How to Indirectly Measure Market Transaction Costs

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Abstract

This paper proposes a procedure to indirectly measure the variable market transaction costs using threshold cointegration models to operationalize concepts of Institutional Economics. Among the advantages, the proposed procedure measures the exchange costs by means of widely applied cointegration models , decomposes those costs into transaction and transportation costs., requires only simple and generally available data, and its results are easy to interpret. Applying this procedure on the international market of ethanol, we found that the transaction costs incurred to export this biofuel from Brazil to United States range from US$ 0.55/gallon to US$ 0.63/gallon. The proposed procedure may be applied to different markets and it is potentially a useful tool for evaluating policies to increase market efficiency.

1. Introduction

Markets are organizations created to facilitate exchange. This is possible because a market comprises a set of institutions developed primarily to reduce a particular type of transaction costs: the market transaction costs. Those costs are important not assess

market efficiency, but also to understand how and in which circumstances two or more markets are interconnected.

There is an abounding literature exploring the degree of integration between markets and trying to measure market transaction costs, among which the cointegration analyses is one of the most popular.. One important shortcoming of this literature is the entanglement of exchange, transportation and transaction costs, due to the inaccuracy about how these concepts are defined. This imprecision has induced the misleading assumption of transportation costs as a synonymous of transaction costs and, consequently, has yielded an inaccurate measurement of the latter. Actually, the lack of a standardized transaction costs definition is a shortcoming of many attempts in different research fields that have already tried to quantify them.

By means of cointegration models, this paper suggests a procedure to indirectly measure market transaction costs in currency values that requires only simple and available date, and can be easily replicated to different markets. This procedure also allows to measuring the exchange and transportation costs associated with a transaction. As an illustration, we apply this procedure to measure the exchange, transportation and transactions costs incurred to export ethanol from Brazil to United States using the current characteristics of the international market of this biofuel.

This paper is organized as follow. The next section describes the limitations and shortcoming of the main attempts to measure the market transaction cost. Since an accurate definition of a variable is a necessary condition for its measurement, we dedicate special attention to the problems associated to the absence of a consensus definition of transaction costs. The third section clarifies the differences between exchange, transaction and transportation costs, and analyzes how the entanglement of those concepts has misled the efforts of the cointegration literature to measure transaction costs. In the fourth section, we present the procedure to indirectly measure the exchange costs in currency values, decomposing transportation and market transaction costs. In the next section we apply this procedure to measure the market transaction costs incurred to export ethanol from Brazil to United States using the international market of this biofuel in its current characteristics. Finally, in the sixth section, we present our concluding remarks.

2. Measuring transaction costs: attempts and limitations

2.1. Main attempts

Transaction costs are the key-variable to understand efficiency in economic organizations. Transaction costs literature has been widely applied in many different research fields, such as development, finance, industrial organization, agricultural economics and natural resource economics, among others[1]. Despite this recognition, measuring transaction costs is still a challenging task. As Allen (2006, p. 6) states, if transaction costs could be measured with reasonable accuracy, the theory would become more valuable. On the other hand, if those costs are measured improperly (e.g. adding transportation costs), the conclusions would be misleading.

Most of the empirical literature on transaction costs has focused on the choice of governance structures (e.g. market, hierarchy, or hybrid arrangement). According to Richman and Macher (2006), usually the governance structure is the dependent variable whereas transactional characteristics, as well as other control variables, are the explanatory variables. The probability of observing more or less integrated forms of organization depends on the underlying properties of the transaction. More integrated governance modes are associated with a higher degree of relationship-specific assets, greater uncertainty, more complex transactions, or more frequent exchange. Among the most studied transactional properties, Richman and Macher (2006, p. 5) argue that asset specificity has been the key variable and has received great attention of the empirical literature.

Among the empirical methods applied, Richman and Macher (2006, p. 8) indicate (i) the qualitative case studies, (ii) quantitative single industry studies, and (iii) econometric analyses. In the econometric analyses, two methods were preferred: (a) two stage estimation procedures; and (b) panel data estimation. The advantage of the first method is the possibility of correcting the selection bias associated with estimating the

[1] See Richman and Macher (2006) and Wang (2003) for a review.

effect of organizational mode on performance (Masten, 1993, p. 16)[2]. The panel data models are useful because they offer many procedures to control unobservable components[3]. Despite the effort, in those studies, the absolute amount of transaction costs does not matters; they are interested in a relative ranking of transaction costs associated with different governance structure or contractual choices (Wang, 2003, p. 4).

2.2. Main obstacles and limitations

The most important restrictions measure transaction costs are: (i) data is barely available and most of them are not comparable[4]; (ii) many important characteristics of the transactions are not observable – actually many important transactions are unobservable; (iii) the lack of a consensus definition of transaction costs. Transaction data is usually collected by mail surveys, interviews or firm visits. Despite the advantage of knowing in details the object of study, according to Richman and Macher (2006, p. 8), these data are subject to the general limitations of survey collection because "*they are based on respondents' stated beliefs rather than non-subjective valuations. Definitional differences and potential subjectivity across survey respondents mean inter-industry comparisons, and sometimes even inter-firm comparisons, are difficult and therefore must be made with caution*."

Because transaction costs are one important element influencing what goods are traded in which contractual form or in which governance structure, sometimes those costs are so high that the transaction simply does not take place. That means, sometimes it is difficult, or even impossible, to measure, or even to identify, the 'other side', the relevant alternative to the realized transaction (Allen, 2006, p. 7-9). Benham and Benham (2001, p. 3) indicate other difficulty: estimation is also tough because production and transaction costs are jointly determined, leading to serious endogeneity problems.

Finally, the absence of a standard definition of transaction costs is also an obstacle to measure them (Benham and Benham, 2001; Wang, 2003). There are several different

[2] Some examples: Macher (2001), Masten et al. (1991), Nickerson and Silverman (2000), Poppo and Zenger (1998), Sampson (2006), and Saussier (2000).
[3] Soma examples: Gonzalez-Diaz et al. (2000), Ohanian (1994), Park and Russo (1996), Silverman et al. (1997), and Ngwenyama and Bryson (1999).
[4] The analyses of transaction costs in financial markets are one of the rare exceptions: the data in this field is abundant and, consequently, there are many proxies and indexes measuring transaction costs.

and sometimes contradictory definitions of transaction costs and this mess disturbs the identification of what really is being measured:

- According to Williamson (1996, p. 379), transaction costs are "*the ex-ante costs of drafting, negotiating, and safeguarding an agreement and, more especially, the ex-post costs of maladaptation and adjustment that arise when contract execution is misaligned as a result of gaps, errors, omissions, and unanticipated disturbances*";
- More concisely, North (1990, p. 27) defines transaction costs as the "*costs of measuring attributes of what is being exchanged and the costs of protecting rights and policing and enforcing agreements*";
- In a similar vein, for Barzel (1997, p. 4), transaction costs are "*the costs associated with the transfer, capture, and protection of rights*";
- Eggertsson (1990, p. 14) explains that when "*information is costly, various activities related to the exchange of property rights between individuals give rise to transaction costs*"

Despite there is no clear-cut definition of transaction costs, most of those definitions relate those costs to the expenses incurred to establish and protect economic property rights. For Allen (2006, p. 3), this relation is important because is central to the Coase's idea of transaction costs. Economic property rights are the ability of someone to freely exercise a choice and transaction costs are the costs incurred to establish and maintain those property rights. In a world with perfect property rights (i.e. property rights well established and protected), the transactions costs are zero –the Coase's theorem applies. However, since property rights are imperfect delineated, it is necessary to incur in costs, the transaction costs, to protect them.

Transaction costs are not homogenous. They can differ depending on which 'environment' the transaction takes place. Furubotn and Richter (2005, p. 51) classify transaction costs in three large groups: (i) market transaction costs: the transaction costs of using the market (the price mechanism); (ii) managerial transaction costs: the costs of exercising the right to give others within the firm; and (iii) political transaction costs: the array of costs associated with the running and adjusting of institutional framework of a polity. The procedure this paper proposes measures specifically the market transaction

costs, that is, the type of transaction costs closest to the idea Coase discussed in 1937: the costs of using the market mechanism.

