

Spatial Distribution of Logistics Services in Brazil: a Potential Market Analysis

Abstract

The main objective of this article is to investigate the present and long-term spatial distribution of the logistics sector in Brazil. In order to do so, this study seeks to answer the following questions: i) how is the logistics sector organized in Brazil? that is, is there evidence of logistics clusters?; ii) what is the long-term perspective of this organization? The Logistics Potential Mapping Model (MapLog), inspired by Krugman's Core-Periphery Model, will serve as an analytical tool to verify the long-term spatialization of the logistics sector. The results point to a change within five decades (2015-2065) of the locational pattern of the logistics sector focused on industry but not for the logistics sector focused on agriculture.

Keywords: locational decision; logistics clusters; New Economic Geography

1 Introduction

The flows of goods between regions translate the needs of production and consumption by individuals and firms, directly influencing the economic dynamics of a region (Button, 2010). According to Thomson (1974), movement by transport is desired and necessary because there is spatial heterogeneity so that none parts are capable of supplying alone all the products that people desire. That is, a varied set of goods can only be obtained by any movement between the supplier and the consumer. Logistics, in turn, is the function responsible for this movement (Waters, 2003).

The main components of logistics – transport, storage and management – have been important elements of industrial and economic life throughout the ages, but it is only in the relatively recent past that logistics has been recognized as a relevant function in and of itself (Rushton, Croucher & Baker, 2010). Technological changes in markets, institutional structures and management theory have led to new ways of thinking about logistics and associating it with the production process (Brewer et al., 2008; Hugos, 2011). At a national level, the ability to transport goods quickly, safely, economically and reliably is now seen as vital to the prosperity and capacity of a nation seeking to compete in a rapidly globalizing economy (Brewer et al., 2008).

Achieving a high level of logistics performance is important for business profitability and for regional and national competitiveness (Heaver, 2008), so that several operational activities of the firms, including transportation and logistics services, were assumed by third parties. Consequently, there has been increasing specialization in the management of external relations of production and control of flows, from the inputs to the final product acquired by the consumer. The term “Supply Chain Management” was created in the 1970s to represent these activities¹ (Hall & Braithwaite, 2008).

The supply chain is a sequence of processes and flows that takes place within and between the different stages of the production chain, and that combine to meet a customer's need for a product (Chopra & Meindl, 2003). The main objective of any supply chain is to satisfy customer needs and generate profit for the participating firms during the process. The term "supply chain" brings the idea of products moving from suppliers to manufacturers, moving to distributors and resellers, and reaching the end consumers. These flows, in turn, are not unique or unidirectional. By the way, a manufacturer can receive material from several suppliers and then supply their product to various distributors.

Supply chain performance is measured in terms of responsiveness (i.e., time) and efficiency (i.e., cost minimization), and will depend on the characteristics of the logistics drivers (Chopra & Meindl, 2003). Logistics drivers are understood to be elements that can be used to improve supply chain performance (Chopra & Meindl, 2003; Hugos, 2011). The theorists cited define five drivers, namely: production, inventory, location, transport and information. In this study, the locational component will be highlighted.

The location refers to the geographical location of supply chain facilities, especially logistics firms. It also includes the decisions related to the activities that must be carried out in each installation. The trade-off presented here is related to the decision to centralize activities in fewer locations for economies of scale and efficiency, or to decentralize activities in many places close to customers and suppliers for faster operations. When making decisions related to location, managers need to consider a number of factors that relate to a particular location (locational factors), including the cost of the facility, the local labor cost, the skills available in the job market, the infrastructure conditions, taxes and tariffs and the proximity to suppliers and customers. Location decisions tend to be strategic because they involve large amounts of money with long-term horizons

¹ In the literature, logistics and supply chain management are often used synonymously, although there is a subtle difference between the two. Supply Chain Management is more strategic in its nature, while logistics is more operation-oriented. Supply Chain Management deals with chain links, contracts and relationships, supplier selection, information and financial flows, as well as material flows, creating new facilities such as factories, warehouses and distribution centers. The scope of logistics is confined to the routine work of transporting and storing goods (Ballou, 1985). It should be noted that throughout this work these terms will be treated as synonyms.

for investment maturation. In addition, the locational choice of logistics units determines, in part, the performance of several productive chains and regional and national productivity (Bhatnagar & Sohal, 2005; Chopra & Meindl, 2003; Hugos, 2011). Thus, the determinants of this locational decision must be better understood.

The main motivation of this study is to investigate the present and long-term spatial distribution of the logistics sector in Brazil. In order to do so, we seek to answer the following questions:

1. How is the logistics sector organized in Brazil? Or rather, is there evidence of logistics clusters?
2. What is the long-term perspective of this spatial organization?

To answer those questions, this work has as theoretical and methodological cores the approaches developed in Fujita, Krugman, & Venables (1999), Krugman (1991, 1998) and Krugman & Venables (1996, 1995), which make considerations about the location and formation of agglomerations of economic activities, to the point of developing a line of research called New Economic Geography (NEG).

Geographic space is an inherent dimension to the study of economic phenomena and its treatment involves a significant degree of heterogeneity. Economic agents and firms choose their locations based on spatial attributes, generating an unequal distribution of economic resources. This spatial differentiation can be perceived by regional disparities in the remuneration of factors of production, price levels and transport costs (Capello, 2009; Capello & Nijkamp, 2009; Combes, Mayer, & Thisse, 2008). The various economic agglomerations, which reproduce the unequal nature in space, influence the way the economic system works and the regional performance itself (Capello, 2009; McCann & Van Oort, 2009).

Lemos (2008) argues that the advantages arising from the economic agglomerations constituted in certain regions are nothing more than agglomeration economies, which represent localized returns to scale. The existence of increasing returns to scale and the perfect mobility of resources imply the spatial concentration of economic activities. Even at an initial state they are homogeneously distributed (Dubey, 1977; Losch, 1954). Thus, there is an incompatibility between the structure of competitive markets in a homogeneous space and the formation of spatial agglomerations (Fujita & Thisse, 2013). The hypotheses of constant returns of scales and perfect competition seem to be incapable of dealing with the empirical existence of the agglomeration of people and firms in space (Combes et al., 2008). Thus, the association of increasing returns and imperfect competition is one way of integrating spatial aspects into economic theory.

NEG emerged in the 1990s as a new field of research, with the purpose of revaluing and inserting geographic analysis into the economic mainstream (Krugman, 1998)². Their main concern is to explain why many economic activities are geographically concentrated. In general, the central aspect for the understanding of the spatial configuration of economic activities and their repercussions lies in the trade-off of two main types of forces: economies of scale (agglomerative force) and transport costs (repulsive force) (Fujita & Thisse, 2013). Krugman (1991) innovates by inserting these elements in a mathematical modeling and developing for it the Core-Periphery Model.

Given that the main objective of this study is to observe the long-term spatialization of the logistics sector in Brazil, the Core-Periphery Model will be the basis for the development of the Logistics Potential Mapping Model (MapLog).

In addition to this introductory section, this article is divided as follows. The second section will make an exploratory spatial analysis of the Brazilian logistics sector in order to understand in detail the local pattern and its relation with the other sectors of the economy. The third section will show the MapLog model, capable of describing the long-term distribution of logistics activity in Brazil, followed by the fourth section that shows the main results. Finally, the fifth section shows the final considerations.

2 Exploratory Analysis of Spatial Data: Identifying Logistics Clusters

2.1 *Some Spatial Concentration Metrics*

The definition of spatial agglomerations is based on the choice of desirable metrics that allows us to verify the location and size of concentrations, and that can be measured using available data. Hence, we chose for this analysis: the Horizontal Cluster Locational Quotient (*HCLQ*) in conjunction with the Logistics Establishments Participation (*LEP*), the Univariate Local Moran's I (I_i) and the Bivariate Moran's I ($I_i^{Z_1Z_2}$).

