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Cross-correlation analysis on Brazilian gasoline retail market

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HIGHLIGHTS

- We studied multi-scale cross correlation analysis in gasoline retail market.
- We compared fifteen different cities from all Brazilian regions.
- We found strong cross-correlation values between three capitals of Southeast region.

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ABSTRACT

In this paper we investigate the cross-correlations between Brazilian gasoline retail markets in fifteen capitals. The hypothesis that is not expected any strong cross-correlation or anti cross-correlation between these markets was tested by applying the multi-scale cross correlation analysis in the of Average Retail Margin of gasoline type C. Our empirical results support a significant cross-correlation value between three capitals of Southeast region for both short-term and long-term, regardless of time scale (weeks). Moreover, São Paulo–Belo Horizonte and São Paulo–Rio de Janeiro pairs presented strong correlation from time scale of thirty three weeks. And also São Paulo market seems exerts some regional influence in the Average Retail Margin behaviors. The main contribution is that cross-correlations results have importance in terms of taking decisions for investors as well as for Brazilian energy policies.

1. Introduction

The Brazilian energy matrix is characterized by the diversification of sources, mainly for transportation. In the case of the automotive fleet, the diesel is the second demanded fuel used by large road vehicles, basically trucks and buses, which is not competing with other fuels in the urban zone, like ethanol, compressed natural gas (CNG) or gasoline. Besides of the spatial distinctions, the modern flex-fuel vehicles, with an internal combustion engine designed to run more than one fuel, has represented a strategic role in the Brazilian energy policy and economics [1]. This fuel is usually gasoline blended with any ratio of ethanol. According to the National Agency of Petroleum, Natural Gas and Biofuels (ANP) [2,3], the gasoline blended (gasoline with percentage of ethanol), called gasoline type C, was the best seller fuel in 2011, and also presented an increase from 2005 to 2014, 88.36%, in sales volume, as showed in Table 1.

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Table 1
Sales' volumes of gasoline type C in Brazil between 2005 and 2014 by wholesale market (in mil m^3) [2].

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
23.553	24.008	24.325	25.175	25.409	29.844	35.491	39.698	41.426	44.364

The additional feature of the Brazilian retail market is its fragmented participation, with 39,027 retails in 2011 [2]. This market is divided in two categories of companies, known as "white flags" and affiliated retails. The first category is not linked with any wholesale (*i.e.*, it is free to buy from any wholesale company). The second one normally buy its fuel from a specific wholesale and, also, it uses the trademark of the wholesale on the gas station facade, once the Brazilian law does not allowed a wholesale to act as a retail in order to reduce the market power of the wholesale and price alignment [3].

Despite being fragmented, the gasoline price alignment is something possible in the Brazilian retail market. According to [4], the affiliated service stations were responsible for sell 71.7% over total gasoline sales in the country in 2014. It is a concern to the ANP, once the retail companies can intentionally adopt several strategies to improve their financial returns. Thus, based on the size and market scale, the ANP uses a set of assumptions to find out an indicative of price alignment [5].

On the other hand, consumers may cause impact in that market, including the prices of the gasoline type C. The estimation of fuel demand is a concern for energy economics, for example, in Refs. [6–8] were found evidences of spatial and temporal differences in gasoline price related to elasticity of fuel consumption (*i.e.*, the degree of responsiveness of quantity demanded for the changes in the determinants of demand), *e.g.*, gasoline type C price. In this way, there is an expectation of the Brazilian retail market to be competitive in term of the price, taking into account its open and fragmented retail market. Furthermore, as quoted by [9], the economic theory of consumer behavior suggests the hypothesis that consumers are more responsive to prices, adjusting faster towards desired demand levels. It may impact the Average Retail Margin (ARM) in Brazilian gasoline retail markets.

Statistical methods have been applied in energy economics and financial areas in order to evaluate cross-correlations between diversities pairs of time series for several subjects, including: the inter-influence of oil prices and renewable energy sources [10]; cross-correlations between the West Texas International crude oil (WTI) and Baltic Exchange Dirty Tanker Index (BDTI) [11]; relation between oil prices and exchange rates [12–15]; electricity price and trading volume in market of a country [16]; analysis between WTI crude oil and the stock markets of economic the BRIC [17].

