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Spatial Exploratory Analysis of the Industrial Sector in Brazil[1]

Análise Exploratória Espacial do Setor Industrial no Brasil

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Abstract

This paper aims to study the development of the spatial pattern and industrial concentration in Brazilian municipalities. The first step is to create synthetic indicators, which summarize a set of information regarding industry in each municipality. Subsequently, Local Indicators of Spatial Association - LISA is performed to verify any spatial autocorrelation in the calculated dimensions. We use data from Brazilian Institute of Geography and Statistics Ministry of Economy and Human Development Atlas to build 10 economic variables. The main results show the creation of four dimensions associated with: i) Industrial Specialization; ii) Industry Labour Productivity; iii) Income and Schooling; and iv) Urban Agglomerations. LISA indicates the presence of high-high clusters in the South and Southeast regions, while in the North and Northeast mainly, there is the presence of low-low clusters. These heterogenous spatial pattern reinforces economic inequalities along municipalities and regions.

Keywords: Industry; Factors; Spatial pattern; Brazilian municipalities; Regional Development

JEL Codes: C38; R12; R58

Resumo

Este artigo tem como objetivo estudar o desenvolvimento do padrão espacial e da concentração industrial nos municípios brasileiros. O primeiro passo é criar indicadores sintéticos, que resumem um conjunto de informações sobre a indústria em cada município. Posteriormente, a Análise Exploratória de dados Espaciais - AEDE é realizada para verificar a presença de autocorrelação espacial nas dimensões calculadas. Utilizamos dados do Instituto Brasileiro de Geografia e Estatística, Ministério da Economia e Atlas de Desenvolvimento Humano para construir 10 variáveis econômicas. Os principais

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resultados mostram a criação de quatro dimensões associadas a: i) Especialização Industrial; ii) Produtividade do Trabalho na Indústria; iii) Renda e escolaridade; e iv) Aglomerações urbanas. O LISA indica a presença de clusters alto-alto nas regiões Sul e Sudeste, enquanto nas regiões Norte e Nordeste, principalmente, há presença de clusters baixo-baixo. Esse padrão espacial heterogêneo reforça as desigualdades econômicas ao longo dos municípios e regiões.

Palavras-Chave: Indústria; Fatores; Padrão Espacial; Municípios Brasileiros; Desenvolvimento Regional.

Códigos JEL: C38; R12; R58

1. INTRODUCTION

The relevance of the role of industry for understanding the economic growth performance is based on the idea that sectors of the economy have different dynamics. Structural transformation, i.e., the transfer of labor based on lower-productivity activities to the modern tradable sector, based on higher-productivity activities, such as in the industry, can explain well the rapid take-off of East Asian countries in the postwar period (Rodrik, 2013). More specifically, the East Asian Tigers experienced rapid convergence with the developed economies based on industrialization and exports of manufactures.

According to a vast literature, industry in general and manufacturing, in particular, represents the most important tradable sector for developing countries (McMillan *et al*., 2014; Gabriel and Missio, 2018). As manufacturing develops, externalities among firms and sector, along with their macroeconomic and distributive effects, may produce leaps in the growth process (Rosenstein-Rodan, 1943). Moreover, the capacity of industrial activities are important vectors of economic dynamism spreading in the economy, through backward and forward linkages (Hirschman, 1958).

Within countries the fastest growing regions are those that have the largest share of the industrial sector in Gross Domestic Product (GDP). It is for this reason that Kaldor (1966) emphasizes the need to understand growth in view of sectoral differences, since increasing returns, mainly from industry, are responsible for feedback into the growth process.

In spatial terms, Diniz (1993) and Diniz and Crocco (1996) verified the formation of an industrial polygon in Brazil among a group of delimited micro regions in South and Southeast in the last thirty years of 20th century. Between 2003 and 2011, Saboia, Kubrusly and Barros (2014) identified traditional industry (e.g., food and beverage, textile, rubber and plastic, among others) more intensively located in the North, Northeast and Midwest regions, while the durable industry (e.g., electronic equipment, transport equipment, among others) is frequently located in the South and Southeast regions, i.e., inside the above mentioned industrial polygon. The main exception, according to them is the Amazonense mesoregion with a high incidence of the durable industry.