² Although Krugman has given new life to the area of economic geography, much of his ideas and concepts have been around for a long time. To a large extent, the history of economic geography can be seen as a process that gradually unified different segments of knowledge, as demonstrated by the different names given to the scientific field (regional and urban economics, locational theory and spatial economics), all within the same theoretical framework in which the focus shifts from perfect competition to imperfect competition and market failures (Fujita & Thisse, 2013).

2.1.1 Horizontal Cluster Locational Quotient (*HCLQ*) and Logistics Establishments Participation (*LEP*)

The Horizontal Cluster Locational Quotient (*HCLQ*) takes into account the relative and absolute importance of the sector in question considering the difference between the number of employees in the sector s (e.g. Logistics) located in the region r (e.g., state, country or other space unit), defined as E_{sr} , and the expected number of employees in the same sector and in the same region when QL_r assumes a value equal to unity, which is the threshold for considering that the region is specialized in a given activity, the latter being represented by \widehat{E}_{sr} (Fingleton, Iglioni, & Moore, 2004).

$$HCLQ_r = E_{sr} - \widehat{E}_{sr} \quad (1)$$

The Locational Quotient (LQ)³ is known to be given by $LQ_r = \frac{E_{sr} \cdot E_{Tn}}{E_{sn} \cdot E_{Tr}}$, then $\widehat{E}_{sr} = \frac{E_{sn} \cdot E_{Tr}}{E_{Tn}}$, when $LQ_r = 1$. E_{sr} and E_{sn} represent the number of employees in the logistics sector (s) in the region r and the country n respectively, while E_{Tr} and E_{Tn} represent the total employees in the regions r and n respectively. It is considered as the cluster indicator $HCLQ_r > 0$.

In turn, the Logistics Establishments Participation indicator (*LEP*), used by Henderson (2003) and Rivera, Sheffi, & Welsch (2014) is a simple ratio between the number of firms in the logistics sector in the region r (f_r) and the total number of logistics firms in the country n (F_n), given by:

$$LEP_r = \frac{f_r}{F_n} \quad (2)$$

where $0 \leq LEP_r \leq 1$. It is evident that, the higher this index, the higher the concentration of logistics firms in a region. Following Rivera et al. (2014), the threshold used will be 0.1. Thus, $LEP_r > 0.1$ will be considered a cluster⁴. The presence of logistics agglomeration is verified by simultaneously satisfying the following condition: $HCLQ_r > 0$ and $LEP_r > 0.1$.

³ The Locational Quotient (LQ) determines whether a region (r) has the specialization of some economic activity, and does so by comparing sectoral-spatial structures. If the quotient value is greater than unity there is evidence that the region is specialized in a particular sector, in relative terms to the national context. Crocco et al. (2006) considers a threshold higher than 1, since small regions with small industrial employment and little diversified productive structure tend to overestimate the weight of a given sector for the region.

⁴ Rivera et al. (2014) uses data on employment and establishments in 3095 counties in the United States. They use the known group validity method (Babbie, 2015) to arrive at that cutoff value.

2.1.2 Univariate Local Moran's $I(I_i)$

The Moran Local indicator or LISA (Local Indicator of Spatial Association) proposed by Anselin (1995), has the capacity of capturing local patterns of spatial autocorrelation. The local Moran coefficient $I(I_i)$ decomposes the global indicator (I de Moran) into the local contribution of each observation in four categories HH-high/high, LL-low/low, HL-high/low and LH-low/high, being expressed by:

$$I_i = \frac{z_i \sum_j W_{ij} z_j}{\sum_i z_i^2} \quad (3)$$

where z denotes the values of the standardized interest variable, Wz represents the mean values of the standardized interest variable in neighbors defined according to a weighting matrix W indicating how regions i and j are connected⁵ (Anselin, 1995). A reasonable proxy for cluster existence is obtained if the HH standard is confirmed where z is the number of jobs in the logistics sector.

2.2.1 Bivariate Moran's $I(I_i^{z_1 z_2})$

The indicators seen so far illustrate possible areas of agglomeration, not relating the phenomenon to any type of factor or variable. With this in mind, this section will show the connection between the logistics sector and the potential users of its services. To do so, the Bivariate Moran $I(I_i^{z_1 z_2})$ is described below.

Let x_{1i} and x_{2i} be two variables of interest. When they are standardized, they become z_{1i} and z_{2i} respectively. Redefining the Moran Local I formula, we arrive at the bivariate indicator:

$$I_i^{z_1 z_2} = z_{1i} W z_{2i} \quad (4)$$

where $W z_{2i}$ is the spatial lag of the standard variable z_{2i} . This statistics gives an indication of the degree of linear association (positive or negative) between the value for a variable in a given location i and the average of another variable in neighboring locations (Anselin, 2003).

Two relations will be verified. The first takes into account the Logistics and Agriculture sectors and the second the Logistics and Manufacturing Industry sectors, where z_i will represent the number of jobs in these sectors by region. This exercise intends to verify a possible intralogistical

⁵ The spatial weight matrix (W) will use the queen criterion (degree 1).

heterogeneity, that is, a logistics set at the service of the agricultural sector and another one focused on industrial activity.

2.2 *Data Description*

This section uses as its data source the Annual Social Information Relation (RAIS)⁶ from the administrative records of the Brazilian Ministry of Labor (MTE). The sectoral and geographical breakdowns of the data allow us to draw more precise conclusions after the analysis. Data were collected on employees and establishments associated to the logistics sector with a focus on freight transport between the years 2006 and 2015. Only in this period the CNAE 2.0 (Subsection) is available, which comprises information at a more disaggregated level. Proceeding with this choice is important because we must remove the passenger transport from the selection. Together, the subsectors shown in Table 1 make up what we call the logistics sector. The choice of these subsectors is based on Rivera et al. (2014). In addition, the space analysis unit in question takes into account the 558 Brazilian microregions. This level of observation will allow us to verify detailed changes in the organizational structure of the activity.

[Insert Table 1]

2.3 *Observing the Logistics Agglomerations*

Figure 1 shows the spatial distribution of the logistics clusters, that is, the microregions that met the condition ($HCLQ > 0$ and $LEP > 0.1$). We chose to demonstrate only the initial and final period analyzed (2006 and 2015). In 2006, the 89 clusters were almost entirely located on the south-southeast axis (88% of the total). In turn, in 2015, it is possible to verify a considerable modification of the spatial pattern, in which there is the rotation of the axis towards the center-west, with an increase in participation in 17% between the period analyzed.

The previous results are reiterated by Figure 2, which refers to the Univariate Local Moran's I, with the advantage of giving more details regarding the classification of the clusters. Again, the

⁶ It should be noted that the RAIS data are underestimated, since they disregard employees and firms from the informal environment. This point is a limitation of the results, given the existence of informality, especially in road transport activity.

existence of two regions classified as high-high (regions with high logistics potential surrounded by peers of the same level) is noticed. The first belongs to the south-southeast regions and a second emergent group of the central-west region. On the other hand, the low-low regions (regions of low logistics potential surrounded by peers of the same level) are present in the north-northeast range of Brazil.

[Insert Figure 1]

[Insert Figure 2]

The following analyses verify the relation between the logistics clusters and the productive system, for which they provide their services. For that, we selected the Agricultural and Manufacturing Industry sectors⁷. It can be seen from Figure 3 that the high-high relationship, which comprises microregions with high participation in logistics jobs close to regions with high participation in agricultural employment, is centered in the central-west region. It is clear that the logistics cluster present there is mostly appropriate for the activities of this sector. In addition, continuing the analysis, and observing the correlation between logistics activities and the manufacturing industry, reported in Figure 4, it is possible to verify the high-high grouping (i.e., agglomerations of logistics activities surrounded by industrial activities), centered in the south-southeast region, indicating a possible link to provide a specialized service industry.