Finally, for any of those types of transaction costs, they can be either fixed or variable. The fixed transaction costs represent the specific investments made in setting up institutional arrangements, and the variable ones are the transaction costs that depend on the number or volume of transactions (Furubotn and Richter, 2005, p. 51). As will be clear later, the difference involving fixed and variable transaction costs is central in our proposed procedure to estimate them.

3. Measuring market transaction costs

3.1. Transportation, transaction, and exchange costs

Exchanging a good is a costly activity. As well as it is necessary to incur expenses to produce a good, it is also necessary to allocate resources to market it. According to Coase (1988, p. 7), market is an institution that exists "*to facilitate exchange*", that is, it exists "*in order to reduce the cost of carrying out exchange transactions*". Thus, we assume for now on that market is an organization created to facilitate the exchange. It is possible because a market is composed of a set of institutions that reduce the market transaction costs. Those costs are associated with the necessary activities to elaborate and to enforce the contract that will intermediate the exchange[5].

The literature that has tried to measure market transaction costs frequently has considered those costs synonymous to transportation costs. However, transportation and transaction costs represent costs of different origins; while transportation costs represent the costs of transfer physically a good from one market to another, taking into account fuel, freight, taxes, tariffs, wages, fares, etc., market transaction costs are linked essentially to information and bargaining costs. Moreover, combined the market transaction costs and the transportation costs form the exchange costs. This idea is reflected in Benham and Benham (2001) definition of exchange costs: "*the opportunity*

[5] According to Furubotn and Ritcher (2005, p. 324), those activities can be organized in three categories: (i) pre-contractual activities (search and inspection); (ii) contract formation (bargain) activities; (iii) post-contractual activities (execution, control, and enforcement).

cost faced by an individual to obtain a specified good using a given form of exchange within a given institutional setting" (p. 3).

Higher exchange costs make the trading process more expensive. Actually, they can even insulate markets. Markets for the same good can be in equilibrium with different prices because it is costly to ship products from one market to another to take advantage of arbitrage opportunities triggered by a price difference. It is worth to highlight it is not any price difference that can consolidate a profitable arbitrage opportunity; this difference must be higher than (or at least equal to) the exchange costs. Therefore, *ceteris paribus*, the higher the exchange costs, the lower is the probability of different markets be integrated. According to Fackler and Goodwin (2001, p. 978), "market integration is best thought of as a measure of the degree to which demand and supply shocks arising in one region are transmitted to another region"[6].

A market reduces exchange costs primarily because it makes the information disclosure process less costly. As information becomes a cheaper asset, become easier to indentify possible gains from arbitrage opportunities taking advantage of the price difference in the two or more markets. Thereby better information flow improves the degree of integration between different markets. In sum, both transportation and market transaction costs (i.e. the exchange costs) influence decisively the degree of integration between different markets. Thus, it is necessary to take them into account to analyze empirically the connection of two or more markets.

3.2. The cointegration analysis

Many empirical procedures have been applied to study market integration but the cointegration analysis has been one of the most popular approaches. This literature assumes the degree of price transmission as a proxy for the level of market integration because it can 'measure' the market efficiency in taking advantage of possible arbitrage opportunities. Interestingly, Marshal's (1920) market definition gives support to this assumption: similar goods belong to the same market whenever their prices converge. For

[6] It is important to clarify that market integration is different from economic integration. As Fackler and Goodwin (2001, p. 979) explain "*economic integration means that there is no border restrictions restricting the flow of goods, but an specific market can be not integrated, i.e. it is possible to see two regional and insulated markets*".

the cointegration literature there is convergence when the prices of those goods share the same long-run stochastic trend. This convergence means the existence of a long-run equilibrium influencing the prices behavior in the short run. In this situation, according to Fackler and Goodwin (2001, p. 973), market integration is usually a measure of the degree of price transmission between different markets and market efficiency is used to denote a situation in which the agents have left no arbitrage opportunities.

There is an important assumption in the linear cointegration models: the prices in the short run adjust to any deviation in the long-run equilibrium, do not matter how small this change is. It is a strong assumption because, as we have already discussed previously, the arbitrage opportunity is profitable only if the price difference is higher than the exchange costs. Meyer and von Cramon-Taubadel (2004) also criticize the assumption of linear and symmetric adjustment in cointegration models. According to them, the asymmetric price transmissions are more frequently than the symmetric ones due to the presence of: market power, political intervention, inventory management, adjustment costs (menu costs), and asymmetric information (different search costs among the agents involved in the transaction) (p. 586). Curiously, although Meyer and von Cramon-Taubadel (2004) list two important market transaction costs (adjustment and search costs), they do not employ the term transaction costs.

Actually, the cointegration literature has already developed non-linear models that incorporate asymmetric adjustments and exchange costs in its analyses[7]. Enders and Granger (1988) is one of the first papers to suggest an approach to evaluate price transmission equation with asymmetric price adjustments. Balke and Fomby (1997) suggest a method to incorporate transaction costs in the cointegration models; those models are known as the threshold cointegration models. Briefly, the threshold cointegration models incorporate the transaction costs[8] including nuisance parameters linking the equations of the system. Those nuisance parameters are called thresholds and they allow splitting the system in different regimes. With different regimes, it is possible

[7] Asymmetry and exchange costs are not the same thing. The presence of exchange costs can cause asymmetric adjustments, but not all asymmetry is a consequence of exchange costs. However, both can be modeled using the threshold cointegration models.

[8] It is important to highlight that the cointegration literature employs imprecisely the term transaction costs as a synonymous to transportation costs or to exchange costs. In the following paragraphs we maintain this terminology to preserve the original idea of this literature but later we discuss this point in details.

to evaluate empirically in which situations the prices are linked (i.e. in which situations the markets are integrated), how strong this connection is in each regime, and what the trade flow direction is. Moreover, the value of each threshold is read as a measure of the transaction costs.

Meyer (2004) proposes a procedure to measure indirectly the transaction costs in currency values using the threshold influence on the price transmission equation. With the variables in natural log, the threshold represents how much, in percentage, the deviation has to be above or below the long-term equilibrium to trigger the regime change. This long-term equilibrium is calculated substituting the variables in the cointegration vector by their respective sample mean.[9]

Despite the popularity of the cointegration models, this approach presents several limitations[10]. In the next paragraphs we focus on the misled concept of transaction costs applied in this literature. There are also two conceptual inaccuracies in this literature:

- it has employed the concept of transaction costs improperly: what they have named transaction costs are better expressed by the term exchange costs, the combination of transportation costs and variable market transaction costs;
- besides using the concept of transaction costs far from the Coase's idea, this literature use almost only examples of transportation cost to justify the existence of a persistent price difference. Transportation and transaction costs capture different aspects of an exchange; they are not synonymous[11].

It is possible to cite many examples. Bekkerman et al. (2013) employ a definition of transaction costs close to the idea of exchange costs: "*the cost required to transfer a good from one market to another*" (p. 2713). However, when they model those transaction costs, they select only variables associated with transportation costs like fuel costs and seasonality components (p. 2706). The same approach is observed in Campenhout (2007) who use transportation variables (steep passes, road bad conditions, heavy traffic, number of police check posts, bribes, and costs of living) as proxies for

[9] See Mayer (2004, p. 332) for an example.
[10] See Fackler and Goodwin (2001) and Meyer and von Cramon-Taudabel (2004) for a review.
[11] It is important to highlight that this confusion is not recent neither exclusive to this literature. In 1979, Dahlman had already criticized the usage of transportation costs as a proxy of transaction costs: "a trade may be costless to carry through, but may still require resources to organize: there may be setup costs associated with each exchange" Dahlman (1979, p. 146). Such a cost is no longer proportional to the trade itself, and can be even a fixed cost independent of the amount exchanged.

transaction costs. Perhaps 'bribes' can be a reasonable proxy for transaction costs, but his idea about this concept is clearly far from Coase's idea: "*as expected, the estimated transaction costs are generally proportional to the distance between two markets*" (p. 123).

