Revista Brasileira de Gestão e Desenvolvimento Regional
G&DR. V. 16, N. 2, P. 472-483, mai-ago/2020. Taubaté, SP, Brasil.
ISSN: 1809-239X

Received: 02/07/2020
Accepted: 04/30/2020

TRUCK DRIVERS STRIKE: THE MOST AFFECTED SECTORS AND THEIR SPACE DEPENDENCES

GREVE DOS CAMINHONEIROS: OS SETORES MAIS AFETADOS E SUAS DEPENDÊNCIAS ESPACIAIS

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Abstract

This study aims to investigate which sectors of the Brazilian economy were the most affected by the truckers strike that took place in May 2018, and if these sectors have spatial dependence on each other. The methodological approach of this research is made with Inoperabilty Input-Output Model (IIOM) and Exploratory Spatial Data Analysis (AEDE). In addition to the ground transportation sector itself, the sectors that were most affected by the truckers' strike were: the oil refining and coke oven sector and the automotive parts and accessories manufacturing sector, due to their high connections. with the paralyzed sector. In addition, global and local Moran I tests showed that in both univariate and bivariate analysis, the sectors most affected by the truckers strike have a statistically significant spatial dependence with the presence of clusters in the northeast region.

Keywords: Truckers strike; Inoperability Input-Output Model; Exploratory Analysis of Spatial Data.

Resumo

O presente estudo tem como objetivo averiguar quais setores da economia brasileira foram os mais afetados pela greve dos caminhoneiros ocorrida em maio de 2018 e se esses setores têm dependências espaciais entre si. A abordagem metodológica dessa pesquisa é feita com o modelo de Inoperabilidade de Matriz Insumo-Produto (IMIP) e com a Análise Exploratória de Dados Espaciais (AEDE). Observou-se que, além do próprio setor de transporte terrestre, os setores que mais foram afetados pela greve dos caminhoneiros foram os setores de refino de petróleo e o de fabricação de peças e acessórios para veículos automotores, devido às suas altas ligações com o setor paralisado. Além disso, os testes de I de Moran global e local apresentaram que, tanto na análise univariada quanto na análise bivariada, os setores mais afetados pela greve dos caminhoneiros têm dependência espacial estatisticamente significativa com a presença de *clusters* na região nordeste.

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Palavras-chave: Greve dos caminhoneiros; Inoperabilidade de Matriz Insumo-Produto; Análise Exploratória de Dados Espaciais.

Introduction

With the advance of globalization, interregional and intersectoral trade ended up have been increasing. That has influenced factors such as logistics, outsourced, a supply of inputs, among others. According to Blos and Miyagi (2015), the interconnectivity and interconnection between sectors have become increasingly greater. Therefore, increasingly vulnerable to interruptions in their activities. This interdependence between sectors has a ripple effect when one of these sectors becomes unopened, thus affecting not only industries in that sector but also the local development.

This interconnection is available at the level of links between sectors of an economy, as in the land transport sector. Toyoshima and Ferreira (2002) emphasize the relevance of the transport sector, especially when there are some imbalances. This because it is a sector linked both backward and forward with the other sectors in the Brazilian economy is important in demand for inputs from different industries and in offering its services to others. The transport sector is essential, especially in countries that have a vast territory for scale production. Without the terrestrial transport sector, industries would be left without inputs and products. The terrestrial transport sector is a horizontal sector, which makes other sectors highly dependent on its services (ERHART; PALMEIRA, 2006).

The Input-Output model, developed by Leontief in 1936, presents an interactive structure between sectors of an economy. On top of the work of Leontief, other methodological ramifications of the Input-Output matrix have been developing, such as the Inoperability of Input-Output Matrix (IIOM) explained by Santos and Haimes (2004). In this approach, the impact of the inactivity of a sector is observed in other sectors. In the IIOM methodology, the inability of one sector to operate causes a ripple effect on other sectors of the economy, and this can be measured by a percentage of inoperation.

