Rivista di Economia Agraria, Anno LXXI, n. 3, 2016: 197-224

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Keywords: Price transmission, Soybeans, Bran, Soybean oil, TVEC

JEL Code: G13, C58, Q17

Restrictions for biodiesel markets growth: an analysis of transaction costs and price transmissions of soybeans from the US to Brazil

The present study is aimed to analyze the price transmission of soybeans commodities, the main input for production of biodiesel in Brazil. Our goal was to capture the presence of transaction costs in markets of soybean from a dynamic perspective in the presence of the Law of One Price (LOP). Statistical tests and Vector Error Correction (VEC and TVEC) models were estimated. The results indicated that 1) over the long term, the prices of soybeans and soybean bran quoted in the city of Oeste, Passo Fundo and Rondonópolis tend to follow the changes in commodity price quoted in the CBOT 2) the prices for soybean oil were relatively protected. Also, to developing biodiesel markets in Brazil is necessary minimize the environmental impact of soybean cultivation, mainly on Amazon and Cerrado biomes.

1. Introduction

In recent decades, Brazilian agribusiness has made advancements both in the quality and quantity of products. It was primarily motivated by the production and exportation of certain commodities, especially soybean and its derivatives, which have acquired increasing importance in the world scene. This excellent performance has placed agribusiness as one of the most dynamic sectors of the economy and the largest generator of a positive balance or trade surplus. In the recent years, it was pushed by the production of biodiesel. Around 45% of the energy consumption and 18% of the fuel consumption in Brazil is from renewable resources (Agênca Nacional do Petróleo – ANP, 2015).

The concept of agribusiness in Brazil emerged in the 1980s, with the expression "Agro-Industrial Complex", which evolved later into agribusiness. According to the Ministry of Agriculture, Livestock, and Food Supply (Ministério da Agricultura Pecuária e Abastecimento - MAPA), agribusiness can be understood as the productive chain that includes the manufacture of raw materials, through production in agricultural businesses and through transformation until its final consumption. Agribusiness also incorporated the activities of research, processing, transportation, commercialization, credit, expor-

DOI: 10.13128/REA-20568
ISSN (print): 0035-6190
ISSN (online): 2281-1559

tation, distribution (dealers), exchanges, and consumption. The complex can be characterized by five markets: supply, production, processing, distribution, and final consumption (MAPA, 2014).

Currently, Brazil is considered one of the most important countries in terms of agribusiness. According to the Ministry of Development, Industry, and Foreign Trade (Ministério do Desenvolvimento, Indústria e Comércio Exterior – MDIC), the country has 22% of the world's arable land, a diversified climate, regular rain, abundant solar energy, and almost 13% of all the fresh water on the planet. Besides it, the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA) and the Brazilian National Biodiesel Program (Programa Nacional de Produção e Uso de Biodiesel - PNPB) has made Brazil the owner of the best technology in production of biodiesel of the world, helping to introduce high technology in rural areas, by producing specialized scientific knowledge. These factors render Brazilian agribusiness a modern, efficient, and competitive sector on the international scene.

In terms of the soy complex and its indicators of production, productivity, and cultivated area in Brazil, embracing the steps from the domestic growth for commercialization of the grain to its transformation into bran or oil, all demonstrate high performance. Soybeans are the principal oilseed cultivated and produced in the world, given that it is the grain with the highest production capacity of vegetable oil. In this context, soy is consumed or exported, being an important raw material in the production of animal feed due to its high protein content (40%), and its vegetable oil is also used as biodiesel.

In this sense, the Law nº 11.097, published on January 13th of 2005, introduced the biodiesel in the Brazilian Energetic Matrix and amplified the actuation field of the National Petroleum Agency (Agência Nacional do Petróleo – ANP), that was renamed as National Petroleum, Natural Gas and Biofuels Agency. In comparison with diesel produced from petroleum, biodiesel had environmental advantages in terms of its impacts: reduces lifecycle greenhouse gases by 86%, lowers particulate matter by 47% and reduces hydrocarbon emissions by 67% (National Biodiesel Board, 2012).

Environmental commodities, among them the oilseeds like soybeans, play a prominent role. They are goods that originate from natural resources in sustainable conditions and are important inputs for the maintenance of agriculture and industry. In Brazil, for example, the main input for production of biodiesel is soybean, followed by palm, sunflower, babassu, peanut, castor and animal fat. Regardless, agribusiness and commodities are characterized by their cyclical behavior as a result of various factors of the market and of nature. Therefore, price volatility is an important characteristic.

The relationship between prices charged in various biodiesel markets depends on the opportunities for long-term arbitrage. If it is inexistent, the Law of One Price (LOP) goes into effect. In other words, in the absence of transaction costs, the prices of homogenous products have the tendency to converge. Nonetheless of the market in which it is traded, there will be incentives for this to occur because, if the price in one market is higher than in another, an instantaneous opportunity exists for profit due to the purchase of the product in the lower-priced market and its sale in the higher-priced market. Because this is a dynamic in which the operation of arbitrage is reproduced recursively, the prices of all the markets tend to converge to a singular value.

By contrast, in the presence of transaction costs, this logic rarely changes because the agents only arbitrate if the earnings are greater than the costs. Thus, as the transaction cost between two markets increases, the lower the dependence between its prices is. In the soy complex, a higher level of correlation between the commodity prices traded on the CBOT and the prices charged on the spot market in the domestic market is expected. It should be noted that these costs, when excessively high, can harm the commercialization of the good, by inhibiting the economic profit incentives. In this context, methodologies that use time series data, for example, to provide information on the magnitude of these costs, can be very useful in decision making.

The hypothesis adopted in this research is that the positive or negative variations in the prices of commodities traded on the CBOT are transmitted to the domestic spot markets, characterizing a long-term relationship. This supposition is based on the LOP, which postulates that homogenous goods, sold in various locations where free competition and freedom from barriers prevail, should be quoted at the same price, in the same currency. By estimating some parameters, known as threshold, we can measure transaction costs in soy markets, which could be understood as restrictions to development of the biodiesel market in Brazil.

Thus, the present study is aimed to analyze the transmission of prices of soybeans, soybean bran, and soybean oil priced on the CBOT to the spot prices in some Brazilian cities as Oeste, state of Paraná-PR; Passo Fundo, state of Rio Grande do Sul (RS); Rondonópolis, state of Mato Grosso (MT); and São Paulo, state of São Paulo (SP) during the period from August 2007 to November 2015. Aiming to estimate the empirical analysis of cointegration between prices, stationary, unit-root, and cointegration tests will be applied to the price series quoted.

Hansen and Seo (2002) tests will be performed to test the statistical significance of the threshold effect, and the Vector Error Correction (VEC) and the Threshold Vector Error Correction (TVEC) models of the two regimes will be estimated, allowing an examination of the relationship between long-term and short-term prices. Our main hypothesis is that besides Brazil is the worldwide leader country in terms of soybean production, the prices are determined in

CBOT, US. This way, our findings will offer some empirical evidence about how they are affected: positively or negatively, and if the relations are ruled by short or long term effects. Precisely, we will estimate threshold parameters which will represent the presence of transactions costs on this market, and therefore restrictions for biodiesel markets growth.