The Brazilian retail market is complex system, with different regional features for a same product, as gasoline type C, *e.g.*, different costs with gasoline station labors; complex taxes and fees systems; largest regional differences for gross domestic products (GDP); fleet of vehicles and logistics; local environmental laws, among other factors; which suggest an inequity in terms of ARM composition between markets as well. According to [18], the Brazilian fuel sector presents a moderate degree of concentration in the markets, weak barriers to entry, and unstable demand and cost conditions, structural factors that do not facilitate the formation of cartels. On the other hand, it presents the strong presence of market organizing agents — the unions. The retail market analysis by using ARM approach simplifies the evaluation of a complexity gasoline price markup, leaving aside innumerable endogenous factors, previously described.

The aim of this paper is to assess the spatial cross-correlation in the Brazilian gasoline retail market, and verify the hypothesis that is not expected to find any strong cross-correlation or anti cross-correlation between these markets. For this proposal the scaling ρ_{DCCA} method was applied in ARM of gasoline type C for fifteen Brazilian cities in five capitals throughout the Brazilian territory. This paper is divided in four section as following: after this introduction, the second sections present the data source and the statistical method; the third section is the results and; the fourth section is the conclusion of this paper.

2. Materials and methods

2.1. Data

To evaluate the relationship between common gasoline dealer markets in Brazil, it was used the $ARM_w = rs_w - c_w$, where ARM is the Average Retail Margin signal, *rs* is the average price of gasoline on the retail market, *c* is the average gas price on the wholesale, and w is the time in weeks (517 weeks), between 2005 and 2014. The ARM were calculated from the sets of data collected from weekly survey of gasoline prices, where that are carried out in 555 municipalities, This service is provided monthly by ANP repository [5].

The ARM of the gasoline type C were calculated from sets of data in fifteen cities with relevant markets. The criterion to choice the cities were to have more than 500,000 inhabitants, to be a capital and limited to three cities per region. The Fig. 1 is shown the chosen cities for this analysis.

2.2. Brief review of the method to determine the detrended cross-correlation coefficient

It has been used the ρ_{DCCA}, proposed by [19]. It is based on the self correlation theory [20] and the study of cross-correlation between time series by power law [21]. The ρ_{DCCA} method has been applied in diverse fields, such as: climatic issues [22,23], crime studies [24] and finances [25–30]. According to [31] the multiscale cross-correlation is sub-area of econophysics that

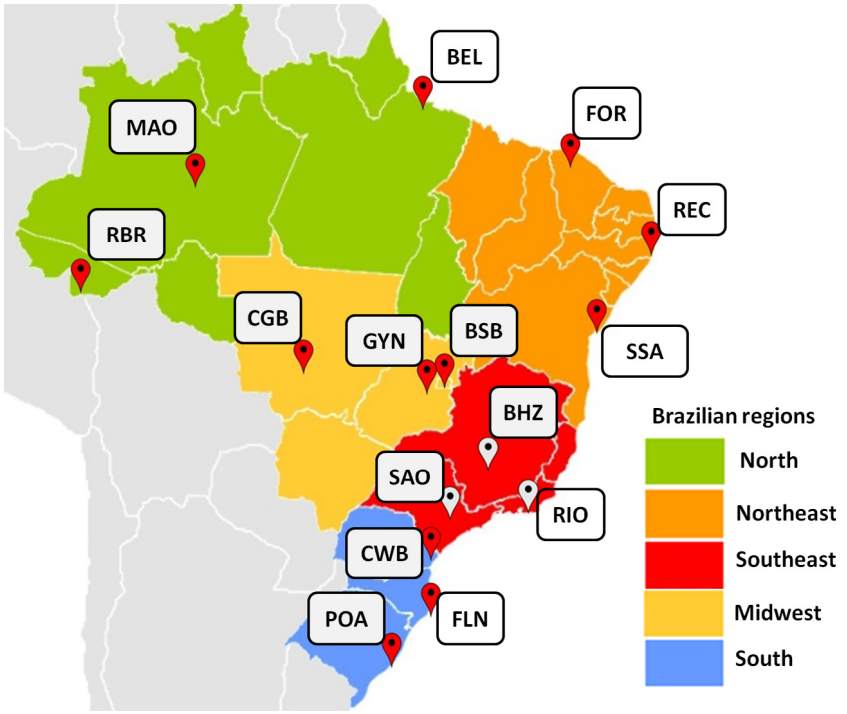

Fig. 1. Brazilian map with fifteen retail market — Belém (BEL), Belo Horizonte (BHZ), Brasília (BSB), Cuiabá (CGB), Curitiba (CWB), Florianópolis (FLN), Fortaleza (FOR), Goiânia (GYN), Manaus (MAO), Porto Alegre (POA), Recife (REC), Rio Branco (RBR), Rio de Janeiro (RIO), Salvador (SSA), São Paulo (SAO).