Several causes interrupt the activity in a given sector, for instance, environmental catastrophes as dealt with in Paula Junior and Auriglietti (2019) or even non-environmental ones, such as the strike of truckers that paralyzed the road transport sector that happened in May 2018 in Brazil. Given the relevant theme, the main purpose of this study is to verify which sectors were most affected by the strike of truckers, and how these sectors are spatially dependent on each other. To fulfill this objective, IIOM is first applied to the interstate matrix estimated by Haddad et al. (2018). After that, an Exploratory Analysis of Spatial Data (ESDA) was applied to verify if there is a spatial dependence between sectors most affected by the strikers.

The paper is structured in five sections, in addition to this introduction, section 2 deals with the review of the empirical literature on the subject, section 3 presents the data and methodologies of IIOM and ESDA, section 4 presents the results obtained and, finally, the last section shows the main conclusions of this study.

Literature Review

The process of recovering the economy after the shock due to disruption in a given sector is vital to understanding how it affects the sector itself and the community, such as infrastructure degradation. Xian He and Jeong Cha (2018) studied the recovery of an infrastructure network that encompassed energy, water, and telecommunications affected by a hurricane in Galveston, Texas, in 2008, affecting four industrial areas, 16 residential areas, and 19 commercial areas. The results obtained were that the restoration of the power system was 19 days, and the total recovery of the network after the hurricane took about 12 months, affecting the local sectors.

Inoperability can occur in several ways, whether total or partial, such as equipment failure, which slows down the production process of a specific sector, and is used to study several cases. Kasivisvanathan et al. (2013) researched what should be the operational adjustment to be made in multifunctional energy systems affected by inoperalization, where a machine that was operating at only 70% of its total capacity in a Biorefinery. The results were that for the profit to be optimized, it should be the US $ 17,852/h in production with partial inoperability. While in the absence of any type

of inoperability, the profit would be US $ 20,640/h, a variation of 13.5% of what could have been inoperable.

Brosas et al. (2017) studied the case of a plant-based food supply chain in the Philippines. The region has a high vulnerability concerning natural phenomena, in which this supply chain contains one main industry that has five input suppliers and an outsourced responsible for packaging the product, in addition to buyers who are pharmacies and grocery stores. Therefore, any type of interruption in these industries could cause several consequences for any stage of the supply chain. They reproduced a scenario where due to a tropical typhoon, there was a drop in the supply of inputs, responsible for a 10% increase in the price of Malunggay seed, which is an herb used in the production of plant-based foods. They found that although the most significant impact was on the supplier firm in Malunggay, all other companies were affected because of the interdependence between them.

In Japan, Tsuchiya et al. (2007) simulated the impact caused by earthquakes on its infrastructure. The consequence was the disruption of traffic on railways and highways, in interregional flows, the movements of labor and capital were restricted, which causes a delay effect on the dynamics of the economy. Some results were: a significant loss that influences the East-West regions of Japan. The new path after the catastrophe helps to mitigate transport-related losses. The impact on traffic is higher in interregional than in intraregional regions.

Haggerty et al. (2008) estimated the percentages of truck drivers who were prevented from delivering their shipments due to traffic interruption as a result of the Northridge Earthquake that occurred in 1994 when four highways with average daily traffic of 300,000 vehicles were closed. 32.6% of respondents reported that they were unable to complete their delivery. The survey concluded that the loss in monetary values for the United States economy was about $ 1.5 billion. In the case of people who were unable to go to work, about 10% of respondents in the study.

Roquel et al. (2018) studied some scenarios of inoperability in the metropolitan area of Manilla. One of these cases was congestion in which cost around 2.4 billion pounds until 2014 when a law that banned trucks in the city was passed to reduce the traffic. However, this measure had an impact of around 43.85 billion pounds over the seven months of its duration. In addition to congestion, the region has exposed to frequent typhoons, which end up causing several floods. The interdependence was evident and the results obtained show that the sectors that suffered most from the interruption were: Manufacturing, Commerce, Agriculture, and Mining. Bringing a loss of £ 458 million from the disruption in the transport sector. However, the construction of a highway connecting the north to the south of the region would reduce that cost to £ 331 million.