[Insert Figure 3]

[Insert Figure 4]

This piece of information reveals that the locational decision of the logistics activity presents different motivating factors, that is, logistics firms focused on the service of the agricultural sector will tend to be located in areas of greater concentration of this activity. Such reasoning is also valid

⁷ At this point, RAIS data were again adopted, but this time for jobs in the agricultural and industrial sectors. We know the limitations of the data, especially for the agricultural sector, whose informality is significant. However, the spatial and temporal disaggregation of the data leads us to use them. To learn more about the data, visit <http://portalfat.mte.gov.br/wp-content/uploads/2016/02/Nota-T%C3%A9cnica-MTE-2014.pdf>. The sectorial classification is based on the National Classification of Economic Activity (CNAE 2.0). For more details, see <https://cnae.ibge.gov.br/classificacoes/download-concla.html>. We consider agriculture as an aggregation of the agriculture, livestock, forestry, fishing and aquaculture sectors - section A in the CNAE 2.0 code. In turn, the Transformation Industry is represented by section C of the CNAE 2.0 code.

for the industrial case. The empirical evidence shown in this section will be used as an assumption in the mathematical modeling about the future spatial distribution of the logistics sector for the Brazilian case.

3 Modeling

3.1 *Description of the Logistics Potential Mapping Model (MapLog)*

MapLog describes an economy consisting of the agricultural, industrial and logistics sectors. The latter is segmented in the logistics sector focused on agriculture and on industry⁸. This division is necessary, given the empirical evidence found in section 2, which has confirmed the existence of differentiated spatial dynamics of the logistics service sector depending on the demand sector. It is assumed that the locational decision of the logistics sector will be dependent on the locational choice of agriculture and industry. Ultimately, the spatial distribution of the logistics sector will be determined, that is, "pulled" by the migratory movement of agriculture and industry workers. Such a hypothesis seems plausible, since the logistics service sector works in the wake of the productive sectors. This idea is aligned with the industrialist trend that argues that services play a subordinate role in relation to the productive sectors and alone could not induce economic development (Baumol, 1967; Cohen & Zysman, 1987; Ecalle, 1989; Fuchs, 1968; Gershuny, 1987; Gershuny & Miles, 1983; McKee, 1988; Walker, 1985).

The analysis will then start from the demanding sectors of logistics services, generally characterized as agriculture and industry, in order to show the organizational evolution of their areas of occurrence, that is, where the spatial agglomerations occur. Based on this piece of information, it will be possible to check the long-term spatialization of the logistics sector. The existence of economies of scale creates spatial heterogeneity, including the real wage differential between regions. Workers (and simultaneously consumers) are attracted to regions with higher wage levels than the system average. In turn, companies are attracted to these regions, leading to the fall in the price level and consequent increase in real wages, and this is the case. It is noticed that the agglomeration process is related to economic and population concentration. Such a process is self-reinforcing, that is, circular and cumulative. Logistics clusters follow these vectors of centripetal forces.

⁸ In this section, we read the industrial sector as a synonym of Manufacturing Industry, and the agricultural sector will be equivalent to Agriculture.

The MapLog structure will be composed of six blocks of equations, namely: (i) regional product, (ii) nominal wage, (iii) price index, (iv) real wage, (v) migrant flow of workers and (vi) regional logistics potential.

Block 1 - Regional Product

The regional product (Y_r) given by the expression (5) is the result of the sum of the nominal yields from the industry [$\mu\lambda_r w_r^M$] and the agriculture [$(1 - \mu)\phi_r w_r^A$].

$$Y_r = \mu\lambda_r w_r^M + (1 - \mu)\phi_r w_r^A \quad (5^9)$$

Block 2 - Price Index

The second component is the price indices of industrial and agricultural goods. In the case of industrial goods, (G_r^M), it follows the expression (6) dependent on the participation of the industrial workers (λ_s) and the industrial nominal wage (w_s^M) in the regions, the cost of transportation type iceberg between the regions (T_{sr}^M) and the substitution elasticity for industrial goods (σ). The last two are constants over time.

$$G_r^M = \left[\sum_s \lambda_s (w_s^M T_{sr}^M)^{1-\sigma} \right]^{1/1-\sigma} \quad (6^{10})$$

In turn, the price level for agricultural goods (G_r^A) given by expression (7) follows the notion presented in the previous paragraph. However, it is oriented towards agriculture, where ϕ_s represents the participation of farmers and w_s^A is the average nominal yield in the other regions s . Assume an iceberg transport cost for agricultural goods (T_{sr}^A) and constant substitution elasticity given by η .

$$G_r^A = \left[\sum_s \phi_s (w_s^A T_{sr}^A)^{1-\eta} \right]^{1/1-\eta} \quad (7^{11})$$

The constants T_{sr}^M and T_{sr}^A are known to represent the ratio between the quantity of product delivered and the product received. Then $T_{sr}^M, T_{sr}^A \geq 0$, and the closer to 0, the less the waste. These reasons are relevant parts in the calculation of the cost of transport. Empirically, because of data

⁹ In the illustrative case of two regions, we have:

(region 1) . . . $Y_1 = \mu\lambda_1 w_1^M + (1 - \mu)\phi_1 w_1^A$

(region 2) . . . $Y_2 = \mu\lambda_2 w_2^M + (1 - \mu)\phi_2 w_2^A$

¹⁰ In the illustrative case of two regions, we have:

(region 1) . . . $G_1^M = [\lambda_1 (w_1^M T_{11}^M)^{1-\sigma} + \lambda_2 (w_2^M T_{21}^M)^{1-\sigma}]^{1/1-\sigma}$

(region 2) . . . $G_2^M = [\lambda_1 (w_1^M T_{12}^M)^{1-\sigma} + \lambda_2 (w_2^M T_{22}^M)^{1-\sigma}]^{1/1-\sigma}$

where $\lambda_1 + \lambda_2 = 1$

¹¹ In the illustrative case of two regions, we have:

(region 1) . . . $G_1^A = [\phi_1 (w_1^A T_{11}^A)^{1-\eta} + \phi_2 (w_2^A T_{21}^A)^{1-\eta}]^{1/1-\eta}$

(region 2) . . . $G_2^A = [\phi_1 (w_1^A T_{12}^A)^{1-\eta} + \phi_2 (w_2^A T_{22}^A)^{1-\eta}]^{1/1-\eta}$

where $\phi_1 + \phi_2 = 1$

unavailability, it is difficult to establish an adequate value for these constants. Thus, the following proxies, described by equations (8) and (9), were established:

$$T_{sr}^M = \tau^M d_{rs} \quad (8)$$

$$T_{sr}^A = \tau^A d_{rs} \quad (9)$$

where τ^M and τ^A are limited exogenous constants in a range between 0 and 1 and d_{rs} are the interregional distances. The greater d_{rs} , the greater T_{sr}^M and T_{sr}^A will be. The proxy seems reasonable. Therefore, it is expected that the greater the distance traveled in the transport of the load, the greater the probability of losses. For the Brazilian case, we consider that $\tau^A > \tau^M$, indicating that the waste in the transport of agricultural products is greater when compared to the case of industrial goods. Due to its relevance and presence in the Brazilian context, the road modal will be chosen; this includes interregional distance information.

Block 3 - Nominal wage

From the Dixit-Stiglitz model, it is possible to deduce the nominal wage for the industrial case (w_r^M) as (10):

$$w_r^M = \left[\sum_s Y_s T_{rs}^{M^{1-\sigma}} G_s^{M^{\sigma-1}} \right]^{1/\sigma} \quad (10^{12})$$

And, similarly, the nominal wage for the agricultural sector (w_r^A) follows (11):

$$w_r^A = \left[\sum_s Y_s T_{rs}^{A^{1-\eta}} G_s^{A^{\eta-1}} \right]^{1/\eta} \quad (11^{13})$$

The components in the equations have already been listed in the previous blocks.