This research is structured in seven sections. In addition to this introduction, in the second section we describe the relationships between the Brazilian soy complex, biodiesel production, and offer some empirical evidence from previous studies. In section three we specify the methodological procedures. The following section describes the data and sample used. In the five section we analyze the results obtained and in the last section some conclusions are presented.

2. Brazilian soybean market, price transmissions and empirical evidence

Currently, production has hit a record of 75,324.3 thousand tons of soy, which, according to the USDA report (2013), means that, if this volume for the 2012/2013 harvest is confirmed, Brazil would, for the first time, lead the world's soy production. The advance in the cultivated area of soy made Brazil reach a grain volume that it has never before achieved. Part of the explanation lies in the good market prices in recent years, which producers who have invested more in technology have capitalized on. In this harvest, 27.6 million hectares were sown, 2.6 million more than in the previous. This difference should increase production by 17 million tons, which will add up to 83,400 thousand tons. The U.S., the main global producer, produced 82.1 million tons in this same period.

According to the Brazilian Association of Vegetable Oil Industries (Associação Brasileira das Indústrias de Óleos Vegetais – ABIOVE), in the year 2013, Brazil grasped R$ 30 billion in soy exports, including grain, bran, and oil. According to MAPA (2014), in terms of Brazilians exportations, soy represents 31% of the agribusiness exportations. The insertion of the Brazilian soy sector into the world economy confers great dependence on the product's price to the external market.

Accordingly to Bentivoglio, Finco and Bacchi (2016) in the middle of 2000s the worldwide price boom of foodstuffs affects specially the agricultural commodities. They pointed that prices were stable until the end of 2006. While from 2007 to 2008 they increased more than two times. In 2009 they declined again and reaching 2006 levels. The authors also observe that in the second half of 2010 prices increased again, followed by a slight fall in 2011. As results, biofuels may impact on both renewable and non-renewable resources and, for instance, have effects on its sustainability and that of food.

In Brazil, price transmissions in the soy market have been examined across several studies, such as those by Pino and Rocha (1994) and Margarido and Sousa (1998), for example. In the studies that analyze data from the 1990s and 2000s, results show that variations in international prices influence prices in the domestic market (Costa *et al.*, 2006; Giembinsky and Holland, 2003; Tonin and Barczsz, 2007).

Pino and Rocha (1994) examined the price transmission of soybeans received by the producer on the domestic market, represented by the city of Canoas (RS), and on the foreign market, represented by the prices charged on the Chicago Board of Trade (CBOT) – the prices of soybean bran and soybean oil received by the industry in the domestic market in São Paulo and in the foreign market by the CBOT. The authors used transfer function models (Baillie, 1980) relating to the prices received by soy producers and those received by the Brazilian industries with the prices charged on the CBOT. The results showed that the elasticity of price transmissions of soybeans increased from 1985-1987 to the second period (1988-1990).

Margarido and Sousa (1998) conducted an analysis to identify how the price of soy in the CBOT influences the prices charged domestically in Brazil and in the state of Paraná. The authors used average monthly prices between 1987 and 1997 and applied analyses of autocorrelation and partial autocorrelation functions. The study identified whether the generating process was autoregressive and/or a moving average, and to measure the price transmissions, a distributed lag model was adopted. The results showed that variations in soy prices in the United States were transmitted instantaneously, without lags, to the prices received by grain producers in Paraná; however, only a fraction of this total was transferred to domestic prices. Additionally, the domestic price of soy was influenced by the variations that occurred on the international market, i.e., the country was not the price-setter of this product but a price-taker in the foreign market.

Based on a broader analysis, Câmara *et al.* (2000) analyzed the system of soy price formation in Brazil. The authors used the soy price in the Brazilian spot price market, the soy price in the domestic futures market quoted on the former Commodities and Futures Exchange (Bolsa de Mercadoria & Futuros – BM&F), now called BM&FBovespa, the future soy price quoted on the CBOT, and the domestic exchange rate. A vector autoregressive (VAR) model with 12 lags for each variable was estimated. Granger causality tests were also performed to establish the relationships of causality between the variables. Finally, the impulse-response functions of the variables in the VAR system based on the shock in the residues of the variables were presented.

Goodwin and Piggott (2001) were the pioneers in using threshold cointegration models applied to price transmissions in commodities markets.

The authors estimated price transmissions between daily corn and soy prices among different U.S. cities. The analysis was based on the cointegration between markets and did not take into consideration the presence of transaction costs. Linear and threshold autoregressive models were estimated to model differences in prices between cities and the remainder of the linear regression between the prices of the two cities as a representation of the terms of error correction. Then, the authors also tested whether the remainders of the regression have non-linear behavior using the Tsay's test (1989). The results of the study by Goodwin and Piggot (2001) showed that the markets in question are highly integrated. Additionally, the analysis points out that the threshold effects were significant and, moreover, could influence the relationship between prices in different cities.

Margarido, Turolla, and Fernandes (2001), for instance, analyzed the elasticity of price transmission in the soybean market between the Port of Rotterdam and Brazil between July 1994 and September 2000. The authors used three series with monthly periodicity: the CIF (cost, insurance, and freight) price of soybeans in Rotterdam, the FOB (free on board) price of soybeans in Brazil, and the nominal exchange rate. After the performance of unit-root and cointegration tests, a VEC model was estimated to measure the effect of the variables on each other. Their results indicated that, over the long term, soy prices in Brazil tend to fully follow the changes in prices in Rotterdam and in the nominal exchange rate. Additionally, over the short term, the prices of agricultural commodities responded more to conditions of demand rather than to the nominal exchange rate.

Costa *et al.* (2006) analyzed soy price transmissions between the Brazilian and U.S. markets. The authors used the soybean prices charged on the physical Brazilian and U.S. markets for the period from January 1995 to January 2005. They applied the cointegration test of Engle and Granger (1987) to verify the price transmission domestically, and it was ascertained how the prices are transmitted within Brazil. The results suggested the possibility of long term equilibrium between the prices traded in Brazil and those in the United States. Additionally, the analysis of price transmission was conducted domestically. The authors also observed that the commercial policy adopted in Brazil did not seem to be very distant from the validity of the LOP in the international soybean market because, over the long term, approximately 57.3% of the price variations of these products in the United States were transferred to the domestic prices in Brazil.

In Giembinsky and Holland (2008), it was necessary to use the VEC method due to the presence of cointegration. The authors encountered difficulties in the analysis of causality of external prices on domestic prices. Although this direction of causality was to be expected based on the market, causality was found in both directions, despite the attempt to alter the lags. In a recent study, Paz, Freitas, and Nicola (2009) investigated soy price transmission between Brazil and the international market and, also, between the state of Rio Grande do Sul and Brazil.

This last authors also performed unit-root tests because, generally, the price series are of type I(1), i.e., the temporal processes are only stationary in the first difference. After the performance of causality and cointegration tests, the authors chose to adopt a VEC model to verify how price transmission occurs in Brazil. For the data sample employed, the study showed a result in which the soy market in Rio Grande do Sul seemed to be integrated into the national market; however, the international market did not seem to have this same level of integration with the national market, i.e., the external variations of prices did not seem to be transmitted completely to the national prices. The authors attributed this result to the mismatch of the periods with greater or lesser supplies of grains between the two territories.

