied.

2 LITERATURE REVIEW

Given the relevance of market efficiency to the Brazilian commodity producer, in this section, the concepts of market efficiency and empirical studies on it will be discussed, emphasizing the study by Fama (1970).

2.1 Market Efficiency

Market efficiency is a relevant topic in financial management and has been discussed in several studies, such as those by Bachelier (1900), Cowles (1933), Working (1934), Roberts (1967), and Fama (1970), among many others who employed the theory of random paths, whose aim is to analyze whether the market is efficient.

The precursor of such studies on security price behavior in relation to the financial market was Bachelier's (1900) thesis *Théorie de la speculation*, in which he proposed a test to analyze the behavior of commodity prices (Bachelier, 1900).

Bachelier's (1900) study on the theory of efficient markets was systematized by Roberts (1967) and later refined by Fama (1970), who stated that all relevant market information is incorporated immediately and correctly into asset prices, thus providing the best way to estimate security (Roberts, 1967; Fama, 1970).

The concept of market efficiency in the context of the agricultural commodities market has been the subject of much study by academic researchers (Aráujo et al., 2018; Rodrigues & Martines Filho, 2015; Tonin, Parré, & Tonin, 2014; Harzes et al., 2012 ; Silva & Takeuchi, 2010; Silva Neto, Fraga, & Marques, 2010; Alves, Duarte, & Lima, 2008; Bitencourt, 2007; Melo, Lima, & Moraes, 2006; Amado & Carmona, 2004).

Such surveys have had the objective of examining the behavior of a price on the part of agents acting in specific markets when assisting decision-makers in uncertain scenarios (Fraga & Silva Neto, 2011). Chart 1 below shows the chronological order of some of the concepts of market efficiency and their respective authors.

Chart 1 - Concept of Market Efficiency

Author	Definition
Robert (1959)	A market is efficient when all the relevant information is incorporated, immediately and correctly, into the prices of securities and the best estimate for the price of a security is its current price.
Fama (1970)	A market is efficient when prices fully reflect all the available information.
Jensen (1978)	A market is considered efficient when, with a set of information, economic profits cannot be achieved.
Brealey & Myers (1995)	The market is efficient when any transaction involving the purchase and sale of securities at the current market price does not have a positive net present value.
Demodaram (1996)	A market is considered efficient when the market price is an unbiased estimate of the real value of an investment.
Ross *et al*. (2009)	A market is efficient when the prices of current market assets reflect all the information available.

Source: The authors, 2020.

The table above demonstrates some of the concepts of market efficiency, which are related to the commodity market scenario, in which an efficient market reflects a market strategy in which there are many rational profit-maximizing agents actively competing and trying to predict the futures market value of individual assets and in which important information is available to all participants at a cost close to zero for negotiation (Ross *et al*., 2009; Demodaram, 1996; Brealey & Myers, 1995; Fama, 1970).

In this sense, the concept of market efficiency must be understood as a competition between many intelligent participants that leads to a situation in which, at any moment in time, the real prices of individual assets already reflect the effects of the information available, based on both events that have already occurred and those that the market expects to occur in the future (Harzes *et al*., 2012; Fama, 1970).

2.2 Empirical Studies of Market Efficiency Theory

Market efficiency was addressed by Bachelier (1900) in his research on the influences that determine fluctuations in stock prices. In his study, Bachelier presented the Brownian Movement and an analysis of the stochastic process, arguing that "past, present and even future events are reflected in the market price, but often do not seem to show a relationship with price variations" (Bachelier, 1900). The author defended the idea that asset prices vary randomly in the market, influencing the development of the stochastic calculations and mathematical techniques applied in the financial market and contributing to the design of informational efficiency (Davis & Etheridge, 2006; Bachelier, 1900).

Subsequently, Cowles (1933) analyzed the forecasts of financial agencies, in which they investigated the assets with the greatest potential for profitability to predict the behavior of stock markets. Cowles concluded that the financial agencies analyzed in his research were unable to make effective forecasts of the stock market in relation to the future value of assets (Cowles, 1933).

Working (1934) analyzed the random behavior of commodity prices. In his study, he pointed out the impossibility of predicting the future behavior of prices in the market (Working, 1934).

The studies by Cowles (1933) and Working (1934) confirmed the impossibility of predicting the future behavior of prices in the market. These authors stated in their research that the changes in the price of the assets obtained a random walk; in this sense, the variations could not be antici-

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pated in the market (Working, 1934; Cowles, 1933).

Kendall (1953) researched the behavior of commodity prices. To that end, Kendall analyzed 22 UK stocks, with an emphasis on commodity-price variables. The author concluded that the stock price variables reflected random walks in which they were distributed independently of each other (Kendall, 1953). Thus, Kendall stated in his work that there were no predictable commodity price patterns, that is, prices evolved randomly (Kendall, 1953).

As a result, research on the behavior of commodity prices has evolved. Aware of the complexity of price behavior, Osborne (1959) and Robert (1959) carried out more in-depth studies that explained the randomness of commodity prices (Bitencourt, 2007).

Still, regarding research on the behavior of commodity prices, Samuelson's (1965) study was a pioneering work in providing an explanation from the economic perspective regarding the phenomena observed in the market (Samuelson, 1965). Samuelson (1965) argued that the behavior of futures prices resulted in the perfect functioning of futures markets, defined as a perfect futures market in which the market price would constitute, in all periods, the best estimate to be made based on the current price on the maturity dates of futures contracts (Rodrigues & Martines Filho, 2015; Working, 1962).

Consequently, Mandelbroit (1966) investigated interference from an economic point of view in relation to market behavior. It is important to emphasize that Mandelbroit, in his study, proposed a model for agricultural commodity and industry stocks and soon concluded that, in the speculative markets, the distribution of returns was leptokurtic, and identified conglomerates of volatility (Mandelbroit, 1966). Samuelson (1965) and Mandelbroit (1966) carried out analyses with an emphasis on the model of return expectations from the perspective of market efficiency and the random walk theory (Rodrigues & Martines Filho, 2015; Samuelson, 1965; Mandelbroit, 1966).