Other studies evaluated the pattern or determinants of industrial activity location in Brazil using spatial methods (Domingues and Ruiz, 2006; Silva and Silveira Neto, 2009; Faria, 2011; Bonini, 2017). Domingues and Ruiz (2006) evaluated industrial agglomerations in Brazil using the industrial transformation value indicator for the year 2000. This study indicated significant spatial effects in the analysis and that variables such as patents and higher education were positively related to the value of industrial transformation, while publication of scientific articles and transportation costs in relation to the capital were negatively related. Silva and Silveira Neto (2009) sought to identify the spatial pattern of industrial concentration in Brazil and to verify the determinants of industrial employment growth between 1994 and 2004. Their results indicated that the market linkages were significant for the growth of industrial employment and such growth tends to be greater in locations with smaller firm sizes. In addition, transport costs were negatively correlated with industrial employment growth, while wages were positively correlated.

Faria (2011) using industrial data from the Annual Industrial Survey (PIA) at the municipal level analyzed the spatial pattern of location for the intermediate goods industry in Brazil, as well as the determinants of its location. The results of this study indicated that determinants such as the attraction factors (human capital, economic spending, exports and wealth of industry), industrial density (density of industrial employment and industrial density), local scale (qualification of work and income) and polarization of industry were significant in explaining the location of this industry in the wealthiest regions of Brazil (southeastern and southern states of the country). On the other hand, for the poorest regions (Midwest, North and Northeast), the factors of attraction and local scale were not significant. Bonini (2017) evaluated the determinants of spatial agglomerations of industry in the state of São Paulo through a cross-section analysis for the year 2010. The results of this study indicate that the number of manufacturing industries and the population with at least college degree contribute positively to the occurrence of agglomeration, as well as proximity to the state capital.

More recently, Monteiro Neto, Silva and Severian (2019) highlighted the growth of the relevant industrial agglomerations inside Brazilian industrial polygon mainly in small municipalities. Following Diniz (1993), Monteiro Neto et al. (2019) defined relevant industrial agglomeration as a micro region with at least ten thousand industrial jobs, including extractive industry, which was not included originally by Diniz (1993). At the same time, relevant industrial agglomerations growth took place outside this industrial polygon with less intensity in the North, Northeast and Midwest. More importantly, between 2000 and 2015 the gross value added of the industrial polygon decreased to 66.3% in 2015 (in 2000 was 74.3%) and in terms of the relevant industrial agglomeration quantity it decreased to 65.6% in the same period (in 2000 was 69.7%).

In heterogeneous economies, as is the case of Brazil, it is fundamental to identify regional location patterns of economic activity, industry in particular. This can guide local policies to stimulate regional growth as well as minimize inequalities. Thus, empirical contributions on regional patterns of industrial location help decision making by public and private agents. In Brazil important changes occurred throughout the twentieth century causing changes to the country's productive structure.

In this context, this paper aims to study the development of the spatial pattern and concentration of industry in Brazilian municipalities. Given that industry can be an engine of growth, this study traces the spatial patterns of industrial development in 2014. The first step is to create synthetic indicators through factor analysis, which summarize a set of industry information in each Brazilian municipality. Subsequently, the Local Indicators of Spatial Association (LISA) will verify any spatial autocorrelation in the previously calculated dimensions. This allows us to characterize industrial development in the Brazilian regions from a wide set of information. We use data from Brazilian Institute of Geography and Statistics Ministry of Economy and Human Development Atlas to build 10 economic variables.

The main contribution of this paper is therefore to present new results on spatial pattern and concentration of industry in Brazilian municipalities using Factorial Analysis (FA), in order to produce synthetic indexes and Exploratory Spatial Data Analysis (ESDA) techniques to shed more light on the subject in the recent period. To the best of our knowledge this kind of empirical exercise was not applied to the Brazilian economy data for 2014 (the most recent period available for this data set).

In addition to this introduction and the final remarks, this paper contains three more sections. The next section presents a brief discussion about the Brazilian industrialization process and the theory and evidence concerning the role played by industries on economic growth. The third section describes the methods used as well as the database. The fourth section discusses the results obtained.