About the strike that lasted eleven days throughout Brazil, when most of the highways were blocked, the drivers claimed a reduction in the price of diesel, exemption from tolls on suspended axles and the creation of a regulatory framework for the class. Kreter et al. (2018) presented some products from the agricultural sector that were affected by the strike were milk, beef, pork, and poultry. Since milk production is carried out in such a way that there is a limited time for keeping it on the property, any kind of lack of activity in logistics has direct consequences, such as the disposal of about 280 million liters during the strike, the equivalent of 360 million reais. Concerning beef, there is a high cost for keeping cattle until the resumption of activity in the slaughterhouses. The strike damaged the export of 40 thousand tons of meat, equivalent to about 600 million reais. In the case of pork and poultry, as animal feed is mostly made up of feed, it is estimated that 64 million birds died from lack of food, considering the pigs together with the birds, the loss revolves around 3 billion reais.

Methodology

We used the interregional input-output matrix estimated by Haddad et al. (2018) for the year 2011. This matrix was estimated using the Interregional Input-Output Adjustment System (IIOAS) method that was applied for data unification IBGE with techniques not used in censuses.

Based on these data, the IIOM and ESDA methodologies were applied, which are addressed in the next subsections. With these methodologies, it was possible to verify which state sectors were the most impacted by the truckers strike and also if the inoperation caused by the strike had spatial dependence.

Input-Output model and its inopeberality methodology

Guilhoto (2004) explains that the Input-Product model preserves the macroeconomic identities of the variables related to the national economy. From there, the Input-Output methodology is shown matrix-wise:

$$Ax + c = x \quad (1)$$

where A is the technical coefficients matrix; x is total production vector and c is a final demand vector.

Whereas in order to satisfy the final demand it is necessary to solve equation (1) for the total production vector:

$$x = (I - A)^{-1}c \quad (2)$$

There is an intention on the part of some authors to applied an econometric model in unexpected events. However, according to Donaghy et al. (2007), there are some barriers to do that. One of the problems is that the pattern used in econometric modeling is not conducive to the topic, due to the existence of a few studies for this purpose, reducing the chance of finding a balance. Another factor is that some unexpected events impact on small periods, which can also make econometric modeling difficult.

According to Okuyama (2007), the accuracy of the estimate is questioned when studying the impact of causes that make a given sector inoperal, especially since each event has a unique characteristic. The effect of a strike that paralyzes a sector is different from the impact of a natural phenomenon that would paralyze the same sector. This question about the accuracy of the estimate will be greater when the result of the impact is relatively high.

IIOM is a tool that can assess risks since it is capable of measuring the interconnection between all sectors of the economy, which in this study, the other sectors would be centered on the transport sector. According to Anderson et al. (2007) the IIOM methodology is approached starting from:

$$loss\ of\ normalized\ production = \frac{planned\ production - degraded\ production}{nominal\ production} \quad (3)$$

This research applies to inactivity in the road transport sector due to the strike of truckers in a term called $\tilde{x}_i$, which is the affected production in sector i.

$$q_i = \frac{x_i - \tilde{x}_i}{X} \quad (4)$$

Therefore, in terms of inoperability we rewrite equation (2) as follows:

$$(x - \tilde{x}) = A(x - \tilde{x}) + (c - \tilde{c}) \quad (5)$$

Then, let $\hat{x}$ be the diagonal matrix derived from the vector x and inserted in equation (5):

$$\hat{x}^{-1}(x - \tilde{x}) = \hat{x}^{-1}A(x - \tilde{x}) + \hat{x}^{-1}(c - \tilde{c}) \quad (6)$$

Equation (6) can be rewritten as:

$$q = A^*q + c^* \quad (7)$$

Therefore, the vector of inoperability as a function of the interdependence matrix and the inoperalized final demand is represented in the following expression:

$$q^* = (I - A^*)^{-1}c^* \quad (8)$$

The A^* interdependence matrix represents the degree of connection between sectors of the economy. The elements of a specific line in the matrix indicate how much inoperalization is spread from one industry to another. The vector of inoperability $q^*$is expressed in terms of economic loss similar to equation (3), according to Santos (2007) the elements of the vector may represent the ratio between the production that was stopped due to the stoppage in relation to to the level of commercial production in other sectors.