can be defined as the use of complex systems tools in economics [32–34]. In this context, there are some new progress about cross-correlations methods by [35–42].

The ρ_{DCCA} calculation is obtained following the 5 steps below:

1. Considering two time series, $\{x_t\}$ and $\{y_t\}$ where $t = 1, 2, \ldots, N$ (N is the total number of elements of the time series), it is integrate the time series obtaining two new series Eq. (1).

$$xx_k = \sum_{t=1}^{k} x_t \text{ and } yy_k = \sum_{t=1}^{k} y_t, \ k = 1, 2, \ldots, N \tag{1}$$

2. These two integrated time series are divided, $\{xx_k\}$ and $\{yy_k\}$, in $(N - s)$, overlapping boxes of equal length s, with $4 \leq s \leq \frac{N}{4}$.
3. The local trend of each box is calculated by the least squares adjustment of each series, $xP_i(k)$ and $yP_i(k)$. Then, it is calculated the covariance of residues in each defined box by Eq. (2).

$$f^2{}_{xy}(s, i) = \frac{1}{s+1} \sum_{k=1}^{i+s} (xx_k - xP_i(k))(yy_k - yP_i(k)) \tag{2}$$

4. It is calculated the average over all overlapping boxes to obtain the new covariance function (Eq. (3)).

$$F^2{}_{xy}(s) = \frac{1}{N-s} \sum_{i=1}^{N-s} f^2{}_{xy}(s, i) \tag{3}$$

5. Then, the ρ_{DCCA} is determined by Eq. (4).

$$\rho_{DCCA}(s) = \frac{F^2{}_{xy}(s)}{F_{xx}(s) F_{yy}(s)} \tag{4}$$

where $F^2{}_{xy}(s)$ is the correlation function determined by the method of [21]. $F_{xx}(s)$ and $F_{yy}(s)$ are the autocorrelation functions determined by the method of [20]. Moreover, the cross-correlation coefficient depends on the size of each box s.

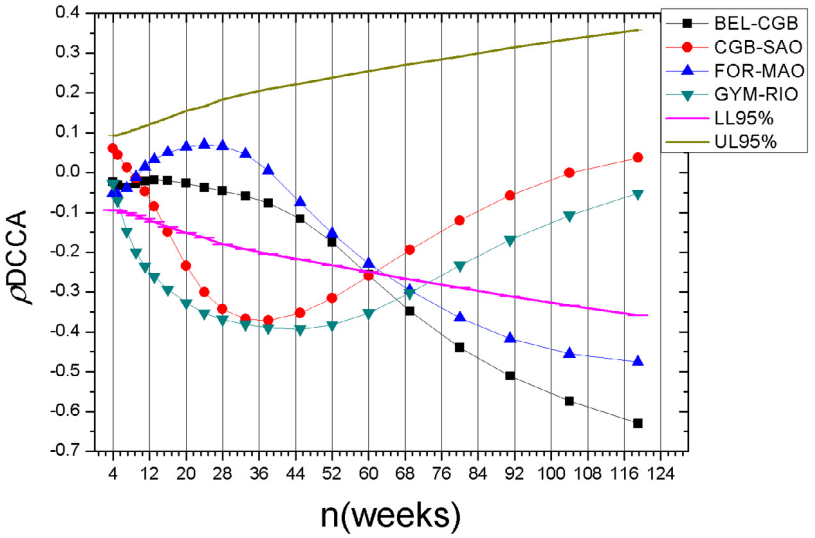

Fig. 2. Anti cross-correlation coefficients between the ARM of four pairs, where CGB appears two times. The LL95% and UL95% are the significant levels calculated and represent the low limits and upper limits respectively, through the time scales (weeks).