According to previous approaches, the concept of market efficiency appears to be related to how information is disseminated among market participants (Bitencourt, 2007). Market efficiency originated from economic theory, as its goal is to examine the factors that influence investor decisions, enabling the improvement of the market and making it balanced and, therefore, efficient (Aráujo et al., 2018).

In this context, the conceptual basis for market efficiency was advanced by Fama (1970), who defined it as a state in which a market's prices always fully reflect all information (Fama, 1970).

Fama (1970) pointed out three conditions for market efficiency: no transaction costs should be involved in securities trading, all information should be made available free of charge to all market participants, and there should be a general agreement on investors' expectations regarding the effects of information on current and future bond prices (Harzer et al., 2012; Fama, 1970). Such conditions are considered sufficient for analyzing the efficiency of a commodity market (Fama, 1970).

Market efficiency consists of two categories: informational efficiency and market rationality. Informational efficiency is understood as the speed with which information is incorporated into the market price of an asset, whereas market rationality concerns the ability of prices to accurately reflect investment expectations regarding the present value of future cash flows (Tonin, Parré, & Tonin, 2014; Elton & Gruber, 1995; Fama, 1970). Market efficiency concerns how quickly information is incorporated into the market but not its possible incorporation into commodity prices.

Fama (1970) highlighted three forms of market efficiency: weak, semi-strong, and strong, as shown in Chart 2.

Chart 2 - Types of Market Efficiency

Form of Efficiency	Description
Weak	This includes the set of information on prices or historical returns.
Semi-strong	This includes the information in the previous category, as well as other publicly available information.
Strong	This consists of all public information and any private information relevant to the development of prices that investors or groups hold.

Source: Prepared by the authors based on Rodrigues and Martines Filho (2015, 351).

These definitions of the forms of market efficiency act as a set of information that is available to the investor, being intercurrent, whereas the rejection of the weak form implies the rejection of the others, and the rejection of semi-strong efficiency implies the rejection of the strong form (Aráujo et al., 2018; Rodrigues & Martines Filho, 2015; Fama, 1970).

Given the above conditions, many researchers have discussed the theory of efficient markets and the concept of a random walk based on the study by Fama (1970), emphasizing the analysis of futures contracts in the commodities market (Aráujo et al., 2018; Rodrigues & Martines Filho, 2015; Tonin, Parré, & Tonin, 2014; Harzes et al., 2012; Silva & Takeuchi, 2010; Silva Neto, Fraga, & Marques, 2010; Alves, Duarte, & Lima, 2008; Bitencourt, 2007; Melo, Lima, & Moraes, 2006; Amado & Carmona, 2004).

2.3 Cointegration Analysis in Commodities

In the analysis of commodities' time series, cointegration is an important methodology. It was discussed by Engle and Granger (1987) and Johansen (1988), in their research on modeling the relationships between time series, which is becoming relevant to the area of finance, as it allows investigation of the long-term relationships between financial series that are non-stationary (Johansen, 1988; Engle & Granger, 1987).

Engle and Granger (1987), Johansen (1988), and Johansen and Juselius (1990) derived methods from statistical procedures to test cointegration, applying the maximum likelihood technique (Johansen & Juselius, 1990; Johansen, 1988; Engle & Granger, 1987). Using this technique, the authors estimated the degree of integration between various markets where they sought to observe the existence of long-term stochastic trends in the derivative market (Moraes, Lima, & Melo, 2009).

In the literature, there are well-founded works in which, in general, the cointegration test was used, such as those by Engle and Granger (1986), Johansen (1988), and Johansen and Juselius (1990), to analyze whether two variables had long-term relationships (Araújo et al., 2018; Oliveira Neto & Garcia, 2013; Harzer et al., 2012; Michelin, Silva, & Ruppenthal, 2012; Fraga & Silva Neto, 2011; Moraes, Lima, & Melo, 2009; Alves, Duarte, & Lima, 2008).

However, the research on cointegration and market efficiency by Lai and Lai (1991) highlighted that there was an intersection between the econometric theory of cointegration and the theory of market efficiency.

In view of the authors' statement, Chart 3 below shows some studies in which the cointegration test was performed to analyze market efficiency in relation to Brazilian commodities.

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Chart 3 - ***Cointegration Test and Market Efficiency in Commodities***

Author	Commodities	Cointegration test
Alves, Duarte, & Lima (2008)	Anhydrous ethanol	Johansen (1988) used it to verify the existence of a long-term relationship, obtained by the likelihood method, with a Monte Carlo approach.
Moraes, Lima, & Melo (2009)	Ox fat	Engle and Granger (1987) used it to test market efficiency in the presence of a risk premium.
Fraga & Silva Neto (2011)	Soy	Johansen (1988), whose method was based on the values of the trace statistics and the maximum eigenvalue statistics obtained by the likelihood method, used it.
Harzer *et al*. (2012)	Coffee	Johansen (1988) used it to verify the existence of a long-term relationship between variables.
Michelin, Silva, & Ruppenthal (2012)	Corn	Engler and Granger (1987) used it for spot and futures corn prices, using the MQO method.
Oliveira Neto & Garcia (2013)	Ox fat	Johansen (1988) and Johansen and Juselius (1990) used it and the VEC model to test market efficiency.
Araújo *et al*. (2018)	Coffee	Engle-Granger (1987) used it to verify that the residuals of a regression were stationary.

Source: The authors, 2020.

As shown in Chart 3 above, the presence of cointegration between the time series demonstrates the existence of a long-term equilibrium relationship in the Brazilian commodities' futures market (Araújo et al., 2018; Oliveira Neto & Garcia, 2013; Harzer et al., 2012; Michelin, Silva, & Ruppenthal, 2012; Silva Neto, 2011).

Given the information presented above, to conduct an analysis of the efficiency of the commodities, the cointegration test was comprised of the time series that were integrated in order (d) and named I (d), since the series could only be called stationary after differentiating it into I (d) (Lai & Lai, 1991; Johansen & Juselius, 1990). In addition, series I (0) was determined to be stationary, just as I (1) had a unit root and was not stationary (Salles, 2010; Lai & Lai, 1991; Dickey & Fuller, 1981).