Oosterhaven (2017) criticizes IIOM, claiming that the model only shows the negative results of an interruption in a specific sector, thus neglecting the positive results that this can bring, even if in lesser terms. A new allocation would be made, such as the demand for a product that was initially purchased from a company, but with the interruption, this demand will shift to another company located in another region that is operating normally, which will be determined by the capacity to inputs available.

However, Haimes et al. (2005) put IIOM as a method that avoids misleading results that do not demonstrate indirect effects after the impact of something that causes inoperability. It is also able to model the recovery of the workforce after the interruption of a specific sector and in its dynamic form it can model the recovery in several sectors.

Therefore, it is observed that two sectors with a large financial volume will have a similar interconnection between sectors. One of its functions is to provide analysts with a tool to detect the most relevant sectors of the economy. And another is to identify sectors that have their vulnerable vulnerability.

Exploratory Analysis of Spatial Data (EASD)

The Exploratory Analysis of Spatial Data is used to verify whether the data are spatially correlated, and for that, the Moran I test is performed. According to Almeida et al. (2008), this technique provides the relationship between the observations of a variable and the weighted average of the neighborhood values.

Moran's I for univariate analysis can be represented as follows:

$$I_t = \left(\frac{n}{S_0}\right)\left(\frac{z_t{}'Wz_t}{z_t{}'z_t}\right) \quad t = 1, \dots, n \qquad (9)$$

where z_t is the vector with n observations in period t in the form of error with the mean, W represents the matrix of spatial weights, and S_0 represents the sum of all the elements that make up W (ALMEIDA, 2012).

When the weight matrix is normalized, Moran's I for univariate analysis takes the following form:

$$I_t = \left(\frac{z_t{}'Wz_t}{z_t{}'z_t}\right) \quad t = 1, \dots, n \qquad (10)$$

To verify whether a variable is correlated with another variable in neighboring regions, a multivariate global autocorrelation analysis is performed. According to Almeida (2007), Moran's I for two distinct variables is expressed as:

$$I = \left(\frac{n}{S_0}\right)\left(\frac{z_1{}'Wz_2}{z_1{}'z_1}\right) \qquad (11)$$

And when the weight matrix is normalized, Moran's I for multivariate global analysis is presented as:

$$I = \left(\frac{z_1{}'Wz_2}{z_1{}'z_1}\right) \qquad (12)$$

For local analysis, the spatial correlation of a variable is done with the Local Indicators of Spatial Association (LISA). According to Anselin (1995), this technique has the function of rejecting or not the null hypothesis of the absence of local spatial correlation. Moran's I for univariate LISA analysis is expressed as follows:

$$I_i = z_{1i}Wz_{1i} \qquad (13)$$

where W_{ij} are elements that represent the proximity between regions, taking of 1 for neighbors and 0 for non-neighbors.

The formula for bivariate LISA is as follows:

$$I_{z_1z_2} = z_{1i}Wz_{2i} \qquad (14)$$

where Wz_{2i} is the spatial lag of the variable z_{2i}.

Results

This section is divided into two subsections, the first showing which sectors of which states were most affected by the strike of truckers by applying the IIOM method. The second presents the results of the statistics used to confirm whether the sectors most affected by the truckers strike have spatial dependence.

IIOM results

Based on the application of IIOM in the Input-Product model updated by Haddad et al. (2018), table 1 shows the 50 sectors in the states of Brazil most affected by the strike.

Table 1: Ranking of state sectors most affected by the truck drivers strike.