In terms of the level of cross-correlation, the ρ_{DCCA} is a dimensionless coefficient that ranges between 1 and -1, where 1 is a condition with a perfect cross-correlation and -1 is a perfect anti cross-correlation. A zero value represents no cross-correlated condition [24].

3. Results

For the analysis of the results, will be considered the statistical test of [43] in which the correlation is significant outside the lines representing lower and upper critical values with significance of 95%, for the test with the hypothesis H0:$\rho_{DCCA} = 0$ and H1: $\rho_{DCCA} \neq 0$.

It is important to point out the combination were used to analyze the cross-correlation between all these time series. Each city were analyzed against all other cities, regardless of the region in which they are or any other economic premise.

It can be observed in Fig. 2 all results that presented anti cross-correlation for any defined time scale. The highlight is CGB that appears two times in four.

Fig. 3 is showing the results with a significant positive cross-correlation in a time scale ranging from four to about twenty-eight weeks. It may be noted that the city that most appeared positively influencing the gross margin of the others cities was RIO, three times in five results. This shows that, for a period of up to twenty-eight weeks, RIO has a positive influence among the other Brazilian cities, two in the northern region (RBR and BEL) and one in the south of the country (POA).

Fig. 4 is showing results that presented cross-correlation for results over sixty weeks. Once again it can be observed that the CGB appeared two times with cities that are situated in the northeast region (FOR and REC). The other cross-correlation was between FOR and REC. It is possible to highlight that all cities that appear in this analysis are located in the North and Northeast region of Brazil.

All results that presented a positive and significant cross-correlation in any time scale are shown in Fig. 5, with the exception FLN–GYM, which became significant after nine weeks. It has been observed that BHZ, SAO and RIO are in the same region (Southeast) and they have State borders. In addition, the value of the ρ_{DCCA} between SAO and RIO exceeds 0.66 already with thirty three weeks of time scale and remains strong for all subsequent scales, reaching almost 0.8 for long time scales.

The same analysis applies to the correlation involving SAO and BHZ, where the ρ_{DCCA} exceeds 0.66 from fifty two weeks and remains above it up to one hundred and nineteen weeks, approaching 0.8. According to [44] a ρ_{DCCA} value above 0.66 can be considered strong.

The significant cross-correlation does not happen for the CWB–FOR, CWB–REC and FOR–REC pairs, that begin to have some significant, but weak, cross-correlation only from a time scale above 52 weeks. However, the pairs BEL–FOR, BEL–RIO, FOR–RIO, POA–RIO, RBR–RIO presented significant cross-correlation only for a short time scale. And the pairs BHZ–CWB, FOR–MAO, CWB–SAO, GYN–RIO presented an anti-correlated behavior for some time scale.

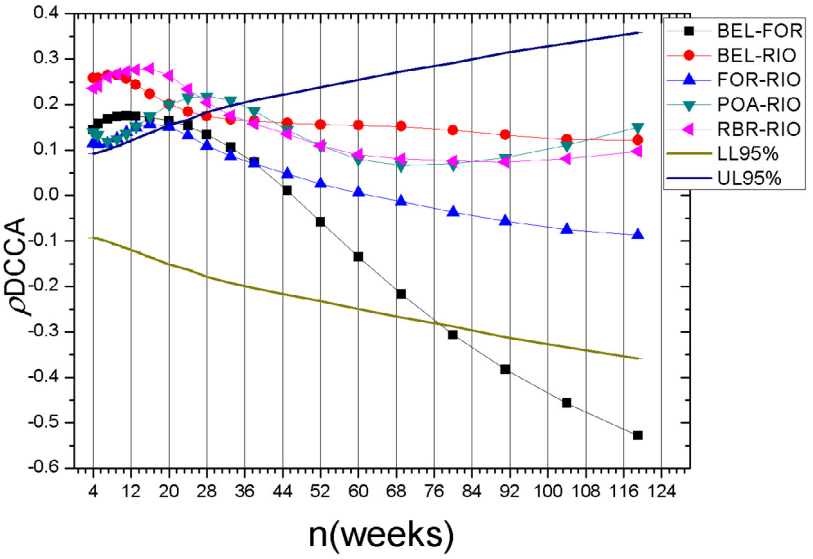

Fig. 3. Significant cross-correlation for a time scale up to 28 weeks. It may be noted that the city that most appeared positively influencing the gross margin of the others cities was RIO, three times in five results. The LL95% and UL95% are the significant levels calculated and represent the low limits and upper limits respectively, through the time scales.