In this sense, when spot prices V_t, and futures $F_{t-1,t}$, both were I (1), the linear combination corresponded to the equation Z_t = V_t - a - $bF_{t-1,t}$, which represented I (1). However, if existence occurred given a and b so that Z_t was stationary or I (0), V_t and $F_{t-1,t}$, they were cointegrated (Lai & Lai, 1991; Johansen & Juselius, 1990). Regarding the equation V_t - a - $bF_{t-1,t}$ = 0, it is considered co-integrated or having a balanced relationship with Z_t, which represents a balance of error (Salles, 2010; Lai & Lai, 1991; Johansen & Juselius, 1990; Dickey & Fuller, 1981).

Therefore, to analyze the spot price variables V_t and futures $F_{t-1,t}$, cointegration testing is a necessary condition for establishing market efficiency (Lai & Lai, 1991). That is, the efficient market hypothesis proposes that the futures price $F_{t-1,t}$ is a biased predictor in relation to the mean of V_t, while the forward price does not consist of a prediction regarding the estimated value of the spot price V_t (Johansen & Juselius, 1990). The variables in sight V_t and futures $F_{t-1,t}$ are not co-integrated, with Z_t becoming non-stationary and V_t and $F_{t-1,t}$, so that the variables tend to change direction (Salles, 2010; Lai & Lai, 1991; Johansen & Juselius, 1990; Dickey & Fuller, 1981), that is, the distance from the variables, V_t e $F_{t-1,t}$, is characterized as reflecting an inefficient market (Lai & Lai, 1991).

For the spot and futures market to be characterized as efficient, a = 0 and b = 1 in the equation V_t - a - $bF_{t-1,t}$ = 0; otherwise, $F_{t-1,t}$, is called a biased predictor of V_t, even when spot and futures prices point to a similar direction in time (Lai & Lai, 1991; Johansen & Juselius, 1990). For this reason, the market efficiency test involves formal econometric tests of restrictions on parameter cointegration (Lai & Lai, 1991; Johansen & Juselius, 1990).

Therefore, the Engle-Granger test (1983) is inadequate due to the hypothesis test in which the cointegration parameters do not follow a distribution standard (Oliveira Neto & Garcia, 2013; Harzer et al., 2012; Moraes, Lima, & Melo, 2009; Alves, Duarte, & Lima, 2008). In contrast, the test developed by Johansen and Juselius (1990) indicates a procedure capable of handling the problem of statistical inference in cointegrated systems (Oliveira Neto & Garcia, 2013; Harzer et al., 2012; Alves, Duarte, & Lima, 2008; Johansen & Juselius, 1990). The cointegration test, called a = 0 e b = 1 in the equation V_t - a - $bF_{t-1,t}$ = 0, is used to conduct asymptotic tests using the procedure proposed by Johansen (1988) (Harzer et al., 2012; Johansen & Juselius, 1990).

Thus, the market efficiency test consists of measuring the relationship between two variables in the long term (Harzer et al., 2012). To accomplish this, cointegration involves analyzing V_t e $F_{t-1,t}$ to evaluate the time series that are presented as non-stationary (Harzer et al., 2012; Johansen & Juselius, 1990). In view of this context, the cointegration test presents the restriction of the parameters as a = 0 e b = 0, through the trace tests (λ_{trace}) and the maximum eigenvalue (λ_{Max}), to verify the existence of some linear combination between the variables (Bueno, 2011; Alves, Duarte, & Lima, 2008; Johansen & Juselius, 1990).

Therefore, estimation and analysis using the cointegration test make it possible to better assess whether there is a long-term relationship between the time series of agricultural commodity prices (Araújo et al., 2018; Oliveira Neto & Garcia, 2013; Harzer et al., 2012). Given the relevance of these works (Araújo et al., 2018; Oliveira Neto & Garcia, 2013; Harzer et al., 2012; Michelin; Silva, & Ruppenthal, 2012; Fraga & Silva Neto, 2011; Moraes, Lima, & Melo, 2009; Alves, Duarte, & Lima, 2008), in this work, the cointegration test methodology of Johansen and Juselius (1990) was adopted to assess the presence of a long-term relationship between the time series of spot prices V_t and futures $F_{t-1,t}$ of Brazilian sugar and alcohol commodities.

3 METHODOLOGY

This research was conducted with the aim of analyzing the hypothesis of efficiency in the sugar and ethanol markets in Paraíba. Thus, the study reflects an exploratory, descriptive approach along with a quantitative approach with econometric applications. Thus, this phase included an investigation with precision analysis and statistical control to provide data to verify the object under study.

3.1 Data Description

Regarding the database, negotiations were carried out to estimate econometric models. To do so, it was essential to seek historical data on spot prices for crystal sugar and hydrous ethanol from the domestic market in Paraíba from the Center for Advanced Studies in Applied Economics (CEPEA/ASALQ); historical data on the prices of futures contacts were extracted from the stock exchange's commodities and futures (BM & FBOVESPA) exchange, as shown in Table 1 below.

Table 1 - Data on Crystal Sugar and Hydrous Ethanol

Assets - Code	Sample period		Number of observations
	First	End	
Crystal Sugar - AC	January 02, 2014	December 21, 2016	736
Hydrous Ethanol - ETH	April 30, 2013	September 27, 2018	66

Sources: the CEPEA (2018) and BM & FBOVESPA (2018).

According to the data reported in Table 1, the period during which the behavior of the daily prices for crystal sugar was investigated extended from January 2014 to December 2016, with a total of 736 observations. For hydrous ethanol, the monthly series price behavior of the period from April 2013 to September 2018 was analyzed, yielding 66 observations.

The spot market prices from the CEPEA/ESALQ were calculated daily through the weighted average of the quotations of the main producing regions of the country. From this perspective, the spot market price of the crystal sugar market is quoted as the number of USD per 50 kg bag, with two decimal places, free of any charges, tax-related or not; its trading unit is 250 bags of 50 net kilos and it is disclosed in February, April, July, September, and November (CEPEA/ESALQ, 2018). Hydrous ethanol from the domestic market in Paraíba is quoted in reais per cubic meter, with two decimal places with variation. The statistical treatment is carried out using the volume-weighted average, with disclosure in all months of the year (CEPEA/ESALQ, 2018).