State	Sector	Code	Inoperation (%)
AC	Terrestrial transportation	111	46,91
PB	Terrestrial transportation	791	46,74
CE	Terrestrial transportation	655	44,73
PI	Terrestrial transportation	587	44,61
RN	Terrestrial transportation	723	43,31
AP	Terrestrial transportation	383	43,11
RO	Terrestrial transportation	247	43,01
PE	Terrestrial transportation	859	42,48
DF	Terrestrial transportation	1811	42,05
SE	Terrestrial transportation	995	41,47
TO	Terrestrial transportation	451	40,85
BA	Terrestrial transportation	1063	39,58
SC	Terrestrial transportation	1471	39,46
RO	Terrestrial transportation	43	39,28
RJ	Terrestrial transportation	1267	37,90
RS	Terrestrial transportation	1539	37,46
GO	Terrestrial transportation	1743	37,22
SP	Terrestrial transportation	1335	37,07
PR	Terrestrial transportation	1403	36,61
AL	Terrestrial transportation	927	36,09
MA	Terrestrial transportation	519	35,72
MS	Terrestrial transportation	1607	35,41
AM	Terrestrial transportation	179	33,55
MG	Terrestrial transportation	1131	33,15
MT	Terrestrial transportation	1675	30,28
ES	Terrestrial transportation	1199	28,73
PA	Terrestrial transportation	315	25,09
MA	Refinery and coking	495	11,21
MA	Auto parts manufacturing	510	9,59
ES	Refinery and coking	1175	9,03
SE	Refinery and coking	971	8,68
RS	Refinery and coking	1515	8,56
SE	Auto parts manufacturing	986	8,26
PI	Refinery and coking	563	8,16
RN	Refinery and coking	699	8,11
PR	Refinery and coking	1379	8,06
SC	Refinery and coking	1447	7,88
PB	Refinery and coking	767	7,84
MG	Refinery and coking	1107	7,78
AL	Refinery and coking	903	7,73
CE	Refinery and coking	631	7,70
SP	Refinery and coking	1311	7,47
RJ	Refinery and coking	1243	7,38
GO	Refinery and coking	1719	7,32
CE	Auto parts manufacturing	646	7,19
TO	Refinery and coking	427	7,16
RN	Auto parts manufacturing	714	7,03
PB	Auto parts manufacturing	782	7,01
PE	Auto parts manufacturing	850	6,97
BA	Refinery and coking	1039	6,91

Source: the authors, with data from the matrix provided by Haddad, Gonçalves Junior and Nascimento (2018).

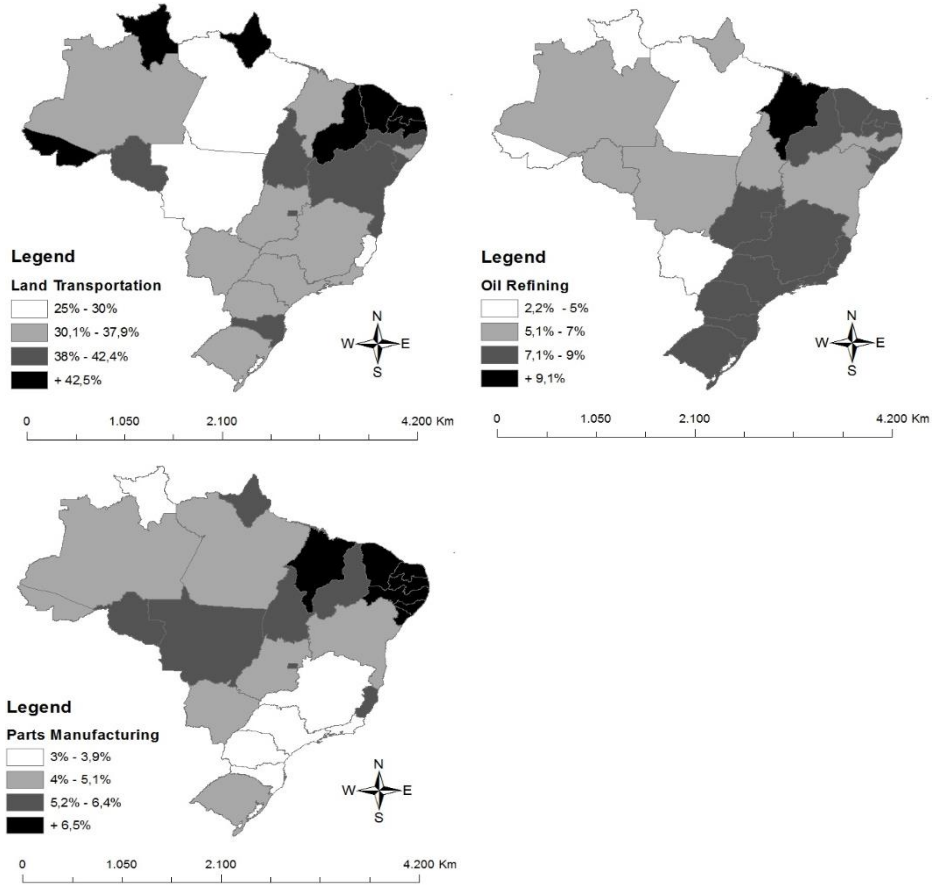
It is noted that the terrestrial transport sector is the one that was most affected since it is through this sector that truckers activities take place. Two other sectors also appear among the 50 sectors most affected by the strike. These sectors are the refinery and coking plants sector and the auto parts and accessories sector. These sectors are directly linked to the sector that was paralyzed by the strike. In the case of the oil refining and coke sector, this effect of inoperalization is reinforced by Betarelli Junior et al. (2010) because the sector is influenced by terrestrial transport, mainly