Stephens et al. (2012) and Goodwin et al. (2002) justify a threshold effect in the price transmission because they analyze perishable goods. This is a good proxy for transaction costs; it can be classified as temporal asset specificity. However, Stephens et al (2012, p. 460) empirically use only transportation costs variables (fuel prices and bus fares) as proxies for the exchange costs.

There are also papers that justify the existence of transaction costs due to market characteristics, even when those features are not clearly transaction costs. Rapsomanikis and Hallam (2006, p. 2) suggest that adjustment costs in the sugar-ethanol processing industry and technical factors (the substitution possibilities between ethanol and oil) explain the existence of transaction costs. Among the market characteristics, Park et al. (2002) cite as transaction costs variables that are not all really transaction costs (trade restrictions, infrastructure bottlenecks, managerial incentive reforms, traders skill, market institutions, the lack of influence of future markets, bribes, and productions specialization policies). But at least they recognize that markets do not emerge overnight; it can be a long and costly process (p. 68).

Many papers, like Serra et al. (2008) and Serra et al. (2006) model possible transaction costs without justifying why can be reasonable to consider them. On the other hand, Balcome et al. (2007) do not present a definition about those costs, but recognize that transportation and transaction costs are expenses with different origins. Moreover, they also recognize the existence of fixed and variable exchange costs (p. 308).

In sum, despite all the efforts, there are some conceptual inaccuracies when the cointegration analysis literature tries to incorporate the exchange costs in its models. What it has been named transaction costs is better expressed by the concept of exchange costs. Furthermore, although this literature has employed the expression transaction costs, it seems that, in realty, this literature has the transportation costs in mind. The point is:

definition matters; it is impossible to measure anything accurately without identifying properly what is to be measured[12].

Finally, perhaps as a consequence of an inaccurate concept of transaction costs, Meyer and Cramon-Taudabel (2004, p. 599) also criticize that the cointegration literature has rarely interpreted the magnitude of the measured thresholds in an economic sense. Meyer (2004, p. 329) also points out, in most analyses, no explicit justification is provided for the number of thresholds applied. Accordingly, Allen (2006) makes the same critique arguing it is important to determine what is driving the price spread to get a better estimate of the transaction costs.

Considering all those difficulties, in the next section we propose an approach to measure indirectly the variable market transaction costs that overcome some of the problems just mentioned.

4. Proposed procedure

Measuring transaction costs is a challenging task. We discussed previously some attempts and their limitations. In this section, we propose a procedure to measure the variable market transaction costs using the already developed cointegration techniques. Because there are exchange costs, not all price difference between two markets triggers profitable arbitrage opportunities. Thus it is possible to measure those exchange costs identifying what is price difference that turns the arbitrage opportunity profitable. Once the exchanges costs can be decomposed in transportation and market variable transaction costs, if it is possible to measure the former, the difference between exchange and transportation costs yields the latter.

The following steps describe in details the proposed procedure for a system with time series of the prices of two markets whose market transaction costs are to be measured:

- With the prices in the same units (e.g. currency/weight or volume), perform unit root, cointegration and non-linearity tests. The cointegration tests must

[12] Actually, transaction costs definition is not an exclusive problem of the cointegration literature. See Richman and Macher (2006) and Allen (2006).

impose that the cointegration vector be equal to one (with or without a constant). This specification reflects exactly the idea of price difference ($P_1 - P_2 = c + \varepsilon$), where P_1 and P_2 are the prices, c is a constant that can be set as zero, and ε is the error. The nonlinear tests, such as Hansen (1999), Hansen and Seo (2002), and Seo (2006)[13], are applied to evaluate if nonlinear cointegration specifications is preferred to linear ones. If it is not possible to reject the desired properties (non-stationarity of P_1 and P_2, and stationarity and nonliearity of ε), the next steps should be followed;

- Estimate a threshold cointegration model. The values of the thresholds represent the exchange costs that trigger the arbitrage opportunities. Because thresholds are the price difference that become the arbitrage opportunity profitable, they are in line with the Benham and Benham (2001) exchange costs definition: "*the opportunity cost faced by an individual to obtain a specified good using a given form of exchange within a given institutional setting*";
- To decompose the exchange costs in transportation and variable market transaction costs, it is necessary to measure directly at least one of them. We suggest quantifying directly the transportation costs because, usually, they have larger fractions of observable costs than the transaction costs. Traditional data collection, as interviews, firm visits, and mail surveys, can provide average values of the transportation costs. Furthermore, data collection like interviews is also important because:
    - to measure the transaction costs precisely, it is necessary to specify thoroughly the characteristics of (i) the involved agents, (ii) the marketed good, (iii) the from of exchange, (iv) the institutional setting, as well as, (iv) the time and the money incurred when the transaction takes place (Benham and Benham, 2001, p. 5); and

[13] It is important to recognize that Hansen (1999) alone does not guarantee that the series and cointegrated, Hansen and Seo (2002) can be applied only after the estimation of the threshold cointegration model, and Seo (2006) is restricted to the case with two thresholds (three regimes).

- determining what is driving the price difference is important to get a better measure of the transaction costs because the price spread can arise over a number of issues and some of them may not be the Coase's transaction costs (Allen, 2006, p. 10).

- Finally, after quantifying directly the transportations costs, the difference between exchange costs (obtained in the second step) and transportation costs (measured in the third step) yields a good proxy of the variable market transaction costs. We are labeling the latter costs as 'variable' because the price difference (i.e. the exchange costs) does not necessarily include some important fixed market transaction costs, like all the expenses incurred to create the institutional setting required to make the transaction feasible. Actually, it also important to highlight that "*as long as the exchange costs are not a constant share of the total transaction costs, considering the former as a proxy for the latter is either misleading or uninformative*" (Allen, 2006, p. 11-2).

This proposal represents an effort to present a standardized procedure that can be applied to quantify the variable market transaction costs incurred transfer a good from one market to another. Its main advantages can be summarized in: (i) it is not necessary to develop new statistical procedure because it uses the models the cointegration analysis literature has already developed; (ii) it is not data hungry; (iii) the results are easy to interpret; (iv) it breaks the exchange costs in transaction and transportation costs; and (iv) those measured costs are consistent with the concepts and recommendations from the institutional economics literature.

Obviously, this approach also has some limitations and it is important to highlight them: (i) it can capture the exchange costs only when the prices series are cointegrated; otherwise, the cointegration models cannot be applied; (ii) it cannot measure the fixed transaction costs; because it focuses on the average exchange costs incurred to make one transaction, it sizes mainly the variable costs. Because this procedure combines the developments of the cointegration analysis literature with the theoretical framework established by the new institutional economics literature, necessarily, it also combines the weakness of both literatures: (iii) all the statistical problems associated with the

cointegration tests and with the relationship among price transmission, arbitrage opportunity, and market integration; and (iv) the arbitrariness of the chosen transaction costs definition.

In the next section we present an empirical example of how this procedure can be used to measure the exchange, the transportation, and the transaction costs incurred to export ethanol between Brazil and United States.

5. Empirical example

From the analysis of the previous sections, one of the main reasons insulating two markets is a price difference lower than the exchange costs incurred to bring the goods from one market to another to take advantage of an arbitrage opportunity. Those exchange costs can be any transportation costs, trade barriers, taxes or transaction costs. In the ethanol trade involving Brazil and United States, there are good reasons to believe that the exchange costs are substantial, higher than only the transportation costs[14].

Most of the ethanol exported from Brazil to United States in the last three years is from a variety labeled advanced. Its main difference from the conventional ethanol (formally called renewable ethanol) is its lower greenhouse gas emissions and there is a premium price for that characteristic. Despite this higher price, however, exporting the advanced ethanol is costly; it is required a substantial paperwork to prove the desired attributes of this variety. To demonstrate the imported ethanol can be classified as advanced, the Environmental Protection Agency (EPA) requires a long list of documents (more than 50) that is neither easy nor cheap to obtain[15].