The prices in the futures market were obtained from the BMF & BOVESPA. These are quoted as the number of USD per sack, with two decimal places, where 508 net 50 kg bags are contracted, with the last trading day being the 15th and having disclosure months in February, April, July, September, and December (BM & FBOVESPA, 2018). The amount of hydrous ethanol is quoted in reais per cubic meter, with two decimal places with a minimum price variation of R$ 0.50 and a contract size of 30 m³ (equivalent to 30,000 liters) with maturity every month of the year (BM & FBOVESPA, 2018). Next, the methods used to treat the data collected in this research will be presented.

3.2 Data Processing

The techniques used to analyze the sugar and ethanol market efficiency of the Paraíba market involved using the following methods: descriptive statistics, the ADF unit root test (1981), and the Johansen and Juselius cointegration test (1990).

3.2.1 Descriptive Statistics

To describe the behavior of the price of crystal sugar and hydrous ethanol in the market in the state of Paraíba, descriptive statistics and histograms were used to verify the central trend and dispersion measures. The research data were presented using graphs and tables created with Excel and E-Viens® software. These provided a summary of the descriptive statistics of the historical series analyzed and gave us the option of presenting a histogram.

They were estimated to describe the behavior of the series of crystal sugar and hydrous ethanol using the mean, fashion, and median to analyze the central trend. As for the dispersion measure, the quantiles, variance, and standard deviation were estimated. To find the normal distribution of the series, the minimum and maximum values, asymmetry, kurtosis, and results of the

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Jarque-Bera-JB normality test were verified. The items mentioned above highlighted whether the variables in question were normally distributed.

3.2.2 ADF Unit Root Test

To analyze the stationarity of the price variables' spot and futures values, we used the ADF unit root test (1981) to estimate whether the prices were stationary. For this purpose, equation (1) was used with the E-Viens software, applying the Schwarz information criterion with a maximum lag of 18 (Morais, Stona, & Schuck, 2016).

$$\Delta y_t = \alpha y_{t-1} + x_t'\delta + \beta_1 \Delta y_{t-1} + \beta_2 \Delta y_{t-2} + \ldots + \beta_p \Delta y_{t-p} + v_t \qquad (1)$$

Next, the Johansen and Juselius cointegration test was applied (1990).

3.2.3 Johansen and Juselius Cointegration Test (1990)

This research included the Johansen and Juselius cointegration test (1990). Its objective was to detect whether there was a long-term relationship between the studied time series. To estimate the level of cointegration between the back series, we used the method pioneered by Johansen and Juselius (1990) to estimate the trace test (λ_{trace}) and the maximum eigenvalue (λ_{Max}) to verify the existence of some linear combination between the variables (Bueno, 2011; Johansen & Juselius,1990).

The trace test was used to measure the presence of cointegration vectors when the null hypothesis indicated that there were at least *r* vectors (Johansen & Juselius, 1990). The trace statistic was represented in the following formula (2), which involved comparing the logarithm value of the model's likelihood function with restriction against the logarithm of the model's likelihood function without restriction (Johansen & Juselius, 1990) when Q was the maximized restricted likelihood function ÷ the maximized likelihood function (Johansen & Juselius, 1990).

$$\lambda_{trace} = -2 log Q = -T \sum_{i=r+1}^{n} log\,(1-\lambda_i) \qquad (2)$$

The maximum eigenvalue test (λ_{Max}) of equation (3) was used to test the null hypothesis of r cointegration relations against the alternative of r + 1 cointegration relationships (Johansen & Juselius, 1990).

$$LR_{max}(r|r+1) = -T log(1 - c\lambda_{r-1} - b) \quad (r|k) - LR_{tr}(r+1|k) \qquad (3)$$

The tests were performed using E-Viens® software. After this brief presentation of the econometric methods used in this study, the next section will be focused on a discussion of the results that were found.

4 ANALYSIS AND DISCUSSION OF RESULTS

In this section, the applications of the proposed methodology in analyzing the hypothesis regarding the efficiency of the market for crystal sugar and hydrous ethanol in Paraíba were

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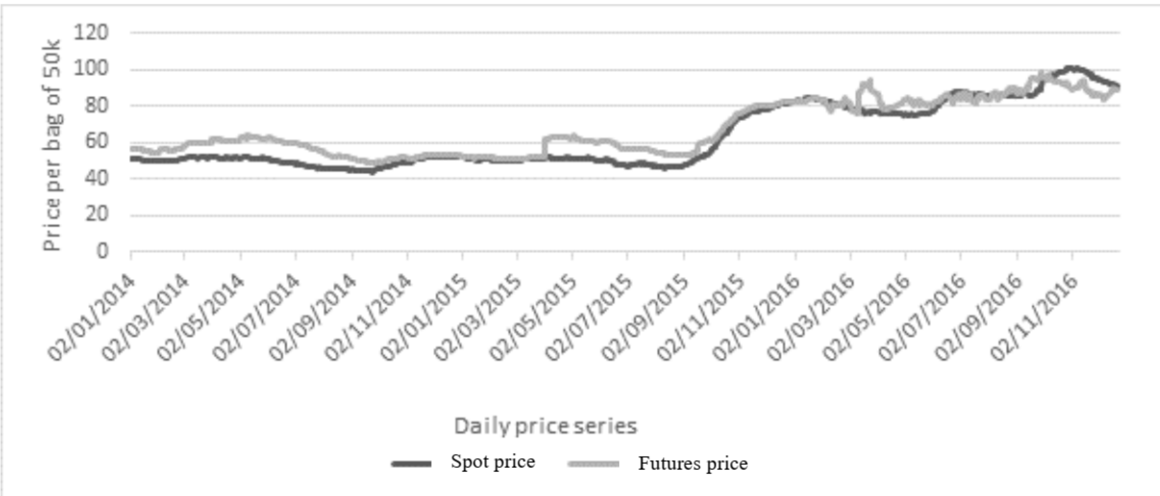
broached. This was initially realized by using Excel to construct graphs of the spot and futures prices to demonstrate their temporal behavior and then, by using the E-Viens® software, which estimated descriptive statistics, performing the ADF unit root test (1981) and the Johansen and Juselius cointegration analysis (1990).