2. THE BRAZILIAN INDUSTRIALIZATION PROCESS AND THE MANUFACTURING ROLE ON ECONOMIC GROWTH

The rise in Brazilian domestic income, due to the expansion of exports of primary products, spurred the beginning of the country's industrialization process until the beginning of the 20th century. Between 1885 and 1921 textile production grew. This is a period that helps to understand the origins of regional inequalities in Brazil because the growth in exports of these primary products, coffee in particular, was concentrated in the Southeast region. Between 1930 and 1970 the national economy underwent transition: the primary export model was replaced by a more industrial logic. This was a moment of significant worker mobility migrating from the rural regions to the urban centers (Suzigan, 2000).

Between 1950 and 1980 Brazil already had a relatively diversified industrial structure and, according to Sarti and Hiratuka (2011), industrial production grew by an average of 8.3% per year. However, from the 1980s this sector lost its dynamism. According to Sarti (1994), this decade was marked by oscillations in industrial performance, with a clear tendency towards stagnation. The phases were: i) recession (1981-83); ii) short-term recovery (1984-86); iii) deceleration (1987-89); and iv) a new and intense recession since 1990. According to Sampaio (2017), the share of manufacturing industry in Brazilian GDP fell from 35.9% in 1985 to 9.8% in 2013.

The scenario described above gave rise to the debate about a possible process of deindustrialization of the Brazilian economy. Perobelli *et al*. (2017) observe that the Brazilian industrial sector is losing intensity. That is, it is becoming less integrated into the productive process of the industrial sector as a whole. According to these authors, the sign of deindustrialization manifests itself most strongly in sectors of low technological content. This is in line with previous studies that have noted, as a symptom of deindustrialization, a reduction in manufacturing share in relation to total GDP since 2005: Feijó, Carvalho and Almeida (2005), Oreiro and Feijó (2010) and Borghi (2017). We must remember that Brazilian industrial development did not occur homogeneously throughout the country (Cano, 1981; Haddad, 1999; Diniz, 2006). About half of the formal employment in the manufacturing industry in 2014 was concentrated in the Southeast region. The spatial concentration of firms is not a Brazilian specificity. Several studies have shown the geographical concentration of firms in the world (Krugman, 1991; Ellenson and Glaeser, 1997, Durnanton and Overman, 2005, 2008, Maurel and Sédillot, 2009).

The pioneering work on this theme is attributed to Marshall (1890). He identifies the existence of agglomeration forces that stimulate industries in the choices of their location. Among the benefits of agglomeration are: i) reduction in transport costs; ii) access to the most skilled workers; iii) technological spillovers; and iv) increased competitive pressure. The literature on regional economics classifies the determinants of economic agglomerations in two types. The first concerns the so-called locational economies - which stem from productivity gains outside the firm but internal to the industry. The second refers to the economies of urbanization - productivity gains that occur due to the diversity of economic activities, which benefit firms from different industries that are concentrated in a space.

Regardless of the reasons that stimulate the agglomeration of activities, it seems evident that the Brazilian industrial sector has developed in a heterogeneous way in space, having concentrated in specific municipalities. Just as important as identifying these regions is to investigate the spatial pattern of industry. Since many of them are interrelated by a user-supplied network, the technological knowledge generated in one industry can be used by others. As a result, the inter-industrial diffusion of technological knowledge brings changes to productivity in related industries. This process can boost economic growth by the effect of Kaldor´s laws throughout the economy.

Kaldor first articulated his theory about why growth rates differ in two lectures: one in Cambridge in 1966 entitled Causes of the Slow Rate of Economic Growth of the United Kingdom (Kaldor, 1966); the other at Cornell University in the same year entitled Strategic Factors in Economic Development (Kaldor, 1967). A great number of works have verified the empirical validity of Kaldor's "laws", among them we can highlight: Léon-Ledesma (2000), Felipe (1998) and Fingleton and McCombie (1998).