Block 4 - Real wage

The industrial (12) and agricultural (13) real wages are derived from the deduction of the nominal wage by the price index (cost of living).

$$\omega_r^M = w_r^M (G_r^M)^{-\mu} (G_r^A)^{\mu-1} \quad (12^{14})$$

¹² In the illustrative case of two regions, we have:

(region 1) . . . $w_1^M = [Y_1 (T_{11}^M)^{1-\sigma} (G_1^M)^{\sigma-1} + Y_2 (T_{12}^M)^{1-\sigma} (G_2^M)^{\sigma-1}]^{1/\sigma}$

(region 2) . . . $w_2^M = [Y_1 (T_{21}^M)^{1-\sigma} (G_1^M)^{\sigma-1} + Y_2 (T_{22}^M)^{1-\sigma} (G_2^M)^{\sigma-1}]^{1/\sigma}$

¹³ In the illustrative case of two regions, we have:

(region 1) . . . $w_1^A = [Y_1 (T_{11}^A)^{1-\eta} (G_1^A)^{\eta-1} + Y_2 (T_{12}^A)^{1-\eta} (G_2^A)^{\eta-1}]^{1/\eta}$

(region 2) . . . $w_2^A = [Y_1 (T_{21}^A)^{1-\eta} (G_1^A)^{\eta-1} + Y_2 (T_{22}^A)^{1-\eta} (G_2^A)^{\eta-1}]^{1/\eta}$

¹⁴ In the illustrative case of two regions, we have:

(region 1) . . . $\omega_1^M = w_1^M (G_1^M)^{-\mu} (G_1^A)^{\mu-1}$

(region 2) . . . $\omega_2^M = w_2^M (G_2^M)^{-\mu} (G_2^A)^{\mu-1}$

$$\omega_r^A = w_r^A (G_r^M)^{-\mu} (G_r^A)^{\mu-1} \quad (13^{15})$$

Block 5 - Migration

Through this block, we insert the dynamics in the model given by the spatial change of workers and farmers (i.e., migration process), which is influenced by real wage differentials, thus changing the values of the variables λ_r and ϕ_r over time. The dynamics assumed closely follows Fujita et al. (1999), and will be given by

$$\lambda_{r(t)} = \lambda_{r(t-1)} + \chi^M (\omega_{r(t)}^M - \bar{\omega}_{(t-1)}^M) \quad (14^{16})$$

$$\phi_{r(t)} = \phi_{r(t-1)} + \chi^A (\omega_{r(t)}^A - \bar{\omega}_{(t-1)}^A) \quad (15^{17})$$

The definition of the locational dynamics of workers in the industrial (14) and agricultural (15) sectors will ultimately indicate the location of the demanding sectors of logistics services.

Block 6 - Logistics Potential

Now, it remains to be seen how the logistics industry will behave. As already stated, the logistics sector will follow the spatial movement of the productive sectors. In this way, the market potential calculation will be used, whose determinants are the shares of industrial and agricultural workers (λ_s and ϕ_s respectively) and the inverse distance $1/d_{rs}$. The expressions follow Isard et al. (2017) and are given by (16) and (17)

$$\Omega_r^{TM} = \sum_s \frac{1}{d_{rs}} \lambda_s \quad (16^{18})$$

$$\Omega_r^{TA} = \sum_s \frac{1}{d_{rs}} \phi_s \quad (17^{19})$$

¹⁵ In the illustrative case of two regions, we have:

(region 1) . . . $\omega_1^A = w_1^A (G_1^M)^{-\mu} (G_1^A)^{\mu-1}$

(region 2) . . . $\omega_2^A = w_2^A (G_2^M)^{-\mu} (G_2^A)^{\mu-1}$

¹⁶ In the illustrative case of two regions, we have:

(region 1) . . . $\lambda_{1(t)} = \lambda_{1(t-1)} + \chi^M (\omega_{1(t)}^M - \bar{\omega}_{(t-1)}^M)$

(region 2) . . . $\lambda_{2(t)} = \lambda_{2(t-1)} + \chi^M (\omega_{2(t)}^M - \bar{\omega}_{(t-1)}^M)$

where, $\bar{\omega}_{(t-1)}^M = (\omega_{1(t-1)}^M + \omega_{2(t-1)}^M)/2$

¹⁷ In the illustrative case of two regions, we have:

(region 1) . . . $\phi_{1(t)} = \phi_{1(t-1)} + \chi^A (\omega_{1(t)}^A - \bar{\omega}_{(t-1)}^A)$

(region 2) . . . $\phi_{2(t)} = \phi_{2(t-1)} + \chi^A (\omega_{2(t)}^A - \bar{\omega}_{(t-1)}^A)$

where, $\bar{\omega}_{(t-1)}^A = (\omega_{1(t-1)}^A + \omega_{2(t-1)}^A)/2$

¹⁸ In the illustrative case of two regions, we have:

(region 1) . . . $\Omega_1^{TM} = \lambda_1 + \frac{1}{d_{12}} \lambda_2$

(region 2) . . . $\Omega_2^{TM} = \frac{1}{d_{12}} \lambda_1 + \lambda_2$

¹⁹ In the illustrative case of two regions, we have:

(region 1) . . . $\Omega_1^{TA} = \phi_1 + \frac{1}{d_{12}} \phi_2$

(region 2) . . . $\Omega_2^{TA} = \frac{1}{d_{12}} \phi_1 + \phi_2$

Ω_r^{TM} and Ω_r^{TA} are the market potential for firms in the logistics sector focused on industry and agriculture, respectively.

3.2 Empirical Implementation

The MapLog model was calibrated using data provided by national statistical agencies and from other studies. Appendix A provides a description of the parameters, endogenous and exogenous variables of the model. The model is simulated for 50 years, from 2015 onwards, and has as its spatial scope the 27 federative units of Brazil, composed of 26 states and 1 federal district. The equations that make up the six blocks of the model received a temporal dynamics and were log-linearized, aiming to reduce the computational effort²⁰.

The purpose of our simulation exercises is to analyze the long-term logistics market potentials that arise from the locational decisions of the demanding sectors of their services, i.e. agriculture and industry. To do so, the simulations follow predefined scenarios. Table 2 summarizes the scenarios adopted in the computational simulations. The key parameters of the model are: substitution elasticity for industrial (σ) and agricultural goods (η), the locational sensitivity of agricultural and industrial labor to real wage deviations (χ^A and χ^M , respectively) of τ^A and τ^M present in the calculation of the cost of transportation of agricultural and industrial goods. Based on a baseline scenario (BS), sensitivity tests (ST) were performed to observe the behavior of the results. Below we find their description:

BS: $\sigma = 2.079$; $\eta = 1.720$; $\chi^A = \chi^M = 0.10$; $\tau^A = 0.60$; $\tau^M = 0.30$

ST.1: variation of the parameters σ and η (+0.2), χ^A and χ^M (+0.05) and τ^A and τ^M (+0.2)

ST.2: variation of the parameters σ and η (-0.2), χ^A and χ^M (-0.05) and τ^A and τ^M (-0.2)

ST.3: variation of the parameters χ^A and χ^M (+0.05), all other parameters being equal

ST.4: variation of the parameters χ^A and χ^M (-0.05), all other parameters being equal

ST.5: variation of the parameters τ^A and τ^M (+0.2), all other parameters being equal

ST.6: variation of the parameters τ^A and τ^M (-0.2), all other parameters being equal

ST.7: variation of the parameters σ and η (+0.2), all other parameters being equal

²⁰ More detailed information on the log-linearization procedure, the replication code of the model, description of the endogenous and exogenous variables of the model as well as information about the sensitivity tests can be requested from the authors.