4.1 Time Series of Crystal Sugar Prices in Paraíba

The section covering the results and presentation of the data in this research begins with a demonstration of the behavior of the time series of spot and futures prices of crystal sugar in the Paraíba market.

Figure 1 shows the daily time series from 2014 to 2016 of spot and futures prices for crystal sugar, which are characterized by constant fluctuation.

Figure 1. Daily Series of Spot and Futures Prices of Crystal Sugar



Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

It is possible to observe, in the 2014-2015 period, instances of the sale of crystal sugar in the futures market at values higher than the spot price. In addition, it can be seen that, in the period from October to December 2016, the spot price exceeded the futures price quote. However, regarding the behavior of the time series regarding the price of crystal sugar, there was a 50% increase in the value of the 2015-2016 crop over that of the previous crop.

This increase in the value of crystal sugar in the Paraíba market occurred due to the opening of new sugar markets in the European Union as well as stagnation in the demand for ethanol. This new reality was reflected in the trend of crushing sugarcane to be used in the manufacture of sugar, which was a heated issue at the time (CONAB, 2016).

Table 2 shows the descriptive statistics of the crystal sugar time series. In this study, it was possible to verify the behavior of measures of central tendency and volatility as well as the distribution of the data of spot and futures prices between 2014 and 2016.

Note that the average spot and futures prices in the analyzed period indicate that the prices were dispersed and varied between a minimum value of R$ 44.11 and a maximum one of R$ 100.92 for the spot price, while the futures price had a minimum value of R$ 48.85 and a maximum one of R$ 98.97, which were defined as the standard deviation values of R$ 17.49 and R$ 14.69, respectively.

Table 2 - Descriptive Statistics of the Spot and Futures Prices of Crystal Sugar

	Spot price	Futures price
Mean	63.33380	67.42188
Median	51.77000	61.11000
Maximum value	100.9200	98.97000
Minimum value	44.11000	48.85000
Standard deviation	17.49454	14.69521
Asymmetry	0.624437	0.425908
Kurtosis	1.785034	1.591624
Jarque-Bera-JB	93.09878 (0.000000)	83.07944 (0.000000)
Observation	736	736

Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

In the Jarque-Bera-JB normality test, the series of spot and futures prices indicated that the null hypothesis of normality should be rejected, since the JB statistic was R$ 93.09 for the spot price and R$ 83.07 for the futures price, with respective p-values of 0.000000.

Table 2 shows the asymmetry of the spot price equal to R$ 0.62, indicating an asymmetric distribution on the right, while the futures price is equal to R$ 0.42, showing that the asymmetric distribution tends to the right and left; that is, the data confirm that both series reported a positive asymmetry coefficient. Regarding the distribution of spot and futures prices for the price of crystal sugar, it can be seen in Figure 2.

Figure 2. Histogram of the Spot and Futures Prices of Crystal Sugar

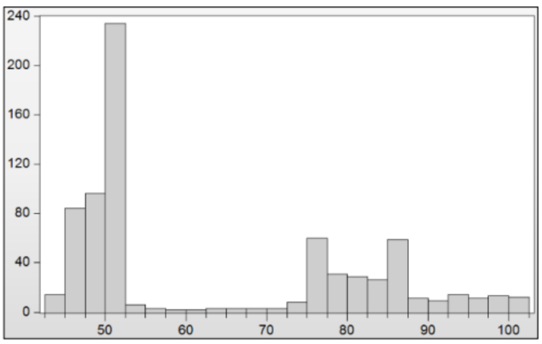


Figure 2a. Spot price of crystal sugar
Source: Prepared by the author based on data from the CEPEA (2018).

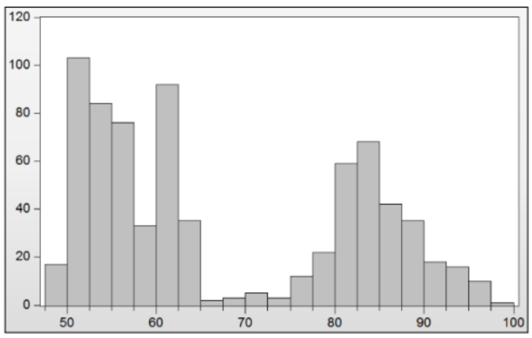


Figure 2b. Futures price of crystal sugar
Source: Prepared by the author based on data from the BM & FBOVESPA (2018).

Thus, it can be seen in Figure 2a that the histogram shows an asymmetry around R$ 50 as well as a distribution that abruptly descends on one side and drops more gradually on the other, producing a steeper descent on the left. This behavior indicates that the average price of crystal sugar was outside the middle of the range. Thus, the anomaly asymmetry was on the right, and the median was below the average.

In Figure 2b, the histogram indicates three peaks with frequencies (R$ 50, R$ 60, and R$ 80) with small, concentrated clusters; that is, it points to a distribution with temporary abnormalities. This means that the abnormality may have been caused by errors in the measurement, registration, or transcription of crystal sugar data by the state.

Thus, the crystal sugar data of the variables displayed in Figures 2a and 2b showed several oscillatory movements with a prevailing tendency toward steep variations in the prices of sugar crystals.

It is important to note that the low and high data points in the series showing the data of crystal sugar in the Paraíba market occurred due to internal and external factors, as explained below: there was excess supply in the international market during the period from 2014 to 2016 and a decline in the sugar and alcohol sector related to the sale of ethanol after the implementation of the gasoline control policy and Decree No. 7.764/2012, in which the CIDE[1] about gasoline was established (Union of the Sugarcane Industry (UNICA), 2014; CONAB, 2016).

In view of this scenario, the sugar and alcohol sector promoted the crushing of sugarcane to be used in the manufacture of crystal sugar, which, in turn, proved to be profitable. At the same time, the surplus created resulted in price fluctuations in the Paraíba market.

To verify the crystal sugar time series hypothesis, the ADF unit root test was performed. The test was used to check the number of unit roots present in the spot and futures price series, as shown in Table 3.