The first law of Kaldors´s law states that there exists a strong causal relation between the growth of manufacturing output and the growth of GDP. The second law states that there exists a strong positive causal relation between the growth of manufacturing output and the growth of productivity in manufacturing as a result of static and dynamic returns to scale. This is also known as Verdoorn's Law in the study of economic growth. The third of Kaldor´s law states that there exists a strong positive causal relation between the rate at which the manufacturing sector expands and the growth of productivity outside the manufacturing sector because of diminishing returns in agriculture and many petty service activities which supply labor to the industrial sector, as whole.

It is worthy to mention the effect of manufacturing on productivity, as highlighted by Kaldor, considering heterogenous sample of countries and the disaggregation of manufacturing. Rodrik (2013) document a robust tendency toward convergence in labor productivity in manufacturing activities, regardless of geography, policies, or other country-level influence. Even with more disaggregated specifications this fact is observed, generally yielding higher estimates. Rodrik (2013) coefficient of unconditional convergence is at 2-3% in most specifications and 2,9% a year in the baseline specification covering 118 countries. According to the author a convergence rate of 2,9% implies that industries that are a tenth of the technology frontier can have a convergence boost in their labor productivity growth of 6,7% per annum.

Three important conclusions can be draw of Rodrik (2013)´s research: i) non-manufacturing sectors does not exhibit convergence; ii) manufacturing´s impact on aggregate convergence is reduced by its small size, especially in developing economies; iii) the growth boost from the reallocation of work is not sufficiently greater in poorer countries.

Given the importance of manufacturing on productivity and, therefore, on economic growth, it is very important to understand its spatial pattern and concentration in developing countries, (such as in Brazil), because in these countries' firms are more likely to gain advantages from agglomeration. This happens, according to Chhair and Newman (2014), because they start from a smaller technological base. Spillovers of new technologies and innovations could have significantly greater impacts on productivities.

In order to analyze the spatial pattern and concentration we use in this work factorial analysis to produce synthetic indexes and exploratory spatial data analysis. In the next section these methods are explained, and the database presented. Afterwards, in section 4, we focus on the results and discussions.

3 METHODS AND DATABASE

3.1 Methods

The empirical strategy used consisted of the use of two methods: 1) Factorial Analysis, in order to produce synthetic indexes; 2) Exploratory spatial data analysis (ESDA), which was conducted to indicate a significant spatial pattern associated with the indices constructed in the factorial analysis. Thus, there is complementarity between these methods in order to generate a more complete characterization of the Brazilian municipalities in relation to the industrial dimensions. The main function of Factor Analysis is to reduce the original number of variables so that these extracted independent factors can explain, in a simple and reduced way, the original variables. The factorial analysis method is a multivariate statistical technique used to represent complex relationships between sets of variables. In the factor analysis model, each of the variables can be defined as a linear combination of the common factors that will explain the variance portion of each variable, plus a deviation that summarizes the portion of the total variance not explained by these factors (Mingoti, 2013). The factorial analysis model from the correlation matrix linearly relates the standardized variables Z and the m unknown common factors:

$$(1) \qquad Z_1 = l_{11}F_1 + l_{12}F_2 + \cdots + l_{1m}F_m + \varepsilon_1$$

$$\vdots$$

$$Z_p = l_{p1}F_1 + l_{p2}F_2 + \cdots + l_{pm}F_m + \varepsilon_p$$

or in matrix notation:

$$(2)\ D(X - \mu) = LF + \varepsilon$$

where D is a diagonal matrix $p{\times}p$ formed by the inverse of the variance of each variable. $F\ (m{\times}1)$ is a random vector containing m unobservable factors $(l \le m \le p)$. The model assumes that the variables i are linearly related to new random variables F_j (factors). $L\ (p{\times}m)$ is the matrix with the coefficients where ij (loading) is the coefficient of the i-th standardized variable i (Z_i) in the j-th factor j (F_j) and represents the degree of linear relationship between i and j. The information of the standardized original variables Z is represented by (p+m) unobservable variables (ε and F). The factors present null means, unit variances, are uncorrelated and are independent. From the definition of the correlation matrix, $P = L'L + \Psi$, where $Var(Z_i) = h_i^2 + \varphi_i$, the coefficients ij (matrix L), relative to the variability of Z_i expressed by m factors, were estimated by the principal components method (Johnson and Wichern, 2007). Most of the variables did not have a normal univariate or multivariate distribution, if they had, the maximum likelihood method could have been applied.