The results support Margarido and Sousa (2012), because the commodity is primarily negotiated on the Chicago Board of Trade (CBOT), U.S, thus, the major impacts of the expectations and in the movements of the market emerged in U.S. With the exception of certain specific periods, the prices of soy in Brazil have followed such prices, in line with the U.S. importance as referential role in the prices of the entire global market. Commodities are standardized goods and are a low value added. Derived from different products and commercialized on a global scale, they have practically inelastic supply and demand over the short term.

Silva, Frascaroli, and Sobel (2013) analyzed soy price transmission between different municipalities of Mato Grosso, considering the presence of transaction costs. To capture the presence of transaction costs on soy price transmission in the physical market of Mato Grosso, the authors estimated threshold-type models of three regimes. The Self Exciting Threshold Auto Regressive (SETAR) models supplied results with three regimes that corroborated the existence of a "neutral band". In addition, the threshold parameters estimated in this work appeared to have a significant positive correlation with the transportation cost. Furthermore, the results estimated from the TVEC model did not indicate the existence of a neutral band. Nonetheless, in the majority of cases, TVEC also managed to capture the existence of transaction costs.

By using the VECM, Bentivoglio, Finco and Bacchi (2016) studied the relationships between weekly prices of ethanol, sugar, and gasoline in Brazil between November 2007 and November 2013. The modeling was supported by Granger Causality tests, impulse response functions and forecast error variance decompositions. Their results propose that ethanol prices are affected by both food and fuel prices in the long run by equilibrium parity. They show that ethanol prices increase with rise in both gasoline and sugar prices. Precisely, they estimate a positive relationship between ethanol and sugar prices, given the influence of feedstock costs within the total costs of producing ethanol (60%). They also reported that gasoline prices may affect ethanol prices.

It is important to increase the production of energy from renewable resources. As pointed before, 18% of the fuel consumption in Brazil is from those renewables ones. In terms of technology and other sources, as for example, based on wind power or solar energy, Brazil is paradox. It holds the comparative advantage, but still not makes progress on competitive advantage. China and Germany as leaders of solar energy producers are an example of it. The Figure A.1 in the Appendix illustrates how soy complex works for biodiesel production, including the transesterification unit.

On the other hand, biodiesel production by using soybean could generate environmental problems, land concentration, impacts on infrastructure choices, besides the genetically modified (GM) crops impacts, as well (Fearnside, 2001; Brookes and Barfoot, 2005; Hill *et al.*, 2006; Vera-Diaz, Kaufmann and Nepstad, 2009; Bentivoglio *et al.*, 2014; Bentivoglio and Rasetti, 2015). Some authors point to soybeans as a powerful threat to tropical biodiversity in Brazil.

One example is the road project of Cuiabá-Santarém, that would generate a net loss of between $762 million and $1.9 billion. This because the investments in infrastructure would generate more than $180 million for soybean farmers over a period of twenty years, but the project ignores the environmental impacts. If the destruction of ecological services and products provided by the existing forests is accounted, we have a massive loss of resources (Vera-Diaz, Kaufmann and Nepstad, 2009).

This result shows the importance of including the value of the natural capital in feasibility studies of infrastructure projects to reflect their real benefits to society as a whole. For instance, these conditions affect negatively the biodiesel production. When analyzed through the agribusiness point of view, we reported that productivity has increased in the last years, but it is necessary to observe if this activity is substituting native vegetation in directions of lands of the Amazon and the Brazilian Cerrado.

Besides it, soybean culture is positively correlated to land concentration. And this is important in terms of barriers to family agriculture development (Bentivoglio *et al.*, 2014). Another question is concerning the GM crops. Brookes and Barfoot (2005) argue that this technology has reduced pesticide spraying in 172 million kg and decreasing the environmental footprint associated with pesticide use, by 14%. It has also significantly reduced the release of greenhouse gas emissions from agriculture, which is equivalent to removing five million cars from the roads.

On the other hand, Bentivoglio and Rasetti (2015) suggest that changes in biofuel prices have little impact on food prices and that the impact of an increasing production of biofuel on food prices is not negligible. According to Hill *et al.* (2006) biodiesel provides sufficient environmental advantages to merit subsidy, i.e., it affords a net energy gain, is economically competitive, and could be produced in large scale, without decreasing food supplies. Beyond the problems which could born in soybean's price dynamics, measured in the present work, sustainable growth of the biodiesel production has to balance the phenomenon mentioned and find the corrects incentives among them.

3. Methodology

3.1 Cointegration of prices and the Law of One Price (LOP)

The Law of One Price (LOP) is based on the logic of the absence of opportunities for long-term arbitrage. This law refers to a situation in which homogenous goods are traded at the same price, even in different locations. However, the law takes into consideration that the prices are in the same currency, there is an absence of transport costs and barriers to commerce, and trade occurs in free markets. That is, in the absence of transaction costs, a given product always converges on the same price, regardless of the market in which it is traded. However, if the price in one market is higher than in others, there is an instantaneous opportunity for profit, which will consist in buying the product in the lower market and selling it in the higher market.

To the extent that this arbitratge operation is repeated, the prices in all the markets tend to converge on a singular value, exactly as described by the *tâtonnement* process (Walras, 1874). In the existence of transaction costs, this logic is altered slightly. In this case, the agents would only perform the arbitrage operation if the revenue obtained was greater than the cost. Thus, the greater the transaction cost between the two markets, the greater the independence between the prices achieved in both.

Thus, for the strategy to achieve the goal of illustrating the functioning of the LOP, threshold models are used to attempt to capture the effects of transaction costs because, as stressed by Goodwin and Piggott (2001), market integration tests that ignore the existence of transaction costs can create flawed interpretations.

Being a simple trade model between two countries or regions, the trade of a homogenous product occurs in the same currency and adheres to the microeconomic axioms present in transactions. When considering a closed economy, the equilibrium between supply and demand determines the price and the quantity of equilibrium of a given product. However, when analyzing the integration between regions across commercial relationships, the force of LOP can occur, involving the following:

$$P_{it} = P_{it}^{*}\theta_t \tag{1}$$

where P_{it} is the domestic price of the product i in the period t; P_{it}^{*} is the world price of the product i in the period t; θ_t is the normal exchange rate in the period t; and ε_t is an independent and identically distributed (i.i.d.) error:

$$P_{it} = \alpha + \beta P_{jt} + \varepsilon_t \tag{2}$$

where P_{it} and P_{jt} are the prices of a given product in two regions i and j, respectively, in a given period of time t; α = constant (or intercept); and β = elasticity of price transmission.

It should be noted that studies on price transmission apply to markets that are strongly cointegrated. The cointegration between the markets, however, does not necessarily need to be linear. The threshold form, introduced by the seminal work of Balke and Fomby (1997), is also used to model and explain price transmission between different markets. There are still few studies applied to the Brazilian data on price transmission with threshold cointegration. Thus, the identification between these markets is important to increase export performance.