For the analysis, the parameters used in the test included a level test, in which the intercept was included, and the Schwarz information criterion, which was used to calculate the number of lags, with a maximum lag of 18.

Table 3 - ADF Unit Root Test for Crystal Sugar

Variables	Statistic t	P-Value	Critical value: 5%	Critical value: 10%
Spot	-0.509662	0.999223	-2.866296	-2.569362
Futures	0.221776	0.997404	-2.865429	-2.568897

Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

Table 3 shows the following statistical results for the cash market spot variable: the statistical t = -0.50 is greater than the critical values of the levels of significance 5% (-2.86) and 10% (-2.56). The t > critical value, the null hypothesis accepts H_0: δ =0, and there is an indication that the spot price is not stationary.

The futures market variable presented the statistic t = 0.22, which was greater than the critical values of the ADF unit root test at significance levels of 5% (-2.86) and 10% (-2.56). Soon, t > critical value, indicating acceptance of the null hypothesis H_0: δ =0, unit root. Therefore, the price of the futures market is not stationary. Thus, both tested series in the ADF had unit roots with statistics showing that t > the critical values, indicating that the null hypothesis H_0: δ =0 (Dickey & Fuller, 1981) could not be rejected for the variables of the spot and futures prices of crystal sugar in the Paraíba market.

1 Contribution of Intervention in the Economic Domain [CIDE]: federal levy applied to the commercialization of oil and its derivatives, natural gas (except in liquefied form) and its derivatives, and ethanol fuel (MINISTERIO DA FAZENDA, 2018).

In view of the ADF's result, the Johansen and Juselius (1990) cointegration test, which requires that crystal sugar prices be non-stationary, was applied. In this sense, Table 4 presents the cointegration test for the spot and futures prices of crystal sugar in Paraíba.

Table 4 below shows the estimate of the cointegration test using the trace statistics (λ trace) and maximum eigenvalue (λ maximum) to project a hypothesis indicating the presence of the cointegration vector (r) in the cointegration vector r + 1.

Table 4 - Johansen and Juselius Cointegration Test for Crystal Sugar

Variables	Eigenvalue	λTrace test	*λMaximum Statistical*	Critical value: 5%	Critical value: 10%
Spot	0.000452	0.262406	0.262406	3.841466	2.705545
Futures	2.42E-05	0.014061	0.014061	3.841466	2.705545

Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

The screening test of the spot variable indicated a statistical result of (λ trace = 0.26) and e (λ maximum = 0.26), which was less than its critical value (3.84) at a significance level of 5%, showing that the null hypothesis was accepted. In other words, the cash price variable in the Paraíba market did not cointegrate.

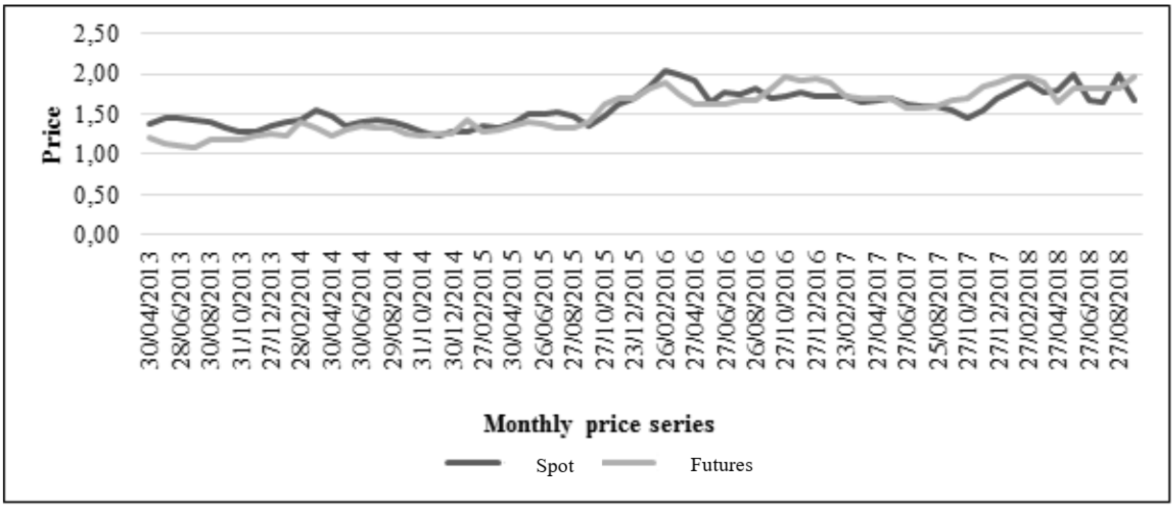
The futures variable pointed to a statistical result of (λ trace = 0.01) and (maximum λ = 0.01), which were less than its critical value (3.84) at a significance level of 5%, implying support for the null hypothesis that there was no cointegration relationship between the variables.

Table 4 shows the results of the statistics by Johansen and Juselius (1990), with the λ trace and maximum λ test, with values less than the critical value at the 5% level. This indicates that there was no cointegration at the 5% significance level; that is, it denotes rejection of the hypothesis. Therefore, it became evident that there was no cointegration vector in the spot and futures market for crystal sugar, indicating that there was no evidence of market efficiency in Paraíba. Next, the analyses of the hydrous ethanol market in Paraíba will be presented.

4.2 Time Series of Hydrous Ethanol Prices (Paraíba's ETH)

The information presented about hydrous ethanol affected the behavior of the time series of spot and futures market prices in the state of Paraíba.

Figure 3. Monthly Series of Spot and Futures Prices of Hydrous Ethanol



Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

Figure 3 shows the monthly time series for the period from 2013 to 2018 quoted on the BM & FBOVESPA futures market and the CEPEA's spot market prices for hydrous ethanol, with oscillatory movements showing downward and upward trends.

Note that, in the illustration, during the period from 2013 to 2014, the price of hydrous ethanol in the spot market closed at a higher price than the futures one. In addition, it can be seen that, in the period from December 2014 to February 2015, the futures price peaked 15% in relation to the spot one.