ST.8: variation of the parameters σ and η (-0.2), all other parameters being equal

[Insert Table 2]

4 Results: Spatial projection of the logistics sector

4.1 *Spatial distribution of the logistics-industry sector*

Figure 5 shows the recent locational distribution of the logistics sector focused on industry (referring to the year 2015) and the results of the computational simulations following the scenario and the sensitivity tests shown in the previous section (referring to the year 2065). Figure 5a shows that, for the year 2015, the logistic-industrial sector is concentrated mostly in the south-east region, in the states of São Paulo (SP), Minas Gerais (MG), Rio de Janeiro (RJ), Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RS).

Figure 5b shows the projections for 2065, about the spatial distribution of the logistics sector focused on industry, based on the baseline scenario. It should be emphasized that, in this model, the logistics sector operates in the wake of the productive sectors and shows the following systematics: centripetal forces and centrifugal forces act on the regions stimulating the movement of the workers inserted in the productive sectors resulting in some regions that are benefited and others that are not. In search of a demanding market, the logistics sector follows this dynamic. Thus, changes in the locational pattern of the logistics sector will be identical to those of the productive sectors that demand their services. In this scenario, we can observe a change in the locational axis of the sector, in which most of the Midwest, North and Northeast regions of Brazil receive a larger number of firms in this sector. It should be noted that these regions showed a greater deviation from the others, that is, they grew above average during this period (2015-2065), which does not mean that the South-Southeast region is no longer important. This result indicates a possible trajectory of convergence of the access to the logistics sector focused on industry. Therefore, logistics activities directed to the industrial sector are spreading across the Brazilian territory, or rather, regions with low level of access to the logistic-industrial services are growing east to have access to higher rates compared to regions with high access to the service. Thus, the gap between regions in terms of access to this type of logistical service is reduced over the period analyzed.

In order to understand how sensitive the results are to the values of the key parameters, the analysis continues, performing the appropriate sensitivity tests (ST's) described above. The results obtained with ST.1 to ST.8 that change the values of the key parameters (i.e., $\sigma, \eta, \chi^A, \chi^M, \tau^A$ and τ^M) is shown in Figure 5c. The results obtained in the eight sensitivity tests are similar. In addition, it can be observed that this map is identical to the base scenario, so that it is possible to affirm that the results found in the base scenario are consistent.

This subsection showed a conclusive result of the MapLog model. Taking into account the baseline scenario (and corroborated by the sensitivity tests), we can observe a change within five decades of the locational pattern of the logistics sector focused on industry in Brazil, indicating a process of spatial convergence of access to this service. The states of Paraná (PR), Santa Catarina (SC), Mato Grosso (MT), Mato Grosso do Sul (MS), Goiás (GO), Tocantins (TO), Ceará (CE) and Piauí (PI) are highlighted in relation to the others. Some reasons present themselves as candidates to explain this process of spatial dispersion. Certainly the strongest are linked to the increase in the cost of transportation and the rent of land due to the agglomeration of space. If transport costs are high enough then interregional freight will be discouraged. Thus, production will take place locally, creating a pattern of regional symmetry. That is, there is a process of diseconomy of scale that leads to spatial convergence. Something similar happens with land rent. Spatial agglomerations raise demand for land, and the latter being limited, it tends to raise its price. This tends to shift production to less concentrated regions.

Figure 5b indicates the regions where the logistics sector will intensify its activities over the next few years, thus exerting pressure on the local transport infrastructure. Knowing this, it is noted that the BR-153 (Transbrasiliana Highway), BR-163 and BR-020 highways will play a central role, and should receive greater attention from policy makers.

[Insert Figure 5]

4.2 *Spatial Distribution of the Logistics Sector for Agriculture*

This subsection is intended to discuss the results found on the spatial distribution of the logistics sector focused on agriculture (see Figure 6). The recent scenario, shown in Figure 6a, depicts the access to logistics-agricultural services for the year 2015. The sector is concentrated in São Paulo

(SP), Minas Gerais (MG), Paraná (PR), Rio Grande do Sul (RS), Mato Grosso (MT), Mato Grosso do Sul (MS) and Goiás (GO).

On the other hand, the simulation base scenario (see Figure 6b) shows the long-term spatial perspective of the logistic-agricultural sector, that is, of five decades. The regions benefited, i.e., that had greater log-deviations of the potential logistics variable, are practically the same ones that already show a concentration of the sector, with emphasis in the regions of São Paulo (SP) and Minas Gerais (MG). It is possible to state that there is no ongoing process of spatial convergence of access to logistics services for agriculture. Or rather, the regions that already have access to the service had log-deviation superior to regions lacking or with little access. Successful logistics groupings require certain geographic attributes, such as significant government investments in physical infrastructure. The highways that will face the greatest pressure from logistical activities for agriculture will be: BR-101 (Translitorânea Highway), BR-116, BR-364 (Marechal Rondon Highway), BR-381 and BR-040 (Rio-Brasília Highway).

Again, to check the consistency of the model, sensitivity tests were constructed (see Figure 6c). The results confirm that there is no sensitivity of the results to the key parameters of the model. In general, based on the baseline scenario, there seems to be no spatial convergence of access to logistic services for agriculture. In this case, centripetal forces appear to be more relevant than centrifugal components, acting in the direction of cluster conservation.

[Insert Figure 6]

As the location of the logistics sector is ultimately the result of the mobility of industrial and agricultural workers, it is possible to say that industrial workers are more likely to migrate compared to agricultural workers. The latter are fixed in space, even in function of the land factor which is immobile. Thus, it is possible to perceive a spatial convergence of the logistic sector focused on industry, while the logistic sector is not focused on agriculture.

5 Conclusion

The main purpose of this work was to investigate the recent and long-term spatial distribution of the logistics sector in Brazil. In other words, the work was aimed at identifying in the literature factors

that explain the location of logistics firms and search through mathematical modeling to project the spatial evolution of the sector. To achieve this goal, the Logistics Potential Mapping Model (MapLog) was constructed, which follows the theoretical tradition of the New Economic Geography (NEG). MapLog is composed of six blocks, namely: regional product, nominal wage, price index, real salary, migrant flow of workers and regional logistics potential, and brings some innovations in relation to the traditional Core-Periphery model, the main one being the insertion of the logistics sector, which specifically addresses the agricultural and industrial sectors.

Two points deserve to be highlighted. First, the results point to a change within five decades of the locational pattern of the logistics sector focused on industry in Brazil, indicating a process of spatial convergence of access to this service. The states of Paraná (PR), Santa Catarina (SC), Mato Grosso (MT), Mato Grosso do Sul (MS), Goiás (GO), Tocantins (TO), Ceará (CE) and Piauí (PI) are highlighted in relation to the others. In contrast, there appears to be no spatial convergence of access to logistical services for agriculture. The regions benefited, that is, that had greater log-deviations of the potential logistics variable, are practically the same ones that already show a concentration in the sector. Therefore, the states of São Paulo and Minas Gerais stand out.

Second, the MapLog model proved to be effective in that it brought results indicating the regions where the logistics sector will intensify its activities over the next few years, thus putting pressure on the local transport infrastructure. At this moment, it is a digression on the model. MapLog starts from an analysis of the spatial concentration of demanding sectors of the logistics sector, and based on this information, we were able to build a simple expression that indicates the logistics potential of the regions of analysis. Thus, these results serve as an action guide for policy makers linked to the transport and infrastructure sectors.