3.2 Cointegration with VEC (Vector Error-Correction) and TVEC (Threshold Error Correction) models

Engle and Granger (1987) introduced the concept of cointegration, and since that time, it has been widely used in temporal series analyses. It refers to the existence of a long-term relationship between economic variables. In other words, two or more variables are cointegrated when a linear combination exists between them that is stationary, although, individually, the variables are not stationary. Statistically, a temporal series is stationary when its mean, variance, and covariance do not vary over time. In this case, the series is denominated by I(0), signifying that it is integrated of order zero. The order of integration is the number of times that a specific variable is differentiated to achieve stationarity. A series that needs to be differentiated once achieved stationarity is denominated by I(1).

In light of this concept, the first procedure in the present study, aiming to analyze price transmission from the futures market (CBOT) to the *spot* market of soybeans, soybean bran, and soybean oil sold in the markets of Oeste-PR, Passo Fundo-RS, Rondonópolis-MT, and São Paulo-SP, was performed to ascertain the stationarity of the presence of unit-root in the price series, i.e., to verify whether the series were integrated of the same order. To obtain the confirmation of the presence of the unit-root, the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test were applied, both in the level and in the first difference. Moreover, to confirm stationarity, the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test was applied. According to Kwiatkowski *et al.* (1992), the ADF test exhibits unit-root as a null hypothesis, while the KPSS test has the presence of stationarity as a null hypothesis.

The second procedure executed to analyze price transmission of soybeans, soybean bran, and soybean oil between the futures and spot markets was to apply the Johansen and Juselius (1990) cointegration test, which aimed to identify the presence of a vector of long run relation between variables.

The third procedure performed was to verify the best model to be adopted for the price series. To that end, the Hansen and Seo (2002) test was applied to the series pairs of prices of soybeans, soybean bran, and soybean oil to test the linearity of cointegration. The null hypothesis is that last one is linear (VEC), against an alternative hypothesis of threshold cointegration (TVEC) of two regimes. In the present study, the results of the test demonstrated that VEC should be used for some price series and TVEC should be used for other price series. Thus, the fourth procedure executed in the present study was to estimate the VEC and TVEC models of the two regimes.

Krishnakumar and David Neto (2009) propose that VEC becomes important by allowing for the connection between aspects related to short-term dynamics and those of long-term stochastic processes. Thus, models of error correction aim to provide a path that combines the advantages of modeling stochastic processes both on the level and in differences. In an error-correction model, the dynamics of the process both in short-term and in long-term adjustments are modeled simultaneously.

According to Johansen and Juselius (1990), when there is cointegration between prices, an equivalent representation in terms of VEC exists, as specified by equation (3):

$$\begin{cases} \Delta Y_t = \alpha_1 + \beta_1 \Delta X_t + \alpha_2 u_{t-1} + \varepsilon_t \\ \Delta X_t = \alpha_1 + \beta_1 \Delta Y_t + \alpha_2 u_{t-1} + \varepsilon_t \end{cases} \tag{3}$$

where the term Δ indicates the first difference; Y_t is the spot price of soy; X_t represents the future price of soy; $u_{t\text{-}1}$ is the lagged error term in a period; and α_1 and α_2 are the parameters.

Equation (3) relates the variation of Y_t with the variation in X_t and the error in the previous period. In this equation, ΔY captures the short-term disturbances, while the error term captures the adjustment for the long-term equilibrium. If it is statistically significant, then the portion of the disequilibrium that is corrected in the following period can be verified. According to Harris (1995), the values of the coefficients of the parameters α_i demonstrate the speed of adjustment of the respective variables in the long-term correlation.

The study of threshold cointegration was initially developed by Balke and Fomby (1997) as a means to combine long run relations and non-linearity. Hansen and Seo (2002) argued that TVEC models were also developed to incorporate the effects of transaction costs into price transmission models, producing several applied studies.

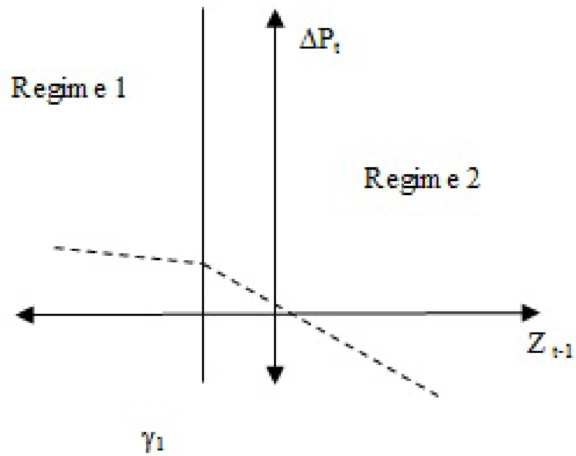
Similarly, Mattos *et al.* (2010) note that, in analyses of market integration, the TVEC model is based on the autoregressive structure of the process of price adjustment between markets, thus representing a form of incorporating non-linearities that are attributed to the presence of transaction costs. In the TVEC model, the extent to which long-term equilibrium shifts are responsible for price adjustment depends on the magnitude of such shifts. Thus, the process of adjustment can be different, depending on whether the shift is above or below a specific value, i.e., a threshold. Below is equation (4) of the representation of the TVEC model of two regimes:

$$\Delta P_t = \begin{cases} \mu^{(1)} + \sum_{i=1}^{k-1} \Gamma_i^{(1)} \Delta P_{t-i} + \alpha^{(1)} Z_{t-1} + v_t^{(1)}, & se\ Z_{t-1} \leq \gamma_1 \\ \mu^{(2)} + \sum_{i=1}^{k-1} \Gamma_i^{(2)} \Delta P_{t-i} + \alpha^{(2)} Z_{t-1} + v_t^{(2)}, & se\ Z_{t-1} > \gamma_1 \end{cases} \tag{4}$$

where P_t is the vector of the natural algorithm of prices in each of the two markets; Δ is the operator of first difference; $\mu^{(1)}$ are (2x1) column vectors of constant terms; $\Gamma_i^{(1)}$ (*i=1,2,...*) are (2x2) matrices of parameters; $\alpha^{(1)}$ are (2x1) column vectors of the coefficients of adjustment; Z_{t-1} are the shifts in the long-term relationship between the price pairs, lagged in a period, used as error correction terms; $v_t^{(2)}$ is the (2x1) column veor of the error term; k indicates the number of lags of the vector P_t; i=1 indicates the price adjustment regime; and γ_1 the *threshold* parameter that delimits the adjustment regimes.

Equation (4) represents a threshold model with two regimes, defined by the value of the error correction term. The matrices of coefficients A_1 and A_2 govern the dynamics in these regimes. In the equation regime 1 demonstrates how the process of price adjustment in period t occurs, when the shift in rela-

Fig. 1. Impact of the error correction term (ECT) on price adjustment for the model with a threshold



Source: Prepared from Mattos et al. (2010).

tion to the long-term equilibrium in period (*t-1*), in terms of absolute value, is equal to or lower than the parameter γ_1. Thus, in this regime, on the basis of transaction costs, prices do not respond to shifts in the long-term equilibrium but do respond to short-term variations, i.e., across lagged variables.