Despite those substantial exchange costs, the international market for ethanol or the trade between Brazil and United States has been incorporated in many models that try to evaluate the impacts of the ethanol production on other crops or food prices, land use, or water resources without considering the associated transaction costs. Some papers have assumed a well developed international market for ethanol or a direct link between

[14] Although, if one plots the ethanol price series of those markets or performs a cointegration analysis, he finds a reasonable connection between those markets, Serigati (2013) shows that those results are mislead by the oil price that influences both autarchic prices and create the false idea of a market linkage.
[15] This is list can be assessed in EPA (2010, p. 14888-9).

Brazil and Unites States (Chen et al., 2012; Fabiosa et al., 2010; de Gorter and Just, 2008). Others have recognized some friction in those markets primarily because of the American trade barriers or the exchange rate (Crago et al., 2010; Elobeid and Tokgoz, 2008). As an example, Elobeid and Tokgoz (2008, p. 923) propose a price transmission equation including the trade barriers and the transportation costs, but assuming there are no transaction costs[16]:

$$\begin{cases} P_E^{US} = P_E^W\left(1+\tau^0\right)+tc & \text{if } P_E^{Endogenous} > P_E^W\left(1+\tau^0\right)+tc \\ P_E^{US} = P_E^{Endogenous} & \text{if } P_E^{Endogenous} < P_E^W\left(1+\tau^0\right)+tc \end{cases}$$

where

P_E^{US} = American domestic ethanol price

P_E^W = World ethanol price

$P_E^{Endogenous}$ = the insulated American domestic ethanol price

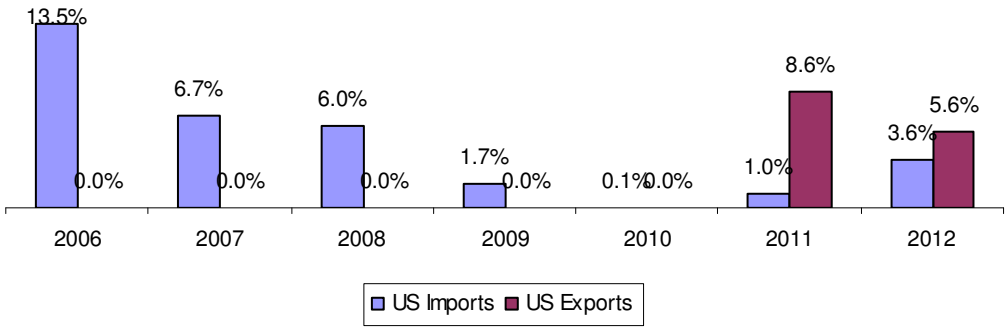
τ^0 = tariff rate

tc = transportation costs

Although Serigati (2013) rejects a strong and direct connection between those two markets, in the last years there were significant export flows between Brazil and United States. Since 2007, Brazil has exported more than 5.6 billions liters of ethanol to United States, mainly in 2007, 2008 and 2012. Conversely, United States have exported to Brazil more than 3.5 billions liters of ethanol since 2007, where 2.2 billions liters were traded only in 2011 and 2012. If there were those exports, it is reasonable to assume that there was a price difference sufficiently high to compensate all the exchange costs. However, because those exports represent a tiny fraction of the domestic production (Figure 1), could have this price difference triggered the connection between those markets?

Figure 1 – American Corn Ethanol Export and Import as Share of the domestic Production

[16] Actually, there is an intriguing situation in Elobeid and Tokgoz (2008) because, despite they do not consider the transaction costs in the price transmission equation, they incorporate them implicitly in the equation setting the volume of imported ethanol from CBI countries. The transaction costs are incorporated in lower transmission coefficients. In their own words: this transmission coefficients "*are included to account for the transaction costs between firms, the time lag between contracts and delivery, and the daily volatility in ethanol prices that are not captured in the annual price data*" (Elobeid and Tokgoz, 2008, p. 923).



Source: RFA

In sum, motivated (i) by the last question, by the fact that (ii) a lot of paperwork is required to export the advanced ethanol from Brazil to United States, (iii) the literature hasn't considered the associated transaction costs incurred to trade ethanol among those countries, and (iv) assuming that those markets are not directly connected, but there were some periods that arose some window of arbitrage that became profitable to exports ethanol, it is important to measure what the price difference is that offset exchange costs or, at least, trigger the conditions to integrate those markets.

5.1. Data and model

Setting the ethanol price difference between United States and Brazil as $\tilde{P}_{US_t} - \tilde{P}_{BR_t}$, it is profitable to trade ethanol among those countries when the window of arbitrage is bind; that is, when the absolute value of the price difference is higher than the exchange costs (δ) incurred to make this transaction (i.e. when $\left|\tilde{P}_{US_t} - \tilde{P}_{BR_t}\right| > \delta$). When this window of arbitrage opportunity is not bind (i.e. when $\left|\tilde{P}_{US_t} - \tilde{P}_{BR_t}\right| \leq \delta$), it is not profitable to make a trade transaction involving those locations and the markets are insulated. Once we have measured the exchange costs, if we subtract from it the transportation and the shipment costs, we can, finally, compute the variable market transaction costs incurred in trading the ethanol between Brazil and United States.

To measure the exchange costs we need to use the price series in nominal values (US$/gallon) without any log transformation. We used the same data employed the monthly price series of the Brazilian sugarcane ethanol and the American corn ethanol in their respective spot markets, from November of 2002 to January of 2013, comprising

123 observations. Those price series can be considered both non-stationary and cointegrated with each other. The Appendices 1 and 2 present the unit root tests (ADF and KPSS, respectively) and the Appendix 3 shows the cointegration tests for those series.

It is important to highlight that to model this window of arbitrage, we need to impose a restriction on the cointegration vector ($\beta = -1$). Otherwise, there is no guarantee that the estimated β is statistically equal to one and, consequently, we can find a price difference weighted by a β that does not represent a window of arbitrage opportunity $\left(\left|\tilde{P}_{US_t} - \tilde{P}_{BR_t}\right| > \delta\right)$. Because the cointegration tests above cannot guarantee that a cointegration vector where $\beta = -1$ yields a stationary relationship, it is necessary to test if the combination $\tilde{P}_{US_t} - \tilde{P}_{BR_t}$ generates a stationary result. According to the Appendix 4, it is possible to reject the hypothesis of non-stationarity of the difference $\tilde{P}_{US_t} - \tilde{P}_{BR_t}$.

To evaluate if it is possible to consider a cointegration relationship with more than one regime to those series, we applied the Hansen (1999) test. In this test, Hansen (1999) proposes a three steps procedure to evaluate (i) if a linear cointegration is preferable to a system with two regimes (i.e. one threshold), (ii) if a linear cointegration is preferable to a system with three regimes (i.e. two thresholds), and, finally, (iii) if a system with two regimes is preferable to a system with three regimes.

Depending on the number of regimes, each system can model different situations. With three regimes, it is possible to have: (i) a regime where the price difference makes profitable to export ethanol from Brazil to United States (i.e. the American ethanol price is higher enough than the Brazilian ethanol price compensating the exchange costs); (ii) a regime where the price difference is lower than the exchange costs, making the trade unprofitable; and (iii) a regime where the price difference makes profitable to export ethanol from United States to Brazil (i.e. the Brazilian ethanol price is higher enough than the American ethanol price compensating the exchange costs[17]).

[17] The exchange costs associated with the first regime does not need to be equal to the exchange costs related to the third regime. It is possible (even reasonable) to expect that the exchange costs to export

When the system contains only two regimes, it is possible to have (i) one regime for each trade flow (Brazil to United States or United States to Brazil) or (ii) one regime when the markets are insulated and the other when the window of arbitrage is bind but, in this situation, only one trade flow is modeled[18]. Finally, a system with only one regime suggests that the relationship between those markets did not change along all the analyzed period.