Although this methodological application allowed us to reach the initial objective of analyzing the present and long-term spatial distribution of the logistics sector in Brazil, advances and extensions can be approached, mainly in terms of details and disaggregation, such as:

1. Consider smaller spatial units, such as microregions or municipalities. In this way, migratory movements can be seen with greater clarity. In addition, it should be emphasized that intra-regional dynamics may show behavior different from its higher level; e.g., microregions that increased the logistical-industrial or logistical-agricultural potential in federative units that showed declining participation, or vice versa. For this reason, the reduction of the space observation unit is recommended as a future research proposal.
2. The disaggregation of the logistics sector and the insertion of other demanding sectors (e.g. trade).

3. Throughout this work, we made the assumption that the logistics firms were able to place their choice of vehicles in the productive sectors. Future work may alter this hypothesis by moving toward a logistics sector closer to the sources of consumption – that is, more connected to the end of the supply chain.
4. Adopt alternative ways of calculating the logistics market potential.

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Tables

Table 1 - Definition of the logistics sector

CNAE 2.0 (Subclass)	Description
4911-6/00	Railroad transportation of goods
4930-2/01	Cargo transportation, except dangerous goods and removals, municipal
4930-2/02	Cargo road transport, except dangerous products and removals, intermunicipal, interstate and international
4930-2/03	Road transport of dangerous goods
4930-2/04	Removals company (road transport)
5011-4/01	Coastal shipping - Freight
5012-2/01	Long-sea shipping - Freight
5021-1/01	Inland freight transport, municipal, except crossing
5021-1/02	Freight transport by cargo, intermunicipal, interstate and international, except crossing
5030-1/01	Maritime support navigation
5030-1/02	Port support navigation
5120-0/00	Air freight transport
5211-7/01	General warehouses - issue of warrant
5211-7/02	Furniture storage
5211-7/99	Deposits of goods for third parties, except warehouses and furniture storage
5212-5/00	Loading and unloading
5221-4/00	Concessionaires of highways, bridges, tunnels and related services
5231-1/01	Port infrastructure management
5231-1/02	Terminal operations
5332-0/00	Maritime agency activities
5240-1/01	Operation of airports and landing fields
5240-1/99	Activities auxiliary to air transport, except airport operations and landing fields
5250-8/01	Commissioner orders
5250-8/02	Customs broker activities
5250-8/03	Freight forwarding, except for maritime transport
5250-8/04	Logistics organization of cargo transportation
5250-8/05	Multimodal transport operator - OTM
5310-5/01	National Mail Activities
5310-5/02	Activities of franchisees and permission holders of National Post Office
5320-2/01	Pouch services not carried out by the National Post Office
5320-2/02	Fast Delivery Services

Source: Elaborated by authors.

Table 2 - Key parameter values in the base scenario (BS) and in the sensitivity tests (ST)

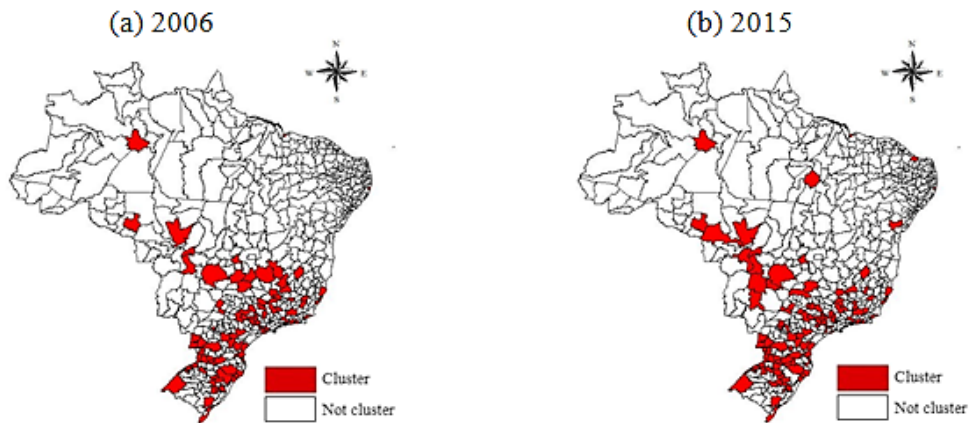
Parameter	BS	ST.1	ST.2	ST.3	ST.4	ST.5	ST.6	ST.7	ST.8
σ	2.079	2.279	1.879	2.079	2.079	2.079	2.079	2.279	1.879
η	1.720	1.920	1.520	1.720	1.720	1.720	1.720	1.920	1.520
χ^A	0.100	0.150	0.050	0.150	0.050	0.100	0.100	0.100	0.100
χ^M	0.100	0.150	0.050	0.150	0.050	0.100	0.100	0.100	0.100
τ^A	0.600	0.800	0.400	0.600	0.600	0.800	0.400	0.600	0.600
τ^M	0.300	0.500	0.100	0.300	0.300	0.500	0.100	0.300	0.300

Note: The symbols present in the table can be described as: σ -elasticity of substitution for industrial goods; η -elasticity of substitution for agricultural goods; χ^A - locational sensitivity of agricultural labor to deviations in real wages; χ^M - locational sensitivity of industrial labor to deviations in real wage; τ^A - value used in the constant of losses in the transport of agricultural goods (T_{rs}^A) and τ^M - value used in the constant of losses in the transport of industrial goods (T_{rs}^M).

Source: Elaborated by authors.

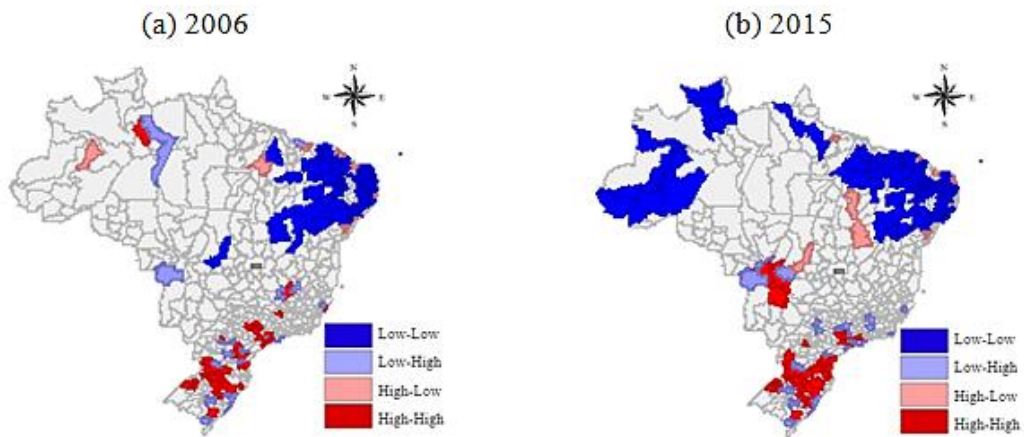
Figures

Figure 1 - Cluster Map ($HCLQ > 0$ and $LEP > 0.1$)



Source: Elaborated by authors.

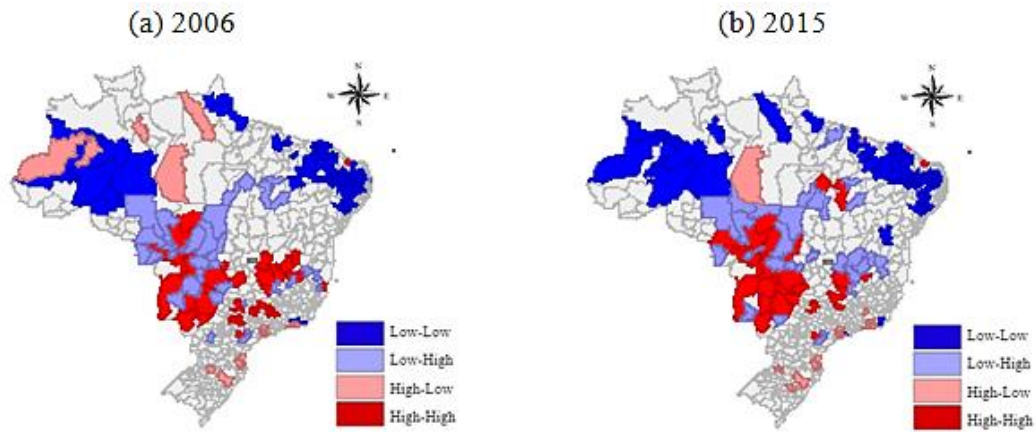
Figure 2 – Cluster map (LISA) for participation in logistics jobs*



Note: * The spatial weight matrix (W) will use the queen criterion (degree 1).