In regime 2, the process of price adjustment is given in period *t*, when the shift in the relationship to long-term equilibrium in the period (*t-1*), in an absolute value, is greater than the parameter γ_1. In this regime, both the lagged short-term variables and the shifts in long-term equilibrium affect price formation. Figure 1 illustrates the price adjustment process.

At this stage, the threshold parameter, which will determine the thresholds between the price adjustment regimes, was estimated. After determining the threshold parameter, its statistical significance was tested at the 90%, 95%, and 99% confidence levels. In the Hansen and Seo (2002) test, the null hypothesis of linearity was tested against the alternative hypothesis of non-linearity with threshold.

3.3 Estimation of the threshold parameter

In the TVEC model, the sample is divided into subgroups, and the criterion adopted in this division is the value assumed by the threshold variable. In the present study, the parameter threshold γ_1 represents the transaction cost pairs of soybeans, soybean bran, and soybean oil. If the value of γ_1 is known, then the estimation of the model exhibited by equation (4) is performed through the method of Ordinary Least Squares (OLS). However, as in the case of the present study, the threshold value is unknown. To resolve this impasse, Balke and Fomby (1997) suggest the use of an algorithm that, initially, uses only one threshold parameter to later estimate the second parameter, considering the first threshold parameter fixed. After the estimation of the second parameter, a new estimation of the first parameter is performed, now conditioned on the second, and so on.

Knowing that the threshold model is non-linear, in the present study, the Hansen and Seo (2002) test is used to stress non-linearity. This refers to an F test, having as a null hypothesis that the model follows an Auto Regressive (AR) process and, as an alternative hypothesis, that the model follows a Threshold Auto Regressive (TAR) process. The test's representation is given by the following:

$$F_{jk} = n \; \frac{S_j - S_k}{S_k} \tag{5}$$

where s_j is the sum of the square of the remainder of the TAR(j) model.

4. Data description and sample

The sample for the present study comprised monthly price data on soybeans, soybean bran, and soybean oil quoted on the CBOT and the spot prices in the markets of Oeste-PR, Passo Fundo-RS, Rondonópolis-MT, and São Paulo-SP, corresponding to the period from August 2007 to November 2015, totaling 100 observations. The price series of futures contracts were obtained from the CBOT and reefer to U.S. soybeans from Chicago Soybean futures contract (first contract forward) No. 2 yellow and par, US$ per metric ton.

We also used the spot price series were available from the Center for Advanced Studies on Applied Economics (Centro de Estudos Avançados em Economia Aplicada – CEPEA/ESAQ) (2013). The markets of Rondonópolis-MT, Oeste-PR, and Passo Fundo-RS were selected since they represent the three states that are the largest producers of soy in Brazil. The time period from August 2007 to November 2015 is justified because one of the price series reviews, soybean bran from the market of Passo Fundo-RS, began trading in the spot price market only in this period.

It was necessary to convert the price series of soybeans, soybean bran, and soybean oil obtained from the CBOT from dollar into real. To that end, the commercial exchange rate (R$/US$) supplied by the Institute for Applied Economic Research (Instituto de Pesquisa Econômica Aplicada – IPEA) was used. To analyze price transmission between the futures market and the spot market, combinations of pairs of price series of the futures market (CBOT) with the price series from the spot market were made, as shown in Table 1.

Tab. 1. Series pairs used in the models

Model	Acronym	Type of foreign price	Type of domestic price
1	SoyCBOT – SoyOESTE	Futures price of soybeans on the CBOT	Spot price of soybeans in Oeste-PR
2	SoyCBOT – SoyPASSO	Futures price of soybeans on the CBOT	Spot price of soybeans in Passo Fundo-RS
3	SoyCBOT – SoyRONDO	Futures price of soybeans on the CBOT	Spot price of soybeans in Rondonópolis-MT
4	BranCBOT – BranOESTE	Futures price of soybean bran on the CBOT	Spot price of soybean bran in Oeste-PR
5	BranCBOT – BranPASSO	Futures price of soybean bran on the CBOT	Spot price of soybean bran in Passo Fundo-RS
6	BranCBOT – BranRONDO	Futures price of soybean bran on the CBOT	Spot price of soybean bran in Rondonópolis-MT
7	OilCBOT – OilSAOPAULO	Futures price of soybean oil on the CBOT	Spot price of soybean oil in São Paulo-SP

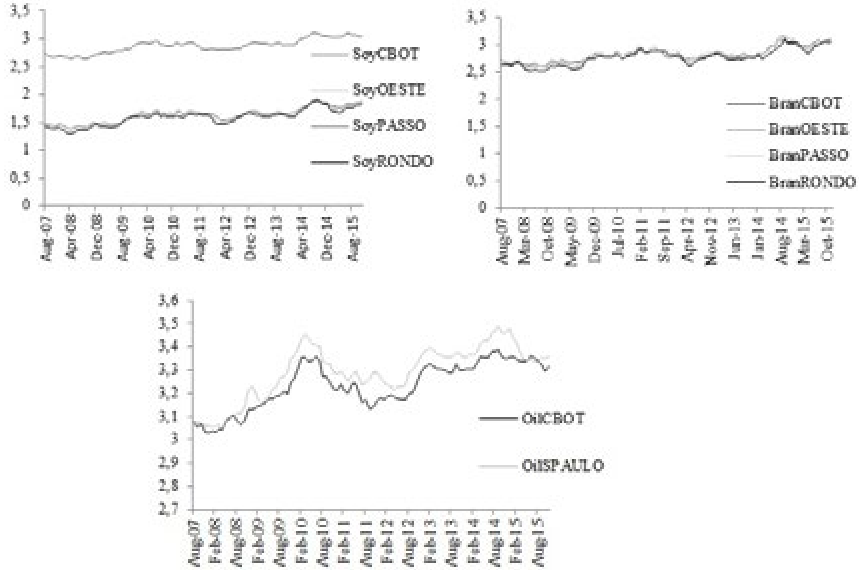
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

Next, the models for these series pairs were entered into the *R* Statistics. Table A.1, in the Appendix, show the descriptive statistics of the data used in R$. The Figure 2 illustrates the sampled time series used in the present work available in first difference. The dynamics of our data sample left no doubts about the long term relation between US commodities prices and the trend of spot prices practiced in Brazilian market of soybean, soybean bran and oil, for any city of our study. This is clear in case of bran, at up right.

In the case of soybean, at up left, is possible to see the difference of almost 1.5%. It is composed of the main costs of carrying position of future contracts and maybe transactions costs. On the other hand, is also possible to verify that for the oil case, the market is more volatile, probably which connected with its aspects of industrialization process of production.

It has already been established in the literature that, as far as the global soybean market is concerned, price discovery occurs on the CBOT and CBOT price shocks spillover into global prices. The literature points to its direction, and we test those findings. However, even making efforts to avoid biased es-

Fig. 2. Dynamics of Sampled time series used available in log returns



Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

timations and bring new results, the dynamics of prices showed in Figure 2 pronounced the following results.