taking into account road modes for the export of the product. However, the product is usually exported in raw form.

Terrestrial transportation is fundamental for the automotive sector in the Brazilian economy and this explains why the sector of auto parts and accessories appears among the 50 sectors most affected by the strike. According to Bahia and Domingues (2010), the automotive sector demands auto parts and accessories for trucks, and since it is the trucks themselves that make up a large part of terrestrial transport in the Brazilian economy, the manufacture of these parts is impaired when occurs strike in the sector terrestrial transport.

The terrestrial transport sector was impacted on the average of 38.58% per state. Among the 10 sectors most affected, six are from the Northeast region, which shows that it may have been the region most affected by the strikers, not only in the terrestrial transport sector but in the others that are connected with this sector.

Figure 1: Spatial distribution degree of inoperalization in the sectors most affected by the truckers strike.



Source: the authors.

In figure 1, we can see that the northeast region was the one with the greatest inactivity in the terrestrial transport sectors during the strike. In turn, the strikers also caused the same region to have the highest concentration of inactivity in the sector of auto parts and accessories. The refinery sector, on the other hand, did not present any cluster of states with levels of inactivity present in the last quartile, with Maranhão being the only state with inactivity in the last quartile.

Resultados do EASD

Given the spatial distribution of the levels of inactivity in the sectors most affected by the strikers, it is necessary to verify statistically whether the sectors have spatial dependence. For this, the univariate and bivariate Moran's I test was applied. The first analyzes whether the inactivity of the land transport sector in state *i* has spatial dependence with the inactivity in the land transport sector in state *j*. The second, on the other hand, verifies whether the inactivities of the refinery and

auto part sectors in state i have spatial dependence on the inactive terrestrial transport sector in state j.

Table 2: Matrix choice test

Matrix	Moran's I	Moran's I*	P-Value
Queen	0,105	-0,038	0,218
Rook	0,105	-0,038	0,218
K-5	0,106	-0,038	0,089
K-7	0,101	-0,038	0,067

Source: the authors.
Moran's I* is the expected Moran's I, its formula is described as $(-1)/(n-1)$.

Table 2 shows that the inactivity of the terrestrial transport sector in state i has a positive correlation with the inactivity of the same sector in state j. This is verified when the Moran's I is greater than the expected Moran's I. However, the queen and rook contiguity matrices did not show statistical significance in their calculated Moran I, only the K-Neighbor matrices showed statistical significance. The choice of the contiguity matrix is determined by the statistically significant highest Moran I, therefore, the EASD will be made based on the matrix of 5 neighbors.