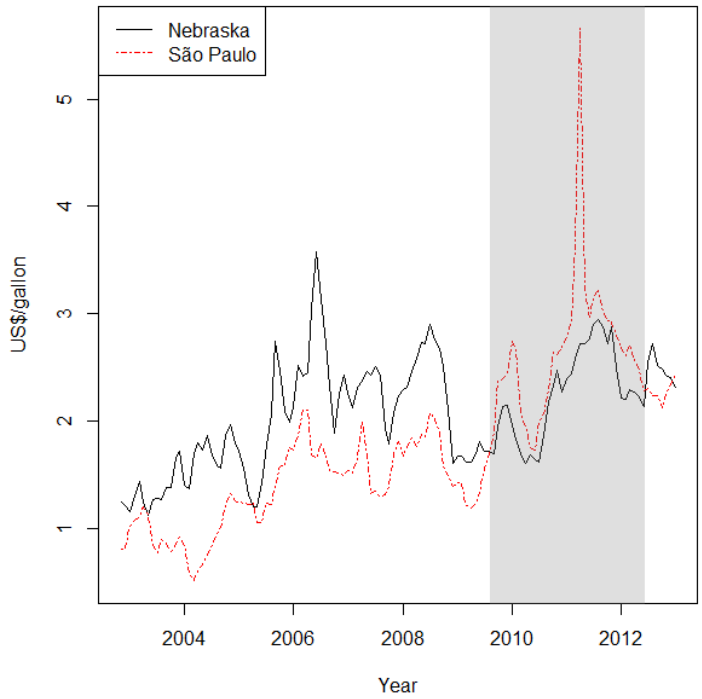
All the three specifications are possible because, as the Figure 2 depicts, there are some moments (most of them) where the American ethanol prices were higher than the Brazilian ones, and there are also some moments (notably between Set/2009 and Jun/2012) where the opposite were observed. Despite there were moments with a price difference favoring each trade flow, there is no guarantee that this price difference was higher enough to compensate the exchange costs neither lasted long enough to connect those markets.[19]

Figure 2 – Monthly Anhydrous Ethanol Prices: United States (NE) x Brazil (SP)

ethanol from United States to Brazil be different of the exchange costs to export ethanol from Brazil to United States.

[18] For Meyer (2004), in a situation with one thereshold (two regimes) and exchange costs, it is reasonable to expect the trade flow in only one directon: "*if price adjustment in the presence of significant transaction costs is expected to occur in only one direction, a threshold error correction model with only one threshold could be appropriate. Under such circumstances we would expect price adjustment due to deviations from equilibrium in the other direction to be insignificant.*" (p. 329)

[19] According to Coleman (2007, p. 2), "*if there is trade with a third city, estimating exchange costs from the price transmission involving only two markets can be misled. One way to circumvent this problem is to use trade data in conjunction with price data.*" Fortunately, according to the trade data, there is no a third important final destination involving the ethanol trade between Brazil and United States.



Assuming a delay parameter as one, that is, the regime change in *t* depends on the *t-1* value of the deviation from the long-run equilibrium, and a trim parameter of 0.05, we estimated two set of the Hansen (1999) test: the first modeling the equations with two lags in level; and the second modeling the same equations with three lags in level. We choose those numbers of lag because they are suggested by the lag length criteria tests (AIC, Schwarz, Hannan-Quinn, and FPE). Tables 1 and 2 present the results.

Table 1 – Hansen (1999) test with two lags in level

Regimes	Test statistic	pvalue	10%	5%	1%
1vs2	37.75	0.005	18.22	22.96	31.33
1vs3	49.98	0.118	52.42	62.21	90.15
2vs3	9.32	0.666	26.64	22.96	31.33

	Thresholds	
Models	th1	th2
Setar(2)	-0.625	-
Setar(3)	-0.566	0.512

Table 2 – Hansen (1999) test with three lags in level

Regimes	Test statistic	pvalue	10%	5%	1%
1vs2	52.44	0.017	23.98	34.82	61.31
1vs3	57.80	0.233	79.17	95.71	136.11
2vs3	3.73	0.996	29.01	34.82	61.31

	Thresholds	
Models	th1	th2
Setar(2)	-0.656	-
Setar(3)	-0.625	0.519

According to both Hansen (1999) tests, a system with three regimes (i.e. two thresholds) must be rejected favoring either a linear cointegration model or a system with two regimes. Both tests also reject the hypothesis that a linear cointegration model is preferable to a system with two regimes. Therefore, the tests suggest that it is not possible to reject the hypothesis of a nonlinear dynamic involving the Brazilian sugarcane and the American corn ethanol prices and a system incorporating both series should be modeled with two distinct regimes. The Equation 1 represents this model.

Equation 1 – The general model

$$\begin{cases} \text{Lower regime} \left(\left| P_{US_t} - \beta P_{BR_t} \right| \le \theta \right) \\ \begin{bmatrix} \Delta P_{US_t} \\ \Delta P_{BR_t} \end{bmatrix} = \begin{bmatrix} \alpha_{US}^{low} \\ \alpha_{BR}^{low} \end{bmatrix} \left(P_{US_{t-1}} - \beta P_{BR_{t-1}} \right) + \sum_{i=1}^{p-1} \begin{bmatrix} \gamma_{11,i}^{\text{low}} & \gamma_{12,i}^{\text{low}} \\ \gamma_{21,i}^{\text{low}} & \gamma_{22,i}^{\text{low}} \end{bmatrix} \begin{bmatrix} \Delta P_{US_{t-i}} \\ \Delta P_{BR_{t-i}} \end{bmatrix} + C^{low} D_t + \begin{bmatrix} \hat{u}_{US_t}^{low} \\ \hat{u}_{BR_t}^{low} \end{bmatrix} \\ \text{Upper regime} \left(\left| P_{US_t} - \beta P_{BR_t} \right| > \theta \right) \\ \begin{bmatrix} \Delta P_{US_t} \\ \Delta P_{BR_t} \end{bmatrix} = \begin{bmatrix} \alpha_{US}^{up} \\ \alpha_{BR}^{up} \end{bmatrix} \left(P_{US_{t-1}} - \beta P_{BR_{t-1}} \right) + \sum_{i=1}^{p-1} \begin{bmatrix} \gamma_{11,i}^{\text{up}} & \gamma_{12,i}^{\text{up}} \\ \gamma_{21,i}^{\text{up}} & \gamma_{22,i}^{\text{up}} \end{bmatrix} \begin{bmatrix} \Delta P_{US_{t-i}} \\ \Delta P_{BR_{t-i}} \end{bmatrix} + C^{up} D_t + \begin{bmatrix} \hat{u}_{US_t}^{up} \\ \hat{u}_{BR_t}^{up} \end{bmatrix} \end{cases} \quad (6)$$

where:

- the α matrix contains the coefficients representing the short-run adjust from the deviations of the long-run equilibrium ($P_{US_t} - \beta P_{BR_t}$);
- the set of parameters ($\Gamma_1 \Delta y_{t-1} + \ldots + \Gamma_{p-1} \Delta y_{t-p+1}$) capture the short-run dynamic, where $y_t = \begin{bmatrix} P_{US_t} \\ P_{BR_t} \end{bmatrix}$; and
- the deterministic terms (CD_t) are included in the model to capture possible linear trends, outliers, and structural breaks.

5.2. Results

We estimated the Equation 01 with different specifications and applying the estimation procedure suggested by Hansen and Seo (2002). Before imposing the restriction $\beta = -1$, we estimated an unrestricted model with two regimes, one lag in the short-run structure, and a trim = 0.05. The model with this specification generates residuals serially correlated, with heteroskedastic variance conditional and problems of non-normality. Therefore, we estimated a model with the same specification but considering two lags in the short-term structure (Model 1).