It is also important to note that, in the behavior of the hydrous ethanol time series, the spot price peaked at 30% in 2016, reaching the highest recorded level in the period studied. However, from December 2016 to April 2018, there was a substantial decrease in the spot price, reaching (-36%) in October 2017. As for the futures price, from 2015 to 2018, there were three peaks, reaching 39% in relation to the quoted price in 2014.

The descriptive statistics of the hydrous ethanol time series are presented in Table 5; using them, it was possible to verify the behavior of the central tendency and volatility measures as well as the distribution of the spot and futures price data in the period from 2013 to 2018.

Table 5 - Descriptive Statistics of Spot and Futures Prices for Ethanol

	Spot	Futures
Mean	1.573939	1.546061
Median	1.560000	1.610000
Maximum value	2.040000	1.980000
Mínimum value	1.240000	1.100000
Standard deviation	0.209041	0.271100
Asymmetry	0.344651	0.021754
Kurtosis	2.227017	1.603982
Jarque-Bera-JB	2.949759 (0.228806)	5.364586 (0.068406)
Observation	66	66

Source: Prepared by the author based on data from CEPEA (2018) and BM & FBOVESPA (2018).

According to Table 5, it is possible to verify that the spot price was around R$ 1.57, the average; the minimum value was R$ 1.24; and the maximum value was R$ 2.04; while the futures price

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pointed to R$ 1.54, the average; the minimum value to R$ 1.10; and the maximum value to R$ 1.98, thus representing a standard deviation of R$ 0.20 and R$ 0.27, respectively.

As for the Jarque-Bera-JB normality test, the series of spot and futures prices indicated little probability; that is, the hypothesis of normality should be rejected. The JB statistics indicated R$ 2.95 for the spot price and R$ 5.36 for the futures one. Regarding the probability, the spot price was 77.11% when the futures one was 93.15%.

In Table 5, the asymmetry of the spot price is equal to R$ 0.32, indicating an asymmetric distribution on the right, while the futures price is R$ 0.02, which shows that the asymmetric distribution tends toward both the right and left, confirming that both series exhibited a positive asymmetry coefficient. Thus, the variables presented a non-normal distribution; that is, the hypothesis of normality must be rejected. The distribution of the time series is shown in Figure 4 below.

Figure 4. **Histogram of the Frequency of Spot and Futures Prices of Hydrous Ethanol**

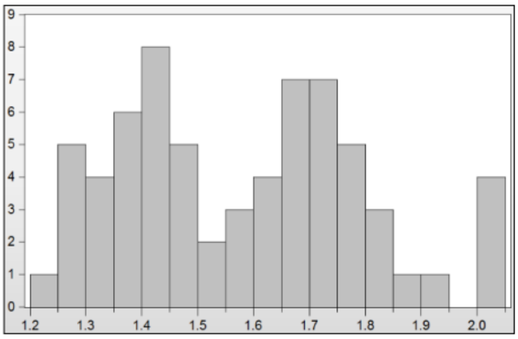

Figure 4a. Spot price of hydrous ethanol
Source: Prepared by the author based on data from CEPEA (2018).

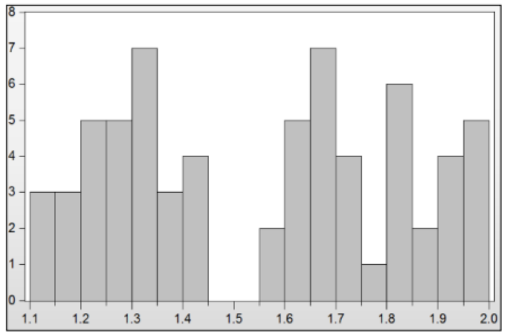

Figure 4b. Futures price of hydrous ethanol
Source: Prepared by the author based on data from BM & FBOVESPA (2018).

Thus, it can be seen in Figure 4a that the histogram shows two peaks concentrated around R$ 1.4 and R$ 1.7 and a low frequency concentration in the other values of the spot price; that is, this trend occurs in situations in which there is a mixture of data with different averages obtained under two distinct conditions.

In Figure 4b, the histogram indicates large, isolated islands with a higher frequency: R$ 1.3, R$ 1.73, and R$ 1.8; that is, the distribution shows three peaks of density, indicating temporary abnormalities, which could have been caused by errors in the measurements, records, or transcripts of hydrous data from the state, producing unique results.

Thus, the hydrous ethanol series shown in Figures 4a and 4b exhibited several oscillatory movements, with a tendency for the low and high variations to prevail in the hydrous ethanol prices in the Paraíba market.

To investigate the hypothesis of the hydrous ethanol time series, the ADF unit root test was performed. The test was used to check the number of unit roots present in the spot and futures price series, as shown in Table 6.

The parameters used in the ADF test were those of a level test, thus it was decided to include the intercept. To calculate the number of lags, the Schwarz information criterion was applied, with a maximum lag of 10.

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Table 6 - ADF Unit Root Test for Hydrous Ethanol

Variable	Statistic t	P-value	Critical value: 5%	Critical value: 10%
Spot	-2.271249	0.935845	-2.906923	-2.591006
Futures	-1.150089	0.959191	-2.906923	-2.591006

Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

Table 6 points to the following statistical results: t (-2.27) was greater than the critical values of 5% (-2.90) and 10% (-2.59), resulting in the acceptance of the null hypothesis H_0: δ=0 of the unit root because the spot price was not stationary.

For the futures market, the statistic t (-1.15) was greater than the critical values at a significance level of 5% (-2.90) and 10% (2.59). Therefore, the null hypothesis H_0: δ =0 of the unit root must be accepted, and the futures price is not stationary.

In conclusion, both series presented a statistic of t > the critical values, meaning that it was impossible to reject the unit root (Dickey & Fuller, 1981). In this sense, the variables of the spot and futures prices of hydrous ethanol in the Paraíba market were not stationary.

According to the ADF's result, the Johansen and Juselius cointegration test (1990) prevailed, which meant that the hydrous ethanol time series was non-stationary.

Therefore, Table 7 presents the cointegration test for the spot and futures prices of hydrous ethanol in Paraíba. The table shows that the cointegration test estimates, using trace statistics (λ trace) and the maximum eigenvalue (maximum λ), imply the presence of the cointegration vector (r) in the cointegration vector r + 1.