Table 3: Bivariate Moran's I

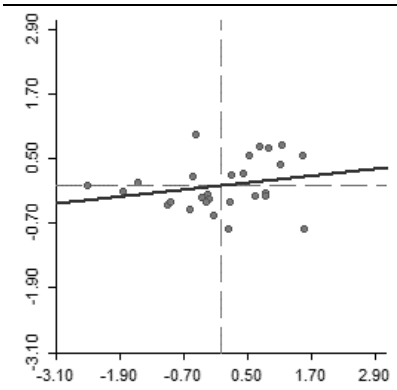
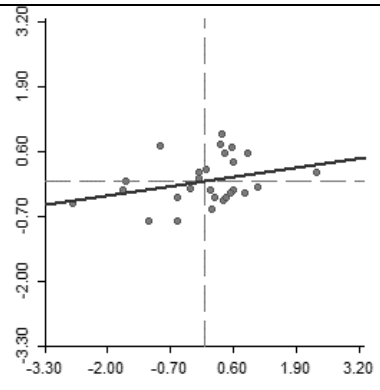
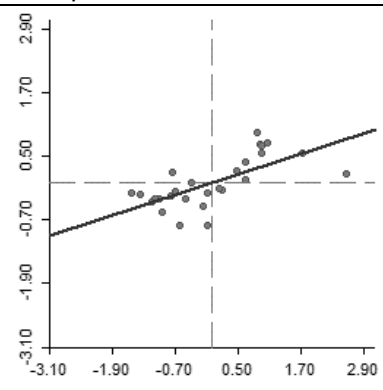
Refining and Terrestrial transportation			
Matrix	Moran's I	Moran's I*	P-Value
K-5	0,1465	-0,038	0,037
Auto parts manufacturing and Terrestrial transportation			
Matrix	Moran's I	Moran's I*	P-Value
K-5	0,3261	-0,038	0,001

Source: the authors.

Table 3 shows that the inactivity of the terrestrial transport sector caused by the strikers is statistically linked to the inoperation with the sectors of refinery and the auto parts and accessories. The global bivariate test confirms that states that have a high level of inactivity in the land transport sector are neighbors of states that have a high level of inactivity in the sectors of refinery and the auto parts and accessories. This is explained by the high link between the three sectors.

To corroborate the positive correlations between the inactivities of the sectors in the global analysis, Figure 2 shows the dispersion graphs of Moran's I with their respective lines. All statistics were significant at 5%, so inactivity in sector i is correlated not only with itself but also with inactivity in sector j.

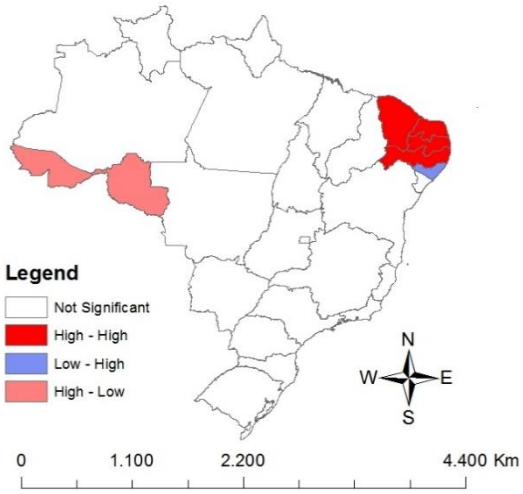
Figure 2: Scatter plots of Moran's I

Univariate – Terrestrial transportation	Bivariate – Refining and Terrestrial transportation	Bivariate – Auto parts manufacturing and Terrestrial transportation
		

Source: the authors.

According to Perobelli et al. (2007), in Moran's I global statistical analysis, spatial dependence at the local level can be unobserved. For this not to occur, it is also necessary to apply LISA analysis, in this case, univariate and bivariate, with this analysis it is possible to verify the spatial correlation of the variables in more detail.

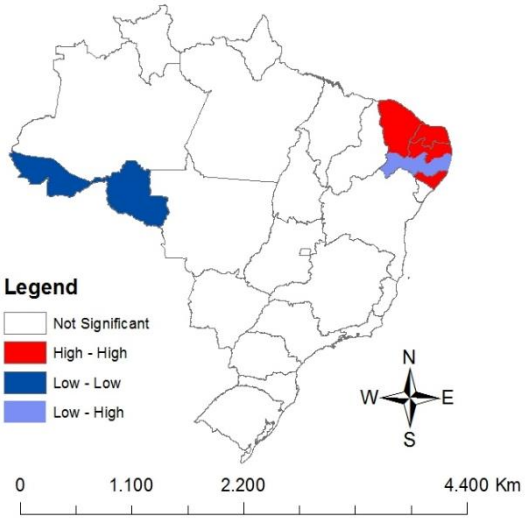
Figure 3: Univariate LISA for the terrestrial transportation sector



Source: the authors.