5. Results

To verify the stationarity of the price series, in level and in first difference, the unit-root ADF, PP, and KPSS tests were applied. In the ADF test, the null hypothesis is of the presence of unit-root. Thus, according to the results shown in Table A.2, in the Appendix, as well Tables A.3, A.4 and A.5, we can observe that, in the first difference, all the price series of soybeans, soybean bran, and soybean oil are stationary and that unit-root does not exist because the null hypothesis of the presence of unit-root was rejected at the 5% significance level.

To increase the robustness of the unit-root test, the PP test was performed. In Table A.3 are shown results that were similar to the ADF test, confirming that all the variables I(1) are stationary and that unit-root does not exist because the null hypothesis of the presence of unit-root was rejected at the 5% significance level. Next, the KPSS test, which tested the null hypothesis that the series prices are stationary, was applied. In this manner, the results exhibited in Table A.4 indicated that, for all variables of first difference I(1), the null hypothesis at the 5% significance level should not be rejected. Therefore, in the first difference the price series of soybeans, soybean bran, and soybean oil are stationary.

Using parsimony criteria we performed those estimations with one lag for the short-term dynamics in the error correction models. The number of lags selected follow AIC, BIC, LR tests. As the price series exhibit behavior of stationarity in the first difference and, thus, integrated by order of I(1), the following procedure involved applying the Johansen and Juselius (1990) cointegration test. The results are described in Table A.5, which shows that, for all the series pairs of soybeans, soybean bran, and soybean oil, the null hypothesis of the existences of a vector of cointegration should not be rejected.

Thus, it is concluded that the series pairs of prices are cointegrated, i.e., there are vectors of cointegration between the prices of soy quoted on the futures market (CBOT) and the price series of soy quoted on the spot market in the cites of Oeste-PR, Passo Fundo-RS, Rondonópolis-MT, and São Paulo-SP. This result indicates that the difference between the futures market price and the spot market price in the long term is due to a constant mean.

Subsequently, to ascertain which model was the best model to be adopted, the Hansen and Seo (2002) test was applied to the series pairs of soy prices. It tests the null hypothesis that cointegration is linear against the alternative hypothesis of threshold (TVEC) of two regimes form. Table 2 presents the results obtained in this test.

Tab. 2. Results of the Hansen and Seo (2002) test

Variables	Statistical test	p-value
SoyCBOT – SoyOESTE	2.063.547	0.000
SoyCBOT – SoyPASSO	1.199.593	0.205
SoyCBOT – SoyRONDO	2.208.541	0.002
BranCBOT – BranOESTE	1.696.043	0.018
BranCBOT – BranPASSO	1.391.442	0.092
BranCBOT – BranRONDO	2.086.219	0.001
OilCBOT – OilSAOPAULO	197.127	0.003

Note: *Indicates 1% significance; **Indicates 5% significance; ***Indicates 10% significance.
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

The results of the Hansen and Seo (2002) test support the rejection of the null hypothesis that cointegration is linear for the majority of series pairs of soybean and soybean bran prices. Therefore, it is concluded that, for the first and third pairs of price series, the threshold (TVEC) model of two regimes is more suitable than that of linear models. For the second pair of price series (SoyCBOT–SoyPASSO), the null hypothesis should not be rejected. Summarizing the test indicated that the threshold (TVEC) model of the two regimes was more suitable than the linear models for the following price series: model 1) SoyCBOT – SoyOESTE ; 3) SoyCBOT – SoyRONDO; 4) BranCBOT – BranOESTE; 6) BranCBOT – SoyRONDO; and 7) OilCBOT – OilSAOPAULO. For the models estimated 2) SoyCBOT – SoyRONDO and 5) BranCBOT – BranPASSO, the most appropriate model was the VEC.

The results indicated that, in the long term, the prices of soybeans and soybean bran quoted on the spot market in Passo Fundo-RS tend to follow the price variations of the CBOT, i.e., the long-term disequilibria are quickly corrected. Hence, the process can be represented by a VEC model. For soybean oil, the null hypothesis that cointegration is linear should be rejected. After identifying the best model to be used, the next step was to estimate the linear VEC model for the series pair of prices of models 2 and 5. Table 3 shows the results obtained.

Tab. 3. Estimates of short term and long term VEC coefficients

Variables	Short-term adjustment coefficients (α_1)	Standard Deviation	Long-term adjustment coefficients (α2)	Standard Deviation
SoyCBOT – SoyPASSO	0.0220**	0.0217	0.0290	0.0199
BranCBOT – BranPASSO	0.0169	0.0839	0.2530**	0.0821

Note: *1% parameter significance; **5% parameter significance; ***10% parameter significance

Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

The results exhibited in Table 3 indicate that, over the long term, the prices of soybeans and bran sold in Passo Fundo-RS tended to follow the variations of the CBOT price, i.e., the long-term disequilibria are quickly corrected. Finally, the TVEC model was estimated for models 1, 3, 4, 6, and 7. Table 4 displays the results of the estimation.

It is important to highlight that the coefficients $\alpha^{(1)}$ are associated with negative shocks in the long-term relationship of equilibrium between the futures market and each of the other spot markets, while the coefficients $\alpha^{(2)}$ are associated with positive shocks. Negative shocks ($z_t < 0$) occur when there are increases in the prices on the futures market in relation to the price in the *i*-th city. On the other hand, positive shocks ($z_t > 0$) occur when there are reductions in the prices on the futures market in relation to the prices of the other spot markets.

Tab. 4. Results of the TVEC of two regimes

Variables	Parameter	Regime 1 (down)		Regime 2 (up)	
		Coefficient	Standard Deviation	Coefficient	Standard Deviation
SoyCBOTSoyOESTE	$\alpha^{(1)}$	0.0938	0.1332	0.0272	0.2294
	$\alpha^{(2)}$	0.1752*	0.0032	0.0368***	0.0833
SoyCBOTSoyRONDO	$\alpha^{(1)}$	0.0382	0.4296	0.0207	0.2592
	$\alpha^{(2)}$	0.1073**	0.0318	0.0387**	0.0401
BranCBOT – BranOESTE	$\alpha^{(1)}$	-0.0215	0.7738	0.3591**	0.0330
	$\alpha^{(2)}$	0.2127**	0.0129	0.6006*	0.0017
BranCBOT – BranRONDO	$\alpha^{(1)}$	0.0601	0.7891	0.0808	0.1757
	$\alpha^{(2)}$	0.6808*	0.0081	0.2342*	0.0007
OilCBOT – OilSAOPAULO	$\alpha^{(1)}$	-0.2436**	0.0367	-0.0180	0.8296
	$\alpha^{(2)}$	0.1007	0.4050	0.1171	0.1835

Note: *1% significance, **5% significance, ***10% significance.
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

The results for soybeans demonstrate that, in the spot market for both the cities and the parameters, the $\alpha^{(1)}$ values were not significant. The same occurs for the bran market, with the exception of Oeste in regime 2, where the estimated parameter $\alpha^{(1)}$ was 0.3591. With regard to estimated coefficients $\alpha^{(2)}$ for oil, it was observed that they were not significant. There are positive shocks effects ($z_t > 0$) due to the significance of coefficient $\alpha^{(2)}$, in the long-term relationship of equilibrium between the futures market and the spotted prices quoted in Oeste and Rondonópolis.