Table 7 - Johansen and Juselius Cointegration Test for Hydrous Ethanol

Variables	Eigenvalue	λTrace test	λ Maximum statistical value	Critical value: 5%	Critical value: 10%
Spot	0.036940	2.371263	2.371263	3.841466	2.705545
Futures	0.027979	1.787806	1.787806	3.841466	2.705545

Source: Prepared by the author based on data from the CEPEA (2018) and BM & FBOVESPA (2018).

Table 7 presents the results of the test tracking the variable in sight, indicating a statistical result of (λ trace = 2.37) and (λ maximum = 2.37), which were less than its critical value (3.84) at a significance level of 5%; that is, the null hypothesis must be accepted. Therefore, the cash price variable in the Paraíba market can be affirmed, and there is no trace of cointegration.

The futures variable pointed to a statistical result of (λ trace = 1.78) and (maximum λ = 1.78), which were less than its critical value (3.84) at a significance level of 5%. Thus, the null hypothesis that there was no cointegration relationship between the variables must be accepted.

Table 7 shows the results of the statistics by Johansen and Juselius (1990) for both variables, where the λ trace and λ maximum tests yielded values lower than the critical value at the 5% level. This means that there was no cointegration at the 5% level of significance; that is, there was no long-term balance between the variables of the futures and spot markets. Therefore, it is evident that there was cointegration in the vector in the spot market and the futures one for hydrous ethanol, indicating that there was evidence of efficiency in the Paraíba market.

Within this context, the results found in the present study corroborated those found by Alves, Duarte, and Lima (2008) and Tonin, Parré, and Tonin (2014) regarding ethanol when they stated that the ethanol market in Brazil might not be considered efficient. Another noteworthy aspect of the findings is the results found by Melo, Lima, and Moraes (2006), which counter the evidence of inefficiency in Paraíba's crystal sugar market that was found in this research. This is because Melo, Lima, and Moraes (2006) pointed out that the historical series of crystal sugar provided evidence of efficiency in the Brazilian market; however, in this research, it can be seen that the Paraíba crystal sugar market does not envisage a long-term bias.

5 FINAL CONSIDERATIONS

This study consisted of an investigation of the hypothesis of efficiency in the crystal sugar and hydrous ethanol market in Paraíba through the cointegration test. We chose this market because sugar is an important agribusiness commodity, and the sugar and alcohol sectors are the main global consumers of sugarcane, considering the figures related to the commercialization of the sugar and ethanol markets. Furthermore, in Paraíba, sugar growing is the most prevalent agricultural activity, and the state is the third largest producer of this commodity in the northeastern region.

To verify the market efficiency hypothesis, descriptive statistics, the ADF unit root test, and the Johansen and Juselius cointegration test (1990), were applied to historical data of the spot prices of crystal sugar and those of hydrous ethanol from the domestic and foreign markets of Paraíba.

First, we sought to analyze the behavior of the data series of crystal sugar and hydrous ethanol, which, in general, presented several oscillatory movements with a tendency toward low and high prices in the market during the period studied. Subsequently, the stationarity of the analyzed variables was assessed through an augmented unit root test, Dickey and Fuller's ADF (1981). In this way, the ADF test for crystal sugar and hydrous ethanol presented a unit root, with a statistic of t > the critical values, meaning that it was impossible to reject the null hypothesis, H_0: δ = 0, for the price variables spot and futures of crystal sugar and hydrous ethanol in the Paraíba market, denoting a non-stationary root.

Regarding the cointegration test, the variables addressed in the research were estimated to verify whether two or more economic variables were synchronized in the long term, using the methodology of Johansen and Juselius (1990), which included statistical tests of screening and the maximum eigenvalue. The results showed that, for crystal sugar and hydrous ethanol, there was no possibility of cointegration at the significance levels of 5% and 10%, which implied rejection of the hypothesis. In this sense, it was evident that, for both variables, there was no cointegration vector, confirming the assumption that the commodity market for crystal sugar and hydrous ethanol in Paraíba was inefficient.

Therefore, it can be concluded that the price of commodities, such as crystal sugar and hydrous ethanol, in Paraíba can deviate from the real market value. However, in the case of an inefficient market, as was found in this research, it should be noted that the ability to correct its issues depends on clarifying agreements between investors and producers regarding the terms of negotiations, examples of transaction costs (size, price/profit indices, price/book value, and time (off-season and weekends)).

From another perspective, it can be concluded from the results obtained in this research show that there is a need to carry out studies that can be used to improve market efficiency in the commercialization of agricultural commodities, since the existence of multiple econometric tests, including the Engle and Granger (1987) and Philips and Ouliaris (1990) cointegration tests, Self-Regression Model (VAR), Ordinary Least Squares Model (OLS), and so on can contribute to verifying whether there is a long-term relationship between various time series.

In the unfolding of this research, some limitations were evident during the exploratory phase, such as restrictions on the period when data on crystal sugar and hydrous ethanol were available at the CEPEA and BM & FBOVESPA, mainly in relation to the cash price and futures variables of the Paraíba market. This restriction limited the research during the period that was analyzed.

Thus, regarding futures research, it was identified that there is a need for research on the market efficiency of sugar and alcohol commodities in the northeast Brazilian market and a need to analyze market efficiency from the perspective of cointegration in northeast Brazil, verifying the role of the three main producers, Pernambuco, Alagoas, and Paraíba, and applying methodologies such as the ADF unit root test (1981), or that of Philips and Perron (1988), as well as the cointegration tests of Engle and Granger (1987), Johansen (1988), and Philips-Ouliaris (1990), to evaluate which of these methods can most effectively improve the region's market's efficiency.

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1. Definition of research problem	√	√	√
2. Development of hypotheses or research questions (empirical studies)	√	√	√
3. Development of theoretical propositions (theoretical work)	√	√	√
4. Theoretical foundation / Literature review	√	√	√
5. Definition of methodological procedures	√	√	√
6. Data collection	√	√	√
7. Statistical analysis	√	√	√
8. Analysis and interpretation of data	√	√	√
9. Critical revision of the manuscript	√	√	√
10. Manuscript writing	√	√	√
11. Other (please specify)			