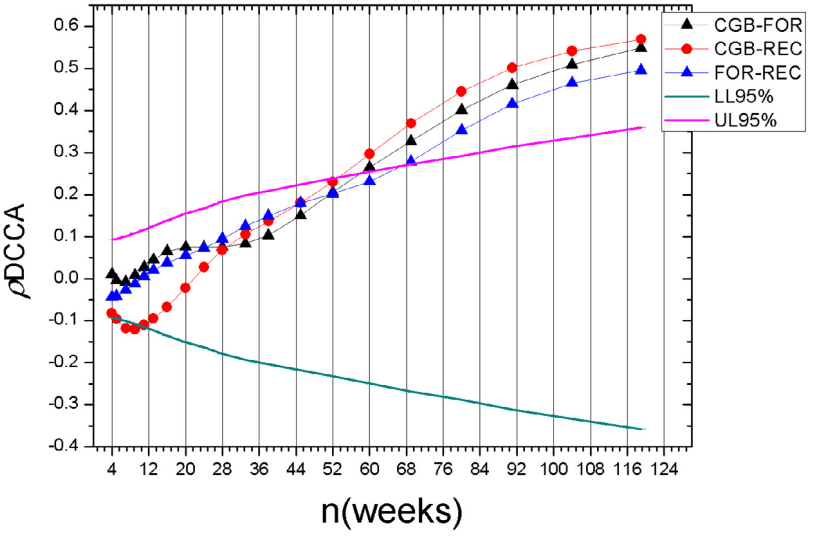

Fig. 4. Cross-correlation for a time scale over 60 weeks. CGB appeared two times with cities that are situated in the northeast region. All cities that appear in this analysis are located in the North and Northeast region. The LL95% and UL95% are the significant levels calculated and represent the low limits and upper limits respectively, through the time scales.

4. Conclusions

It was observed the co-movements of the ARM for fifteen capitals, in different time scales (weeks), by applying the ρ_{DCCA} method. The empirical results obtained from cross-correlation coefficients have rejected the hypothesis that there are not strong cross-correlation or anti cross-correlation between all analyzed Brazilian retail markets.

The causal relationship among these representatives of the Brazilian gasoline retail industry were explored. In spite of the most of coefficients were not significant or showed a weak coefficient value, there were two samples that presented strong correlations, (*i.e.* ρ_{DCCA} values greater than 0.66, according to Ref. [44]), where Belo Horizonte–São Paulo reached it from fifty two weeks and Rio de Janeiro–São Paulo reached it from thirty three weeks. It is mainly concluded that Belo Horizonte–São Paulo and Rio de Janeiro–São Paulo pairs, pairs situated in Southeast region, presented significant cross-correlation for all time scales.