Model 1 – Constant, two lags, and trim = 0.05

$$
\begin{cases}
\text{Lower regime } (y_{t-1} \le 1.058) \\
\begin{bmatrix} \Delta P^{low}_{US_t} \\ \Delta P^{low}_{BR_t} \end{bmatrix} = \begin{bmatrix} -0.020 \\ (-0.646) \\ 0.109 \\ (1.943) \end{bmatrix} \begin{bmatrix} 1 & -1.067 \end{bmatrix} + \begin{bmatrix} 0.418 & -0.003 \\ (4.091) & (-0.060) \\ 0.247 & -0.150 \\ (1.423) & (-1.494) \end{bmatrix} \begin{bmatrix} \Delta P^{low}_{US_{t-1}} \\ \Delta P^{low}_{BR_{t-1}} \end{bmatrix} + \begin{bmatrix} -0.197 & -0.005 \\ (-2.104) & (-0.087) \\ 0.028 & -0.198 \\ (0.170) & (-2.028) \end{bmatrix} \begin{bmatrix} \Delta P^{low}_{US_{t-2}} \\ \Delta P^{low}_{BR_{t-2}} \end{bmatrix} + \begin{bmatrix} 0.024 \\ (1.316) \\ 0.005 \\ (0.171) \end{bmatrix} \left[const^{low} \right] + \begin{bmatrix} \hat{u}^{low}_{US_t} \\ \hat{u}^{low}_{BR_t} \end{bmatrix} \\
\text{Upper regime } (y_{t-1} > 1.058) \\
\begin{bmatrix} \Delta P^{up}_{US_t} \\ \Delta P^{up}_{BR_t} \end{bmatrix} = \begin{bmatrix} -4.955 \\ (-2.711) \\ 0.769 \\ (0.243) \end{bmatrix} \begin{bmatrix} 1 & -1.067 \end{bmatrix} + \begin{bmatrix} 1.303 & -3.219 \\ (2.855) & (-3.264) \\ 0.077 & 0.656 \\ (0.098) & (0.387) \end{bmatrix} \begin{bmatrix} \Delta P^{up}_{US_{t-1}} \\ \Delta P^{up}_{BR_{t-1}} \end{bmatrix} + \begin{bmatrix} 3.810 & -2.506 \\ (2.380) & (-2.351) \\ -0.657 & 0.432 \\ (-0.237) & (0.234) \end{bmatrix} \begin{bmatrix} \Delta P^{low}_{US_{t-2}} \\ \Delta P^{low}_{BR_{t-2}} \end{bmatrix} + \begin{bmatrix} 4.479 \\ (2.656) \\ -0.717 \\ (-0.246) \end{bmatrix} \left[const^{up} \right] + \begin{bmatrix} \hat{u}^{up}_{US_t} \\ \hat{u}^{up}_{BR_t} \end{bmatrix}
\end{cases}
$$

(t−value)

$AIC = -646.0 \quad BIC = -576.3 \quad \text{obs lower reg.} = 93.3\% \quad \text{obs upper reg.} = 6.7\%$

According to the Model 1, only when the price difference is higher than 1.058 (upper regime), there is a clear connection between the American and the Brazilian market. In the other regime, the lower one, both loading coefficients are not significant (i.e. α^{low}_{US} and α^{low}_{BR} are not statistically different from zero). That means, the window of arbitrage is bind only when the price difference is higher than US$ 1.06/gallon and this value represents the exchange costs incurred to trade ethanol involving Unites States and Brazil. Actually, because the markets are connected only when the American ethanol price is higher than the Brazilian ethanol price, it is possible to associate the value of US$ 1.06/gallon to the average exchange costs incurred to export ethanol from Brazil to United States. Finally, the Appendices 5 and 6 suggest this new specification fixed the problem of residuals serially correlated, but the non-normality and the ARCH structure persist.

Interestingly, the estimated β is almost equal to -1 ($\hat{\beta} = -1.067$). Because the cointegration vector is not estimated but established by a grid search procedure, it is not possible to test if the $\hat{\beta}$ can be considered statistically equal to -1. Therefore, we estimated a model with the same specification but imposing the restriction of $\beta = -1$ on the cointegration vector (Model 3.05). The conclusions are the same obtained in the last model and the estimated coefficients are also very close. Only the threshold is slightly higher than the previous one, meaning that, according to Model 2, the average exchange costs to export ethanol from Brazil to United States is US$ 1.14/gallon. Unfortunately, because the threshold is also established by a grid search procedure, it is not possible to test if both values are statistically equal. Lastly, the residuals of the Model 2 also exhibit problems of non-normality and ARCH structure, but they are not serially correlated (Appendices 7 and 8).

Model 3.05 – Constant two lags, trim = 0.05, and restriction $\beta = -1$

$$
\begin{cases}
\text{Lower regime } (y_{t-1} \leq 1.145) \\
\begin{bmatrix} \Delta P^{low}_{US_t} \\ \Delta P^{low}_{BR_t} \end{bmatrix} = \begin{bmatrix} -0.027 \\ (-0.775) \\ 0.116 \\ (1.913) \end{bmatrix} \begin{bmatrix} 1 & -1 \end{bmatrix} + \begin{bmatrix} 0.419 & -0.006 \\ (4.075) & (-0.106) \\ 0.246 & -0.150 \\ (1.416) & (-1.493) \end{bmatrix} \begin{bmatrix} \Delta P^{low}_{US_{t-1}} \\ \Delta P^{low}_{BR_{t-1}} \end{bmatrix} + \begin{bmatrix} -0.195 & -0.006 \\ (-2.071) & (0.115) \\ 0.024 & -0.198 \\ (0.150) & (-2.028) \end{bmatrix} \begin{bmatrix} \Delta P^{low}_{US_{t-2}} \\ \Delta P^{low}_{BR_{t-2}} \end{bmatrix} + \begin{bmatrix} 0.028 \\ (1.409) \\ -0.009 \\ (-0.268) \end{bmatrix} \begin{bmatrix} const^{low} \end{bmatrix} + \begin{bmatrix} \hat{u}^{low}_{US_t} \\ \hat{u}^{low}_{BR_t} \end{bmatrix} \\
\text{Upper regime } (y_{t-1} > 1.145) \\
\begin{bmatrix} \Delta P^{up}_{US_t} \\ \Delta P^{up}_{BR_t} \end{bmatrix} = \begin{bmatrix} -3.331 \\ (-2.437) \\ 0.145 \\ (0.062) \end{bmatrix} \begin{bmatrix} 1 & -1 \end{bmatrix} + \begin{bmatrix} 0.913 & -2.745 \\ (2.543) & (-3.036) \\ 0.216 & 0.376 \\ (0.349) & (0.243) \end{bmatrix} \begin{bmatrix} \Delta P^{up}_{US_{t-1}} \\ \Delta P^{up}_{BR_{t-1}} \end{bmatrix} + \begin{bmatrix} 2.687 & -1.580 \\ (2.029) & (-1.914) \\ -0.133 & 0.094 \\ (-0.058) & (0.066) \end{bmatrix} \begin{bmatrix} \Delta P^{up}_{US_{t-2}} \\ \Delta P^{up}_{BR_{t-2}} \end{bmatrix} + \begin{bmatrix} 3.218 \\ (2.370) \\ -0.154 \\ (-0.066) \end{bmatrix} \begin{bmatrix} const^{up} \end{bmatrix} + \begin{bmatrix} \hat{u}^{up}_{US_t} \\ \hat{u}^{up}_{BR_t} \end{bmatrix}
\end{cases}
$$

(t−value)

$AIC = -644.3$ $BIC = -574.7$ obs lower reg. = 93.3% obs upper reg. = 6.7%

After all, there are two models (Models 1 and 2) suggesting two values for the exchange costs: δ_1 = US$ 1.06/gallon and δ_2 = US$ 1.14/gallon. We use those values to calculate the variable market transaction costs incurred to export ethanol from Brazil to United States. Considering that (i) the costs to bring the ethanol from the distillery (south-central average) to the port (Santos) are US$ 0.26/gallon (road freight + storage + loading costs + fees), (ii) the shipment costs (sea freight + ad valorem tariff) are US$ 0.25 (anhydrous ethanol), and (iii) the variable market transaction costs are the difference between the exchange costs and the above transportation costs, the variable market

transaction costs range from US$ 0.55/gallon (1.06 – 0.26 – 0.25) to US$ 0.63/gallon (1.14 – 0.26 – 0.25).