Source: Elaborated by authors.

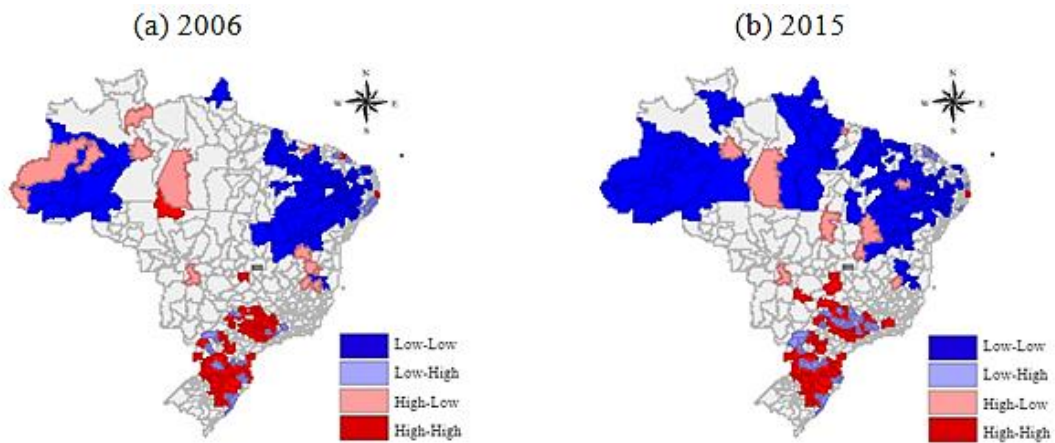
Figure 3 – Bivariate map for job participation in logistics and agriculture*



Note: * The spatial weight matrix (W) will use the queen criterion (degree 1).

Source: Elaborated by authors.

Figure 4 – Bivariate map for job participation in logistics and manufacturing industry*

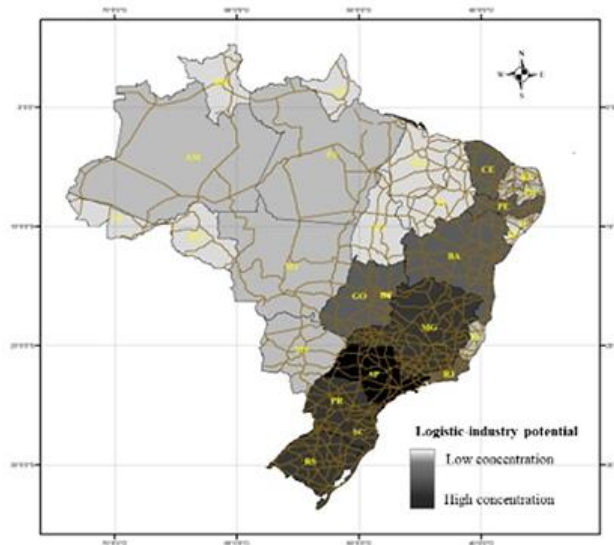


Note: * The spatial weight matrix (W) will use the queen criterion (degree 1).

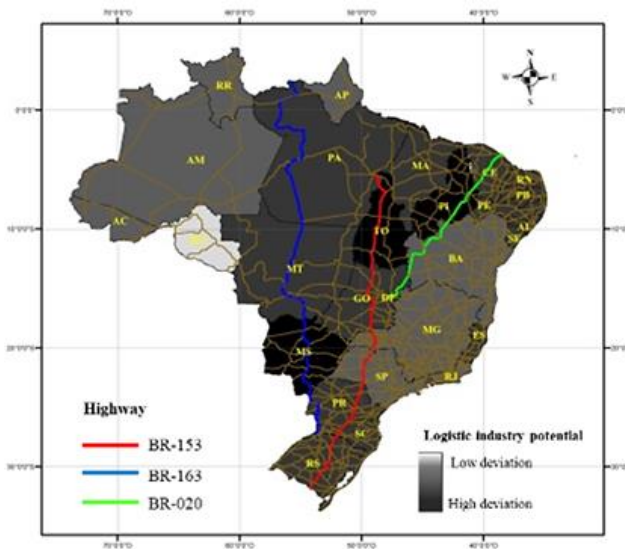
Source: Elaborated by authors.

Figure 5 – Potential for Logistic-Manufacturing Industry sector, current scenario (2015) and projections (2065), for federative units of Brazil, according to model MapLog*

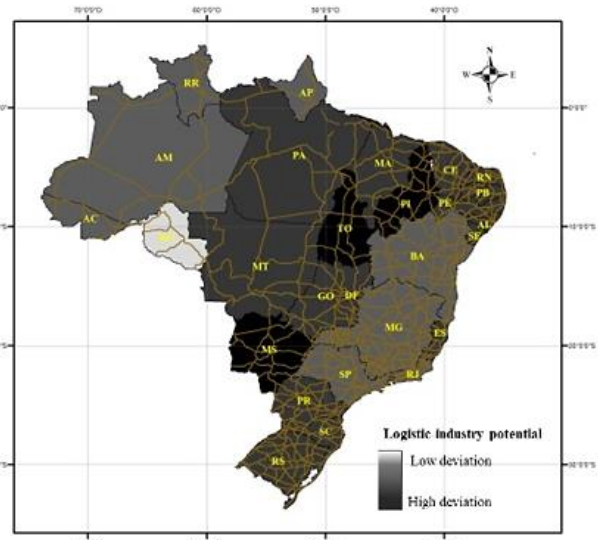
(a) Current (2015)



(b) BS (2065)



(c) ST.1 to ST.8 (2065)

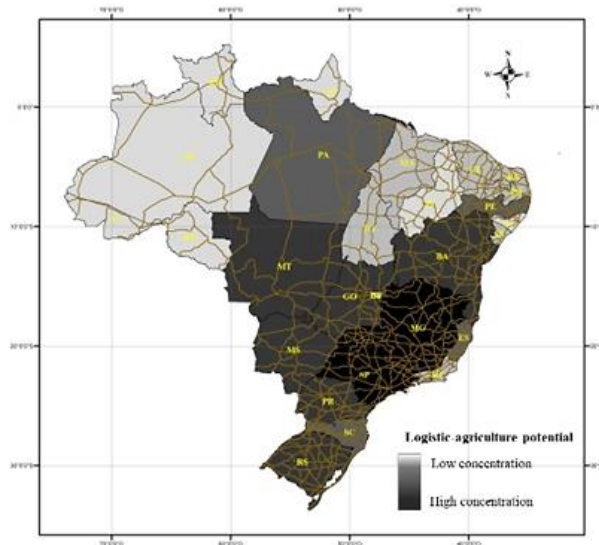


Source: Elaborated by authors.