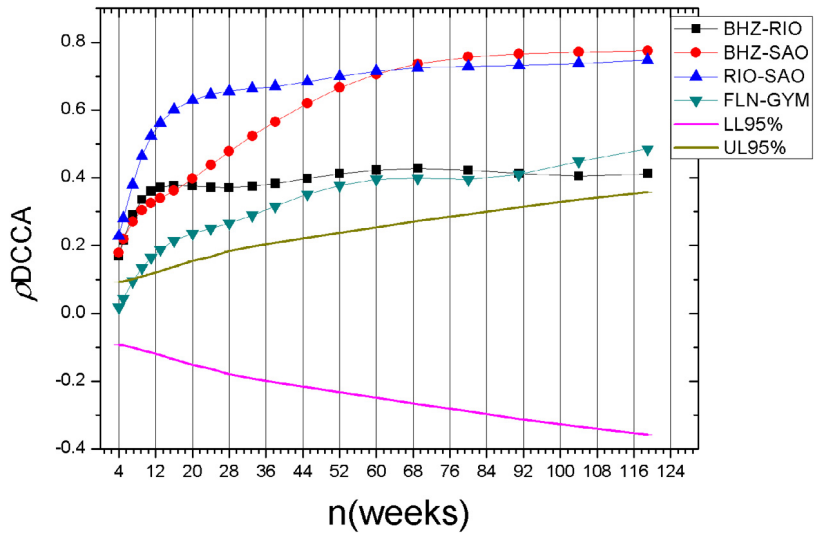

Fig. 5. Cross-correlation results for all time scales between the pairs BHZ–RIO, BHZ–SAO, RIO–SAO, except for the correlation involving the cities FLN–GYM, which became significant after 9 weeks. The value of the ρ_{DCCA} between SAO and RIO exceeds 0.66 already with thirty three weeks of time scale and remains strong for all subsequent scales. SAO and BHZ pair exceeds 0.66 from fifty two weeks and remains above it up to one hundred and nineteen weeks. The LL95% and UL95% are the significant levels calculated and represent the low limits and upper limits respectively, through the time scales.

Although, the Brazilian gasoline retail market deal with homogeneous products and similar costs, the gas station owners still need to face regional issues (taxes and fees, environment rules and logistic process). Thus, the ARM analysis is useful as profit model, by putting aside any regional distortions even adjustments, and it may be a measurement, overall patterns, regardless of retail market size or concentration, revealing their profit behavior straightly. In the economic theory market with low levels of concentration, reflects the presence of a substantial number of similar firms (gas stations) and, at least implicitly, the absence of substantial entry barriers, should be associated with price–cost relationships indicating normal profitability for it [45,46].

Nevertheless, cooperative actions can achieve supra-normal profit, where positive payoff reached by overt or covert or even tacit collusion among borderline gas station owners. Thus, if firms really cooperate strategically, we can empirically propose the idea that the significant correlations are dynamic spatial and temporal cooperative results [45,46]. A typical behavior observed in strategic interactions that arise in a sector with a small number of companies is compared to oligopoly market structures [46,47]. A resembling behavior and market situation was analyzed on the Spanish gasoline market. Despite the Spanish liberalization process, the presence of Repsol Group, a huge and vertically integrated company with a high market share in all segments, does facilitate a collusive price equilibrium [48]. It may be compared to the wholesale market and the affiliated service stations of Petrobras company in Brazil (*i.e.* Petrobras, in 2014, was the leader on the market share of the distributors with 28.5% of the country's market [4]).

Besides that, São Paulo seems to exert control, leading in its region and powerfully influencing Belo Horizonte and Rio de Janeiro ARM, as if they mimic São Paulo's ARM actions, once Belo Horizonte–São Paulo and Rio de Janeiro–São Paulo presented stronger coefficient values than Belo Horizonte–Rio de Janeiro, reaching almost twice the size of this measurement. It may be other indicative of tacit collusion. Tacit collusion does not necessarily involve any collusion in the legal sense, and no communication between the parties is really needed. It is considered a tacit collusion because the consequence may well resemble that of explicit collusion or an official cartel [49]. Companies can make supra-normal profits in tacit collusion situations. It can arise when companies interact repeatedly (such repeated interactions can result in persistent correlations, as observed in the southeast region). Any deviation from this collusive path would cause some kind of retaliation, so the companies may be able to maintain higher profits by tacit agreement [49].

This study may contribute to spatial–temporal research in local energy areas, in terms of taken-decisions. We believe that our findings have important implications for investors. Once they have the possibility of choosing markets that present similarities in their ARM, they may decide to invest (expanding their business) in regions with correlated or non-correlated ARM. Thus, Brazilian investors should take into account the multiscale effect of retail market cross-correlations when they decide to invest, evaluating the advantages of spread their gas stations in different markets widely or concentrate it. Therefore, strong cross-correlation coefficient results could reduce financial benefits of market diversification, observed on stock markets [42].

Moreover, this study could be applied together with any conventional statistic methods, possibly some of the methods currently used by ANP [5], to analyze an indicative of price alignment. The Brazilian energy policy can take advantage of this method to analyze micro-regions to find unexpected co-movements between border cities.

Future research on the Brazilian gasoline retail market may debate the mechanisms of a possible tacit collusion on the Brazilian southeast market, and its social and economic impacts. Another possible approach to be considered is to evaluate small spatial scales in order to verify the hypotheses of tacit collusion effects to access the neighborhood behavior.

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