As a final comment, it is important to point out some caveats in interpreting those numbers. Because in the analyzed period Brazil exported both conventional and advanced ethanol, those values represent a average of the exchange and the transaction costs. Unfortunately, it is not possible to identify the exported volume of each variety; therefore, it is not possible to guess the weight of each one on the above averages. Moreover, the American ethanol pays a premium for the advanced ethanol. Thus, the model can be underestimating the price difference necessary to trigger the window of arbitrage. We hope more comprehensive data are made available to make this analysis more accurate.

6. Concluding remarks

Marketing a good is a costly activity and those costs are named exchange costs. Markets are organizations created to reduce those costs, facilitating exchange. The exchange costs can be decomposed into transportation and market transaction costs, and markets make an exchange less costly because they reduce the latter. The exchange costs also exert important influence on the degree of integration between markets. The higher those costs, the higher a price difference need to be to turn profitable an arbitrage opportunity.

Despite the importance of the exchange costs, measuring them properly is still a challenging task. Cointegration analysis is one of the most popular approaches applied to evaluate the degree of integration between two or more markets. This literature has also developed a procedure that incorporates the exchange costs in its models. However, despite all efforts, this literature has quantified the transaction costs imprecisely. One of the main problems is the misuse of the concepts of exchange, transportation and transaction costs. This literature does not differentiate transportation from transaction costs; it even uses variables of the former as proxies for the latter. This paper argues that transportation and transaction costs are essentially different, and that exchange costs are the sum of both.

Problems with the definition of transaction costs is not an exclusive shortcoming of the cointegration literature; it is a frequent weakness in many attempts to measure those costs. We propose a procedure to measure the exchange, the transportation, and the variable market transaction costs. The procedure comprises three steps. First, we quantify exchange costs in monetary terms, by means of threshold cointegration models. Second, the transportation costs are estimated by means of data collection that describes in details all the process involved performing the exchange. Finally, the difference between the exchange costs and transportation costs is an indirect measure of variable market transaction costs.

We applied this procedure to the international market of ethanol. There is a vast literature, aiming to evaluate the influence of the ethanol markets on other agricultural markets or on other variables (e.g. land allocation, water resources uses, deforestation, etc.), that assumes the existence of a well developed international market of ethanol. This literature has not considered the transaction costs incurred to trade in this market and there is anecdotal evidence that those cost are substantial. Appling the proposed procedures in the ethanol trade between Brazil and United States, we measured the variable market transaction costs ranging from US$ 0.55/gallon to US$ 0.63/gallon. Because we calculated the transportation costs as US$ 0.25/gallon, in our most conservative results, only when the price difference between those two markets is, in average, higher than US$ 1.06/gallon, it is profitable to export this biofuel from Brazil to United States. Bellow this threshold in average the price difference does not compensate the exchange costs incurred to export ethanol from one country to another.

The procedure proposed in this paper uses a widely applied statistical method (threshold cointegration analyses) to operationalize concepts from Institutional Economics that are not easily observed. As shortcomings, the proposed procedure inherits most of the statistical and theoretical problems of the cointegration models and is sensitive to the transaction costs definition. But it advances offering a method to indirectly measure the market variable transaction costs in currency values.

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Appendix 1 – ADF Unit Root Test of the Ethanol Nominal Price Series

Series	Deterministic comp.	Test statistic	1%	5%	10%
American Anydrous Ethanol	trend	-3.07	-3.99	-3.43	-3.13
	drift	-3.04	-3.46	-2.88	-2.57
	none	-0.26	-2.58	-1.95	-1.62
American Anhydrous Ethanol (d)	drift	-7.73	-3.46	-2.88	-2.57
	none	-7.76	-2.58	-1.95	-1.62
Brazilian Anydrous Ethanol	trend	-3.43	-3.99	-3.43	-3.13
	drift	-2.18	-3.46	-2.88	-2.57
	none	-0.12	-2.58	-1.95	-1.62
Brazilian Anhydrous Ethanol (d)	drift	-9.34	-3.46	-2.88	-2.57
	none	-9.36	-2.58	-1.95	-1.62

Appendix 2 – KPSS Unit Root Test of the Ethanol Nominal Price Series

Series	Type	Test statistic	1%	5%	10%
American Ethanol	mu	0.90	0.74	0.46	0.35
	tau	0.21	0.22	0.15	0.12
American Ethanol (d)	mu	0.05	0.74	0.46	0.35
	tau	0.03	0.22	0.15	0.12
Brazilian Anhydrous Ethanol	mu	1.84	0.74	0.46	0.35
	tau	0.09	0.22	0.15	0.12
Brazilian Anhydrous Ethanol (d)	mu	0.03	0.74	0.46	0.35
	tau	0.03	0.22	0.15	0.12

Appendix 2 – Cointegration tests: American vs. Brazilian Ethanol Nominal Prices

Deterministc term	Lagged (in level)	H_0: r = r_0	Test statistic	10% critical value	5% critical value	1% critical value
Johansen trace cointegration test*						
constant and trend inside	2	$r_0 = 0$	33.18	23.32	25.73	30.67
		$r_0 = 1$	12.96	10.68	12.45	16.22
constant inside and outside	2	$r_0 = 0$	24.19	13.42	15.41	19.62
constant inside	2	$r_0 = 0$	24.49	17.98	20.16	24.69
		$r_0 = 1$	5.44	7.60	9.14	12.53
Saikonen & Lütkepohl cointegration test**						
constant and trend inside	2	$r_0 = 0$	24.37	13.88	15.76	19.71
		$r_0 = 1$	9.39	5.47	6.79	9.73
constant inside and outside	2	$r_0 = 0$	16.58	8.18	9.84	13.48
constant inside	2	$r_0 = 0$	15.51	10.47	12.26	16.1
		$r_0 = 1$	0.53	2.98	4.13	6.93

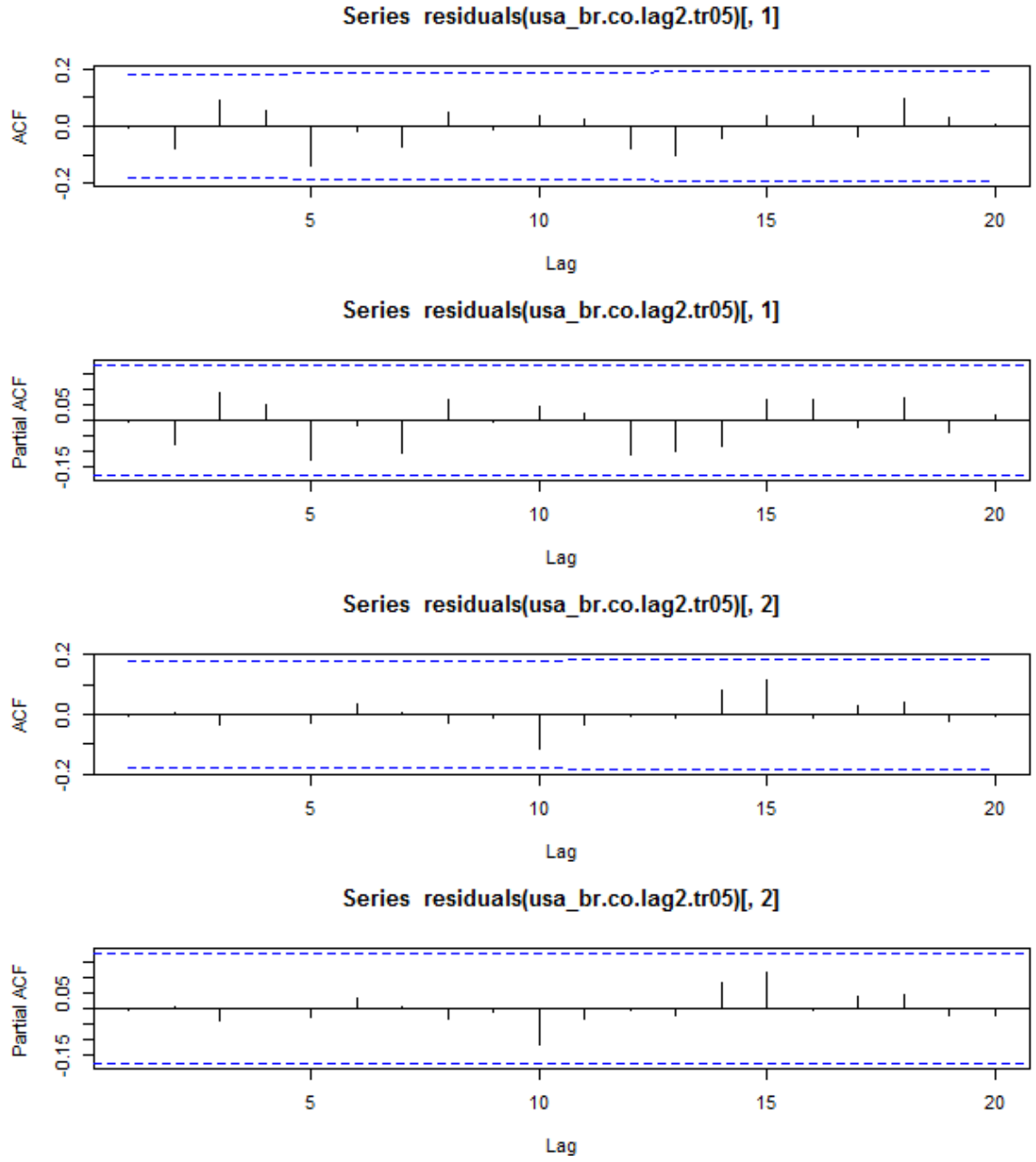
* Critical value from Johansen (1995); ** Critical values from Lüktepohl and Saikkonen (2000, Table 1)