Figure 3 shows a cluster in the northeastern states, a region that had some of its states in the top 10 in the classification for inoperation in the land transport sector (see table 1). The Ceará, Paraíba, Pernambuco, and Rio Grande do Norte states presented a "high-high" significance index in the local analysis. These states had a high level of inactivity caused by the strikers in the terrestrial transport sector and are neighbors of states with a high level of inactivity in the same sector.

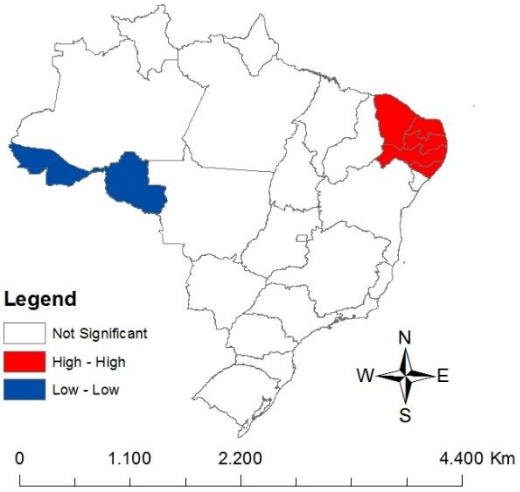
Figure 4: Bivariate LISA for the refining and terrestrial transport sectors.



Source: the authors.

It can be seen in figure 4 that in the Northeast region, there is also a cluster in the LISA analysis between the inactivities of the oil refining and land transport sectors. The Alagoas, Ceará, Paraíba, Rio Grande do Norte states had a high level of inactivity in the refinery sector. They contained neighbors with a high level of inactivity in the terrestrial transport sector, confirming the linkage of these sectors in the northeast region. On the other hand, there is a "low-low" cluster in the Acre and Rondônia states.

Figure 5: Bivariate LISA for the Auto parts manufacturing and Terrestrial transportation



Source: the authors.

The strikers also caused the northeastern region to present a cluster between the inactivities of the parts and accessories manufacturing sectors for motor vehicles and land transport, as shown in figure 5. The Alagoas, Ceará, Paraíba, Pernambuco, and Rio Grande do Norte states had a high level of inactivity in the auto parts sector and to be neighbors of states with a high level of inactivity in the terrestrial transport sector, which also confirms the dependence between the two sectors. The auto parts sector needs transport for the logistics of its production and also for the demand of its products for the maintenance of trucks and other vehicles. The "low-low" cluster was also present in this analysis.

Conclusions

In this paper, it was found that the terrestrial transport sector was the most affected by the strike of truckers, evidently because it was the stoppage that occurred. The sectors most affected were sectors highly linked to transport: refinery and auto parts manufacturing. The highest

percentage of inoperation (see table 1) in the terrestrial transport sector occurred in Acre. The northeast region stands out over other Brazilian regions with a high number of states at the top of the ranking of inoperalization.

The existence of spatial dependencies between the three sectors most affected by the truck drivers strike was confirmed, that is, when one of these sectors for some reason becomes inactive, either temporarily or indefinitely, the sectors in neighboring states are also affected. Therefore, based on the statistical foundation, it is possible to affirm that the paralysis of the terrestrial transport sector had an impact not only on itself but also on other sectors in the Brazilian economy.

Therefore, this paper sheds light on the relevance of the continuous activity of the terrestrial transport sector as being one of the most critical sectors of the Brazilian economy. Public policymakers in this area, especially participants in the Ministry of Infrastructure, should be aware of the fact that a new outbreak of strikes by truck drivers will have negative returns for the production of other sectors of the Brazilian economy, especially in the northeast region.

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