The estimations point out that they are greater in Regime 1 and tend to be stronger in the city of Oeste, if compared to those for Regime 2, and with the Rondonópolis case. In this sense Rondonópolis is the city where the prices were more protected from potential price increasing in the futures market for both regimes. This means that in both regimes the spot prices of Oeste are the most affected of our sample by increasing of the future prices of CBOT, if we also compare with the bran cases. This does not happen for the decreasing in CBOT prices, as we can see by the absence of significance of the coefficients $\alpha^{(1)}$ ($z_t < 0$).

Still for soybeans' case, the estimated values indicated that only price reductions that surpassed the limit of 3.87% of the average price of the futures market would be transmitted to the prices charged in Rondonópolis. On the other hand, it was observed that in the soybean market of Passo Fundo the relation are dominated by short term coefficient α_1 of 0.022. In general, the results indicate that there are fewer restrictions on the transmission of futures market relative price increases to this market.

The values of the threshold parameters for this market were -0.4017 for the city of Oeste and -0.3168 for the city of Rondonópolis. Furthermore, for the city of Oeste, the percentage of observations was concentrated at 6.1% in regime 1 and 93.9% in regime 2. For the city of Rondonópolis, the percentage of observations was concentrated at 8.2% in regime 1 and 91.8% in regime 2.

With regard to the bran market, the values of the threshold parameter were 0.12 for the city of Oeste and 0.013 for the city of Rondonópolis. Furthermore, for the city of Oeste, the percentage of observations was concentrated at 86.7% in regime 1 and 13.3% in regime 2. For the city of Rondonópolis, the percentage of observations was concentrated at 11.2% in regime 1 and 88.8% in regime 2. The coefficients estimated are also analyzed for positive shocks effects ($z_t > 0$) due to its significance ($\alpha^{(2)}$) for prices quoted in Oeste and Rondonópolis. The estimations point out that they tend to be stronger in the city of Rondonópolis in both regimes. They also reveal that only price reductions that surpassed the limit of 23.42% of the average price of the future markets would be transmitted.

In the soybean oil market, the values of the parameter $\alpha^{(1)}$ were 0.2436 for regime 1, showing 1% significance. This result suggests that shocks above 24.36% of the average price of the futures market would be transmitted to the spot market in São Paulo. The estimated parameter was 0.013. The percentage of observations was concentrated at 57.1% in regime 1 and 42.9% in regime 2. Thus, it is concluded that the threshold (TVEC) model of two regimes is more pertinent.

In resume, the threshold parameters estimated suggest the presence of transactions costs on the markets of soybean and bran, mainly for long-run effects of positive shocks on the CBOT prices, as we discussed. In other words, soybean prices and bran prices practiced in Oeste and Rondonópolis respond to U.S. prices or that limits to arbitrage are lower on certain Brazilian exchanges. The transmission is also observed for the case of Passo Fundo, but the relation with futures markets in U.S. did not present a threshold parameter. In general the estimations are an indication that limits to arbitrage play a role in determining prices of soybeans in Brazil, as evidenced. This means restrictions for biodiesel markets growth in terms of presence of transaction costs and arbitrages, as discussed along this research.

As mentioned the soy markets are driven by international markets. China as consumer, with a share of 20% of worldwide production, and U.S., due to the cointegration of soybean prices as estimated. In this context, measures can be assumed by Brazilian authorities to reduce international shocks effects on domestic politics which pretend to impact on the Brazilian energy matrix production. These measures could stimulate biodiesel production, and therefore increase the production of energy from renewable resources. Maybe in terms of technology and other sources, Brazil could make progress on competitive advantages.

6. Conclusion

The present study sought to analyze price transmission in soybeans, soybean bran, and soybean oil from the CBOT to the spot prices in the markets of the cities of Oeste-PR, Passo Fundo-RS, Rondonópolis-MT, and São Paulo-SP. To verify the long-term behavior between price series quoted on the futures market and the spot price, stationarity, unit-root, and cointegration tests were applied. Then, to verify the relationship between the short term and the long term between price series, VEC and TVEC models that sought to capture the presence of transaction costs were estimated.

The attempt to identify which of the three Brazilian exchanges is most closely linked with the futures markets in the U.S. point to long-run behavior essentially for positive shocks in case of soybeans and bran in cities of Oeste and Rondonópolis, respectively. The results of the TVEC for soybeans show that the spot market of the city of Rondonópolis-MT has fewer restrictions, which means that relative increases in the prices of the future market are transmitted to this market (increased presence of transaction costs).

Additionally, Rondonópolis is the market where the prices were most protected from possible price reductions in the futures market. For soybean bran, the results indicate that the city of Oeste-PR has fewer restrictions, which means that relative increases in the futures market prices are transmitted to this market (increased presence of transaction costs). Nonetheless, Rondonópolis continues to be the market where the prices are the most protected from possible price reductions in the futures market. Finally, the estimated results for soybean oil indicate that the prices are well protected from possible price reductions in the futures market.

To understand the dynamics of soy prices, it was necessary for supply-side countries, in addition to those that constitute the demand-side of this commodity, to be considered. In this respect, as noted throughout section 2, China has become a large importer of some commodities, particularly iron ore and soybeans. It is responsible for nearly 60% of the total worldwide importation of both commodities. Given that Chinese consumption and commodities imports have increased significantly over the past decade, the most significant impact of China on global food demand occurs through soy. Soy demand has been motivated by the production of animal food due to the increase in meat consumption in China.

By contrast, in relation to the factors on the supply-side in Brazil, price fluctuations of commodities can lead to an exchange relationship with the planting of other crops. In this case, the production of soy competes with the beef cattle, corn, and rice. The state of Mato Grosso is the largest producer of soy and corn. Another important market is Passo Fundo-RS, which, in addition to soy, also produces wheat in a rotation system.

On results should also be noted that the research performed by agencies such as EMBRAPA has also been an important development vector in this market, increasing productivity per hectare via seed improvement, especially in regions that needed soil adaptation for this crop. Since the end of the 1970s, discoveries in the area of grain genetics have allowed for the creation of varieties that are more appropriate for the Cerrado biome. To put this development into perspective, in Rondonópolis, one of the cities under study, some model farms have achieved productivity of well over 3,000 kilograms per hectare, attracting visitors from the U.S., India, China, etc.

Soybeans and its derivatives are important products intended for various segments of global agribusiness, possessing great importance for the Brazilian trade balance. The results of the present study confirm that the international market for soy is related to the domestic market. This relationship is strong and can be prolonged over a lengthy period of time, whether as a reflection of globalization itself and the integration of the market or by means of Brazil's role as an exporter of commodities.

Regardless, it is necessary develop researches that study the aspects beyond market conditions, on environment and social dimensions. This will be very important to understand the costs and benefits of changing the diesel produced from oil to biodiesel produced using soybean. By studying those dimensions is possible to point to barriers and paths to sustainable growth of this market. In terms of the main political implication of this study and the future direction of scientific research, we suggest that the exchange rate could rule an important aspect of biodiesel market in Brazil.