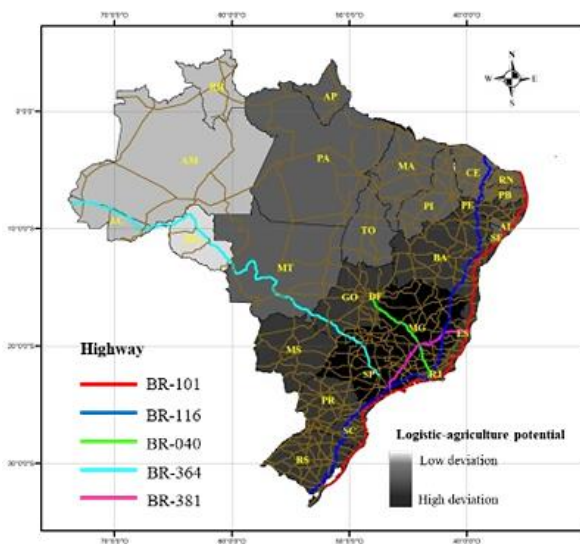
* Note: Figure (5a) presents the current scenario (2015) for the logistic-industrial sector. Figure (5b) shows baseline scenario projections for the regional logistic-industrial potential. Figure (5c) presents a general result of the sensitivity tests, where we changed key parameters of the model: (ST.1) positive variation of all key parameters; (ST.2) negative variation of all key parameters; (ST.3) positive variation of the parameters χ^A and χ^M ; (ST.4) negative variation of the parameters χ^A and χ^M ; (ST.5) positive variation of the parameters τ^A and τ^M ; (ST.6) negative variation of the parameters τ^A and τ^M ; (ST.7) positive variation of the parameters σ and η and (ST.8) negative variation of the parameters σ and η . The results of the sensitivity tests were similar, indicating robustness. It should be noted that the low/high concentration and low/high deviation intervals were defined by quintile.

Figure 6 – Potential for Logistic-Agricultural sector, current scenario (2015) and projections (2065), for federative units of Brazil, according to model MapLog

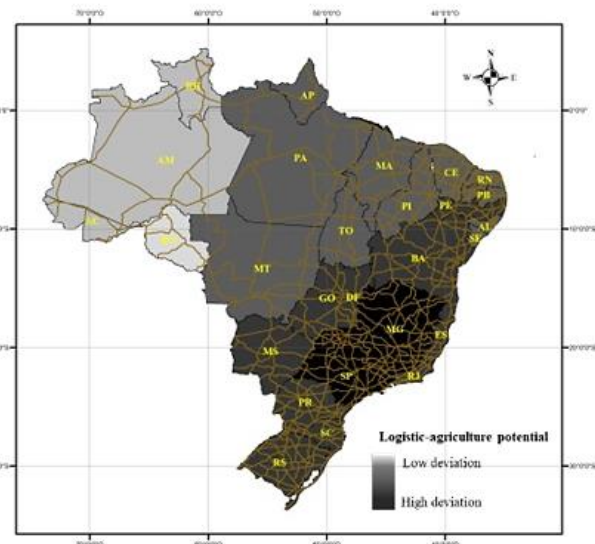
(a) Current (2015)



(b) BS (2065)



(c) ST.1 to ST.8 (2065)



Source: Elaborated by authors.

* Note: Figure (6a) presents the current scenario (2015) for the logistic-agricultural sector. Figure (6b) shows baseline scenario projections for the regional logistic-agricultural potential. Figure (6c) presents a general result of the sensitivity tests, where we changed key parameters of the model: (ST.1) positive variation of all key parameters; (ST.2) negative variation of all key parameters; (ST.3) positive variation of the parameters χ^A and χ^M ; (ST.4) negative variation of the parameters χ^A and χ^M ; (ST.5) positive variation of the parameters τ^A and τ^M ; (ST.6) negative variation of the parameters τ^A and τ^M ; (ST.7) positive variation of the parameters σ and η and (ST.8) negative variation of the parameters σ and η . The results of the sensitivity tests were similar, indicating robustness. It should be noted that the low/high concentration and low/high deviation intervals were defined by quintile.

Appendix A. Endogenous variables, exogenous variables and parameters

Table A1 - Description of endogenous variables*

Variable	Description
\tilde{g}_r^A	Agricultural price index in region r , where $r = 1, \dots, 27$ (log-deviation)
\tilde{g}_r^M	Industrial price index in region r , where $r = 1, \dots, 27$ (log-deviation)
\tilde{w}_r^A	Nominal wage in the agricultural sector in region r , where $r = 1, \dots, 27$ (log-deviation)
\tilde{w}_r^M	Nominal wage in industrial sector in region r , where $r = 1, \dots, 27$ (log-deviation)
\tilde{y}_r	Social income in the region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\phi}_r$	Employment share in the agricultural sector in the region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\lambda}_r$	Employment share in the industrial sector in the region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\omega}_r^A$	Real wage in the agricultural sector in the region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\omega}_r^M$	Real wage in the industrial sector in the region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\Omega}_r^{TA}$	Agricultural logistics potential in region r , where $r = 1, \dots, 27$ (log-deviation)
$\tilde{\Omega}_r^{TM}$	Industrial logistics potential in region r , where $r = 1, \dots, 27$ (log-deviation)

Note: * Given the condition imposed by the log-linearization the endogenous variables present in the model will have zero initial value.

Source: Elaborated by authors.

Table A2 - Description of exogenous variables and parameters (base scenario)

Variable	Description	Value	Sources
G_r^{A*}	(steady-state) Agricultural price index in region r , where $r = 1, \dots, 27^*$	3.6	Values calculated from the model
G_r^{M*}	(steady-state) Industrial price index in region r , where $r = 1, \dots, 27^*$	1.9	Values calculated from the model
w_r^{A*}	(steady-state) Nominal wage in the agricultural sector in region r , where $r = 1, \dots, 27$ (US\$)*	412.91	Based on RAIS**
w_r^{M*}	(steady-state) Nominal wage in industrial sector in region r , where $r = 1, \dots, 27$ (US\$)*	538.32	Based on RAIS**
Y_r^*	(steady-state) Social income in the region r , where $r = 1, \dots, 27^*$	58.64	Values calculated from the model
ϕ_r^*	(steady-state) Employment share in the agricultural sector in the region r , where $r = 1, \dots, 27$ (%)*	0.037	Based on RAIS**
λ_r^*	(steady-state) Employment share in the industrial sector in the region r , where $r = 1, \dots, 27$ (%)*	0.037	Based on RAIS**
Ω_r^{TA*}	(steady-state) Agricultural logistic potential in region r , where $r = 1, \dots, 27^*$	0.35	Values calculated from the model
Ω_r^{TM*}	(steady-state) Industrial logistic potential in region r , where $r = 1, \dots, 27^*$	0.273	Values calculated from the model
d_{rs}	Interregional distances (km)*	2280.95	Retrieved from De Carvalho et al. (2016)
μ^A	Proportion of agricultural workers in relation to total (%)	0.17	Based on RAIS**
μ^M	Proportion of industrial workers in relation to total (%)	0.83	Based on RAIS**
η	Substitution elasticity for agricultural goods	1.720	Retrieved from Faria & Haddad (2014)
σ	Substitution elasticity for industrial goods	2.079	Retrieved from Faria & Haddad (2014)
χ^A	Locational sensitivity of agricultural labor to deviations from real wages	0.10	Assumed value
χ^M	Locational sensitivity of industrial labor to deviations from real wages	0.10	Assumed value
τ^A	Value used in the constant of losses in the transport of agricultural goods (T_{rs}^A)	0.60	Value calculated from Esalq-log data***
τ^M	value used in the constant of losses in the transport of industrial goods (T_{rs}^M)	0.30	Value calculated from Esalq-log data ***

Notes: *The values shown for these variables are from an arithmetic mean.

**RAIS: Annual Report of Social Information. See: <http://trabalho.gov.br/rais>.

***Esalq-log: Group of Research and Extension in Agroindustrial Logistics of the Luiz de Queiroz College of Agriculture (ESALQ / USP). See: <https://esalqlog.esalq.usp.br/>.

Source: Elaborated by authors.