Appendix 4 – Unit Root Tests for the Price Difference

Series	Deterministic comp./ Type(*)	Test statistic	1%	5%	10%
ADF Test					
Price Difference	trend	-4.18	-3.99	-3.43	-3.13
	drift	-2.65	-3.46	-2.88	-2.57
	none	-2.54	-2.58	-1.95	-1.62
Price Difference (d)	drift	-6.24	-3.46	-2.88	-2.57
	none	-6.24	-2.58	-1.95	-1.62
KPSS Test					
Price Difference	mu	1.27	0.74	0.46	0.35
	tau	0.25	0.22	0.15	0.12
Price Difference (d)	mu	0.03	0.74	0.46	0.35
	tau	0.03	0.22	0.15	0.12

* 'Deterministic components' for ADF tests and 'Type' for KPSS tests

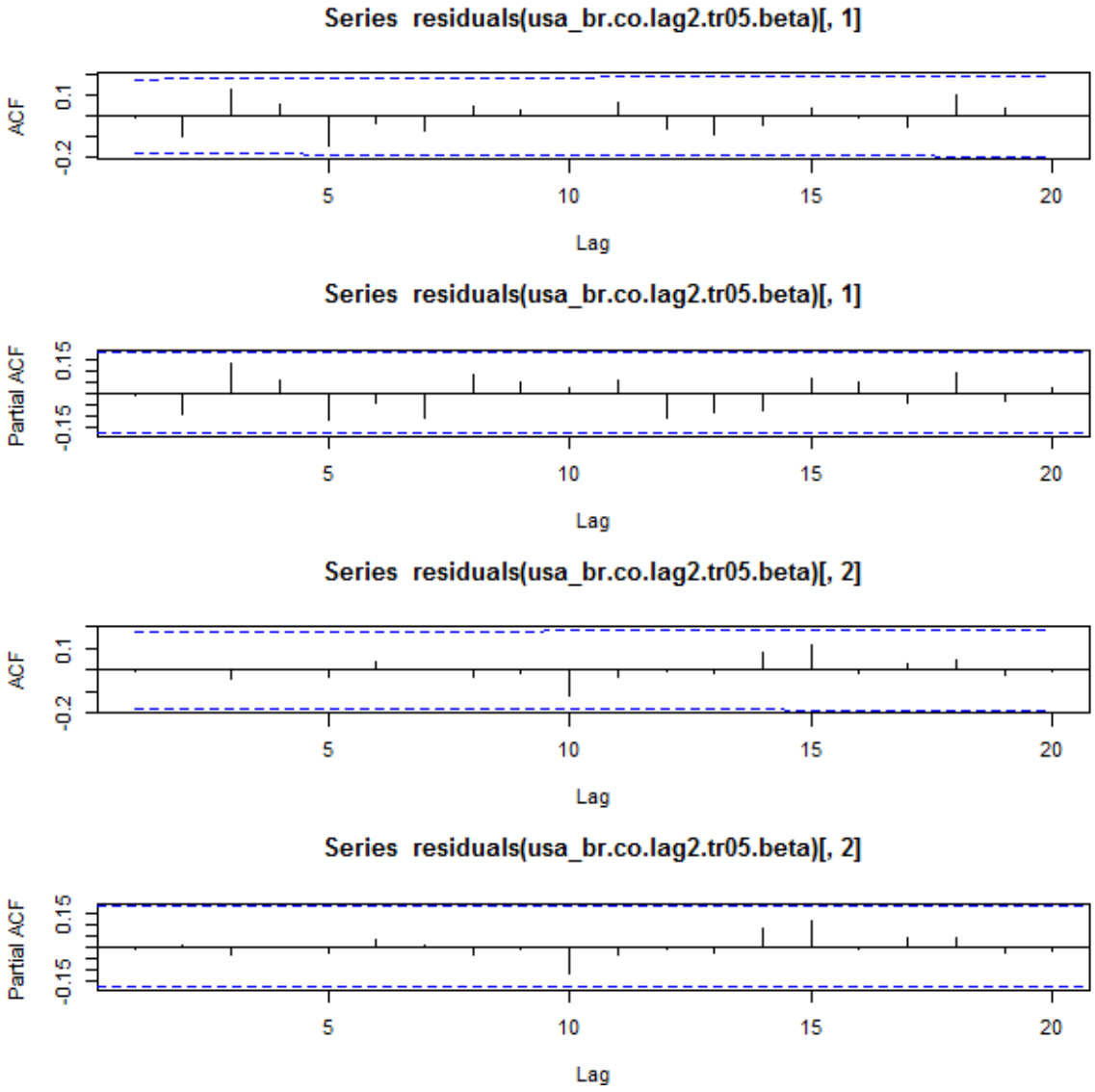
Appendix 5 – Correlogram of the Model 1



Appendix 6 – Diagnostic tests of the Model 1

Residuals of American corn price			*Residuals of Brazilian sugarcane price*		
Test	**Statistics**	**PValue**	**Test**	**Statistics**	**PValue**
Serial Correlation (Ljung-Box)			Serial Correlation (Ljung-Box)		
Q6	4.649	0.590	Q6	0.452	0.998
Q12	6.799	0.871	Q12	2.534	0.998
Q18	10.394	0.918	Q18	5.779	0.997
Q24	17.224	0.839	Q24	6.600	1.000
Normality test (Jarque-Bera)			Normality test (Jarque-Bera)		
JB	11.888	0.003	JB	3671.693	0.000
Conditional Variance test (ARCH-LM)			Conditional Variance test (ARCH-LM)		
ARCH-LM(6)	2.101	0.910	ARCH-LM(6)	36.842	0.000

Appendix 7 – Correlogram of the Model 02



Appendix 8 – Diagnostic Tests of the Model 02

Residuals of American corn price			*Residuals of Brazilian sugarcane price*		
Test	**Statistics**	**PValue**	**Test**	**Statistics**	**PValue**
Serial Correlation (Ljung-Box)			Serial Correlation (Ljung-Box)		
Q6	6.413	0.379	Q6	0.458	0.998
Q12	8.515	0.744	Q12	2.561	0.998
Q18	12.089	0.843	Q18	5.742	0.997
Q24	20.679	0.658	Q24	6.569	1.000
Normality test (Jarque-Bera)			Normality test (Jarque-Bera)		
JB	10.797	0.005	JB	3623.111	0.000
Conditional Variance test (ARCH-LM)			Conditional Variance test (ARCH-LM)		
ARCH-LM(6)	2.018	0.918	ARCH-LM(6)	37.293	0.000