In this sense, we report that after 2011 the exchange rate in Brazil increased to a new average level to balance the new international conditions of lower commodities prices worldwide. However, it does not protect the Brazilian biodiesel markets from volatility in soybean commodities prices. This puzzle must be carefully analized, as observed by some mentioned studies. Also, to create good conditions for biodesel development, is necessary to understand better the transactions costs. This is important to stablize the soybean production and to unlock new investments in the soy complex model for biodiesel production, as described.

On the other hand, developing effective strategies to biodiesel in Brazil require minimizing the environmental impact of soybean cultivation. This requires full comprehension of the forces that drive the soybean markets and their associated infrastructure catalyzing their destructive processes. In terms of expansion of its cultivation, Brazilian autorities need to create in advance protected areas of soybean frontiers, mostly for Amazon and Cerrado biomes. Carry out studies to assess the costs of social and environmental impacts of soybean expansion is also important, improving, as result, the measures of environmental-impact and the regulatory system for biodiesel production.

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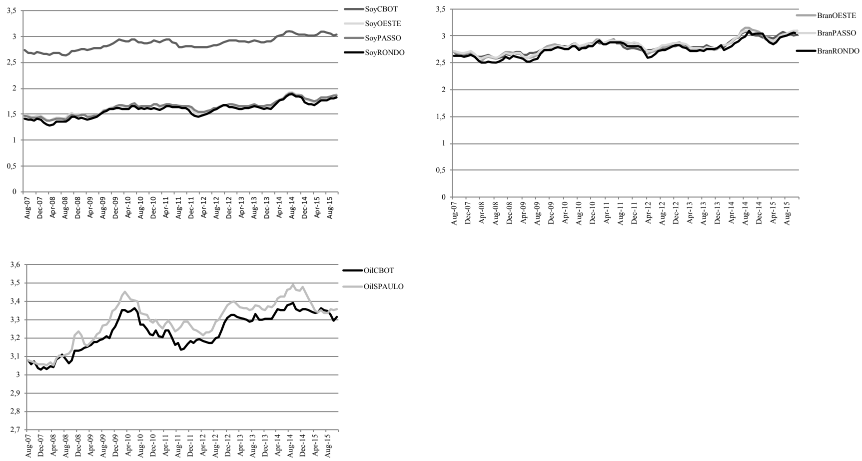
Appendix

Fig. A.1. Soy complex model for biodiesel production



Source: Elaborated from the Trade and Development Report - UNCTAD (2014).

Tab. A.1. Descriptive statistics of the data used

Variable	Average	Standard Deviation	Minimum value	Maximum value
Soybeans futures price on the CBOT	769.64	218.73	432.07	1,263.80
Spot price of soybeans in Oeste	44.886	13.995	23.65	83.95
Spot price of soybeans in Passo Fundo	44.968	13.839	23.73	80.66
Spot price of soybeans in Rondonópolis	40.511	13.22	19.10	77.32
Soybean bran futures price on the CBOT	669.60	207.96	379.10	1,189.58
Spot price of soybean bran in Oeste	687.80	246.29	340.79	1,422.86
Spot price of soybean bran in Passo Fundo	690.98	223.96	382.40	1,269.97
Spot price of soybean bran in Rondonópolis	618.31	220.03	321.57	1,249.32
Soybean oil futures price on the CBOT	1,763.2	394.39	1,064.68	2,459.95
Spot price of soybean oil in São Paulo	2,027.9	505.32	1,123.85	3,092.20

Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

Tab. A.2. ADF (Augmented Dickey-Fuller) unit-root tests

Variables	On level		First Difference	
	Student's t	p-value	Student's t	p-value
SoyCBOT	-25.275	0.3581	-4.4451**	0.01
SoyOESTE	-34.773	0.04765	-4.5988**	0.01
SoyPASSO	-29.232	0.1942	-4.0649**	0.01
SoyRONDO	-3.36	0.06514	-4.5896**	0.01
BranCBOT	-26.603	0.3031	-4.4697**	0.01
BranOESTE	-31.091	0.1172	-4.4463**	0.01
BranPASSO	-32.231	0.0879	-4.3157**	0.01
BranRONDO	-29.334	0.19	-4.573**	0.01
OilCBOT	-27.024	0.2856	-4.3398**	0.01
OilSAOPAULO	-26.591	0.3036	-3.6851**	0.02924

Note: *Rejects the null hypothesis at 1%; **Rejects the null hypothesis at 5%; ***Rejects the null hypothesis at 10%.
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

Tab. A.3. PP (Phillips-Perron) unit-root test

Variables	On level		First difference	
	Student's t	p-value	Student's t	p-value
SoyCBOT	-110.382	0.4752	-73.1409**	0.01
SoyOESTE	-128.485	0.3699	-53.0856**	0.01
SoyPASSO	-108.237	0.4877	-60.7572**	0.01
SoyRONDO	-141.309	0.2953	-52.7554**	0.01
BranCBOT	-122.138	0.4068	-71.2585**	0.01
BranOESTE	-140.448	0.3003	-49.2131**	0.01
BranPASSO	-125.367	0.388	-63.2523**	0.01
BranRONDO	-135.461	0.3293	-68.0971**	0.01
OilCBOT	-79.378	0.6557	-80.5643**	0.01
OilSAOPAULO	-70.741	0.7059	-63.8183**	0.01

*Note:**Rejects the null hypothesis at 1%;**Rejects the null hypothesis at 5%;***Rejects the null hypothesis at 10%.
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

Tab. A.4. KPSS (Kwiatkowski-Phillips-Schmidt-Shin) stationarity tests

Variables	On level		First Difference	
	Student's t	p-value	Student's t	p-value
SoyCBOT	2.4738**	0.01	0.0577	0.1
SoyOESTE	2.4341**	0.01	0.0632	0.1
SoyPASSO	2.5835**	0.01	0.0689	0.1
SoyRONDO	2.4647**	0.01	0.0507	0.1
BranCBOT	2.3236**	0.01	0.0815	0.1
BranOESTE	1.977**	0.01	0.068	0.1
BranPASSO	2.242**	0.01	0.0975	0.1
BranRONDO	2.1411**	0.01	0.0673	0.1
OilCBOT	2.1762**	0.01	0.0969	0.1
OilSAOPAULO	2.0187**	0.01	0.149	0.1

*Note:**Rejects the null hypothesis at 1%;**Rejects the null hypothesis at 5%;***Rejects the null hypothesis at 10%.
Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.

Tab. A.5. Results of the maximum root of the cointegration test of Johansen and Juselius

Locations	r ≤ 1	r = 0
SoyCBOT – SoyOESTE	2.06	28.55
SoyCBOT – SoyPASSO	1.54	15.76
SoyCBOT – SoyRONDO	1.76	33.17
Critical Values		
1%	11.65	19.19
5%	8.18	14.90
10%	6.50	12.91
BranCBOT – BranOESTE	1.74	23.72
BranCBOT – BranPASSO	1.24	15.33
BranCBOT – BranRONDO	1.46	23.93
Critical Values		
1%	11.65	19.19
5%	8.18	14.90
10%	6.50	12.91
OilCBOT - OilSAOPAULO	4.05	18.68
Critical Values		
1%	11.65	19.19
5%	8.18	14.90
10%	6.50	12.91

Source: Prepared by the authors based on CEPEA/ESALQ and CBOT data.