The interpretation of the original factors *1, 2, ..., m* may not be trivial due to close values of the coefficients *ij* in several different factors (violation of the orthogonality of the factors). In order to solve this problem, an orthogonal transformation of the original factors is performed to obtain simpler structures. The orthogonal rotation preserves the original orientation between the factors, keeping them perpendicular. In the present paper, the VARIMAX rotation was used. The first factor corresponds to the highest proportion of common variability and so on. It is possible to describe the steps developed in the factorial analysis as follows: 1) calculation of the correlation matrix of all variables; 2) determination of number and extraction of factors; 3) rotation of the factors, transforming them so as to facilitate their interpretation; 4) selection of a number of factors according to the eigenvalue criterion (factors with characteristic roots greater than one) or considering an adequate proportion of the common variance; 5) calculation of factor loads. Factorial loads will be used to verify the presence of significant spatial patterns in retained factors.

The ESDA consisted of verifying the presence of global and local spatial autocorrelation. Global spatial autocorrelation was tested using Moran's *I* statistic. This statistic gives the formal indication of the degree of linear association between the vectors of observed values (*Z*) and the weighted average of the neighborhood values, or the spatial (*Z*) lags. Values of *I* larger (or smaller) than expected $E(I) = 1/(n-1)$ means that there is positive (or negative) autocorrelation. In formal terms, Moran's *I* statistics can be expressed as (Anselin, 1996):

$$(3) \quad I = \frac{n}{So} \frac{\sum i \sum j \, Wij \, Zi \, Zj}{\sum_{i=1}^{n} \quad Zi^2}$$

where *n* is the number of regions, *Z* denotes the values of the standardized interest variable, *Z* represents the mean values of the standardized interest variable in neighbors, defined according to a spatial weighting matrix *W*. An element of this matrix, referring to region *i* to region *j*, is recorded as *ij*. In summary, Moran's *I* provides three types of information: 1) the level of significance provides information about whether the data is randomly distributed or not; 2) the positive sign of Moran's *I* statistic indicates that the data is concentrated across regions. The negative signal, in turn, indicates the dispersion of the data; 3) the magnitude of the statistic provides the strength of the spatial autocorrelation.

The local spatial autocorrelation analysis was performed using LISA (Local Indicator of Spatial Association) or Local Moran's *I*. According to Anselin (1995), such a statistic should satisfy two criteria: 1) have, for each observation, an indication of significant spatial clusters of similar values around observation (e.g. region); 2) their summation for all regions, must be proportional to the global spatial autocorrelation indicator. LISA is used to detect the extent to which the data set is randomly grouped, dispersed or distributed, local Moran coefficient I_i decomposes the global autocorrelation indicator into the local contribution of each observation into four categories (High-High, Low-Low, High-Low and Low-High). The local Moran coefficient I_i for the standardized variable, observed in region *i*, Z_i, can be expressed as:

$$(4) \; Ii = Zi \sum_{j=1}^{j} \quad Wij \, Zj$$

The matrix *W* indicates the form of contiguity between the spatial units. In the present paper, the spatial weights matrix *queen* was used. Such a weight matrix is of the binary type and specifies the neighborhood occurrence in cases where there is at least one common border point between the spatial units.

3.3 Database

The data used in this study were obtained from various statistical sources, namely: i) Brazilian Institute of Geography and Statistics (IBGE); ii) Annual Report on Social Information (RAIS) of the Ministry of Economy;
and iii) Human Development Atlas of Brazil. Table 1 summarizes the variables as well as their respective sources.

Table 1: Variables description

Initials	Variable description	Source
VAB	Gross value added *per capita* of industry	IBGE
LQ	Industry locational quotient	
SC	Industry specialization coefficient	
PROD	Industrial labour productivity - ratio between the number of formal workers in industry and the industrial gross value added	RAIS e IBGE
EMP	% of formal workers in industry compared to the total number of formal workers in the municipality	RAIS
REND	Average income of formal industry workers	
EST	Number of industrial establishments per 10,000 inhabitants	
EDU	% of formal industry employees with university degree	
URB	% of municipal urban population	Atlas de Desenvolvimento
MERC	Ratio between the difference in the total wage mass (WM) and the Agriculture's WM and the urban population	RAIS e Atlas de Desenvolvimento

Source: Author´s own elaboration.

All variables, except for the percentage of the municipal urban population (2010), refer to the year 2014 - the most recent period available for this data set. This information was collected at the municipal level, totaling 5,570 observations for each variable. The ten variables synthesize recent industrial dynamism among Brazilian municipalities.

The LQ, the Specialization Coefficient (SC), the number of industrial establishments per capita (EST), and the percentage of formal industry workers (EMP) aim to capture the specialization effects of industry. It is worth noting that LQ, in particular, has been used as a proxy for MAR specialization externalities (Glaeser et al., 1992; Combes, 2000; Simões and Freitas, 2014; Ribeiro et al., 2018). Specialization theory, also known as MAR (Marshall, 1890; Arrow, 1962; Romer, 1986) focuses on knowledge spillovers in a specific industry due to the concentration of firms.

The LQ and SC were calculated from the industrial added value data (VAB) of the Brazilian municipalities. According to Haddad (1989), these indicators can be specified as:

$$(5) \qquad LQ_{ij} = \frac{E_{ij}/E_{i}}{E_{.j}/E_{..}} \qquad\qquad SC_j = \frac{\sum_i(|iej - ie.|)}{2}$$

In that: E_{ij} is the number of employees in industry in the municipality j; $E_{i.}$ is the total number of employees in the municipality *j*; $E_{.j}$ is the number of employees in industry in Brazil and $E_{..}$ is the number of total number of employees in Brazil.

The specialization coefficient, according to Haddad (1989, p.240), "compares the productive structure of region j with the national productive structure". Thus, if such a coefficient is equal to zero, it implies that region j has the same structure as the country as a whole, whereas if SC is equal to one (1) region j has a strong specialization in a certain sector or has an employment structure totally different from the national one.

The average income of formal industry workers (REND) and the percentage of employees in industry with a university degree (EDU) measures the profile of the industrial labor force. The industrial value added per capita (VAB) and industrial labor productivity (PROD) synthesize the dynamism of the sector.

This last variable, following Miguez and Moraes (2014), was calculated from the ratio of the number of formal employees in industry to the VAB of the sector. There are different ways of calculating labour productivity in the literature. According to Messa (2015), this indicator is constructed through the ratio between product and some measure of labor.

The percentage of the municipal urban population (URB) and the proxy for market (MERC) seek to capture agglomeration economy effects (Pereira and Lemos, 2003; Lemos *et al*., 2003; Betarelli Junior and Simões, 2011). The latter indicator is calculated by the ratio of the difference between the total wage mass and the agricultural wage and the URB variable. In order to explore the database, Table 2 presents the main descriptive statistics of the sample, considering the 5,570 Brazilian municipalities.

Table 2: Descriptive Statistics

Variables	Minimum	Maximun	Mean	Standard deviation
VAB	0.00	668,932	3,770	13,518
LQ	0.00	3.63	0.58	0.58
PROD	0.00	97,482	283	1,666
EST	0.00	283	25	29
REND	0.00	12,185	1,198	724
EDU	0.00	1.00	0.04	0.08
SC	0.00	1.83	0.16	0.08
URB	0.00	1.00	0.64	0.22
MERC	0.00	10,188	354	373
EMP	0.00	0.90	0.18	0.18

Source: Author´s own elaboration.

In general, we can see intense data heterogeneity from the high value of the standard deviation of almost all the variables. Due to the geographic dimension of Brazil, as well as its discrepant socioeconomic conditions, infrastructure etc., this is expected. The following section presents the results of the factorial analysis and the LISA.

4. RESULTS AND DISCUSSION

First, the factorial analysis results are presented, which construct synthetic indicators based on the variables presented previously. In a second moment, LISA is used to verify the presence of spatial patterns in the generated factors. Tables 3, 4, 5 and Appendix 1 present the factorial analysis results performed for the set of variables in Table 1. Table 2 shows the suitability tests of the sample for factorial analysis.

The null hypothesis that the correlation matrix is an identity matrix is rejected through the Bartlett's Test of Sphericity, that is, the variables are correlated between them. The value of the KMO measure is 0.689, suggesting, together with the result of the first test, that the use of the factorial analysis is adequate for the set of variables used.

Table 3: Tests of adequacy to factorial analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)		0.689
Bartlett's Test of Sphericity	Statistic	22,112
	Degrees of freedom	45
	Probability	0

Source: Author´s own elaboration.

Table 4 shows the number of factors extracted considering the criteria of the eigenvalue greater than one, as well as the percentage of the variance explained by each of the retained factors. According to this criteria, four factors were selected, which together account for 75% of the total variance. The loss of information is relatively low and the synthetic indicators based on the factorial analysis make it possible to adequately characterize aspects of industry in Brazilian municipalities.

Table 4: Eigenvalue and factors' variance

Factor	Eigenvalue	% Variance	% Cumulative Variance
1	3.4	33.7	33.7
2	1.9	19.2	52.9
3	1.2	11.7	64.6
4	1.0	10.4	75.0

Source: Author´s own elaboration

Table 5 presents the factorial loads and the commonalities of the selected factors after the Varimax orthogonal rotation method. The rotation aims to transform the coefficients of the retained factors into a simplified structure, i.e. facilitating the interpretation from the better distribution of the variables' weights between the factors (Mingoti, 2013). The commonalities, in turn, indicate how much of common variance each variable represents. According to Faria (2017), high commonalities suggest that the extracted factors describe the variables well.

Table 5: Component matrix and commonalities after Varimax rotation

Variables	Factors				Commonalities
	1	2	3	4	
VAB	-	0.894	-	-	0.903
LQ	0.673	-	-	-	0.745
PROD	-	0.887	-	-	0.808
EST	0.789	-	-	-	0.702
REND	-	-	0.730	-	0.667
EDU	-	-	0.849	-	0.722
SC	-	-	-	-0.682	0.622
URB	-	-	-	0.786	0.753
MERC	0.778	-	-	-	0.758
EMP	0.849	-	-	-	0.819

Source: Author´s own elaboration.

Factor 1, which accounts for 33.7% of the explained variance, correlates more strongly with the Locational Quotient (LQ) of the industry, with the number of industrial establishments per capita (EST), with the market area indicator (MERC) and the percentage of industrial employment (EMP). Therefore, factor 1 is called "Industrial Specialization".

Factor 2, as can be seen in Table 4, accounts for 19.2% of the variance and is most strongly related to the industrial value added per capita (VAB) and industrial labour productivity (PROD). For this reason, this factor is titled "Industrial Labour Productivity".

The third factor accounts for 11.7% of the variance and is more strongly related to the average income of the industry worker (REND) and to the percentage of workers in industry with higher education (EDU). Factor 3 is denominated "Income and Schooling". Empirical evidence in economic literature that deals with the importance of human capital to explain wage differences has already shown that the higher the level of education of the individual, the greater the income tends to be. For the Brazilian case, we can highlight the works of Ramos and Vieira (2001), Barros et al. (2007), Teixeira and Menezes-Filho (2012), among others.

The fourth factor, in turn, accounts for 10.4% of the common variance and is more strongly correlated with the Specialization Coefficient (SC) of the industry and the percentage of the municipal urban population (URB). Thus, this factor is called "Urban Agglomerations".

The results found in the factor analysis are analogous to those found by Faria (2011). In this study, four factors related to industrial activity were found: i) attraction factors; ii) industrial density; iii) local scale; and iv) industrial intensity. The first comprises variables such as human capital, tax expenditures to encourage economic activities, exports, cultural amenities (presence of cultural services such as cinema, theater and parks). The second factor was represented by population density, density of industrial employment and density of industries. The third factor was formed by the variables of job qualification and income. Finally, the industrial intensity factor was formed by the variables degree of industrialization (percentage participation of the industrial sector in the municipality's employment) and industrial polarization (percentage participation of the industrial sector in the municipality).From the factorial scores, LISA is used to verify spatial patterns of the four synthetic indicators created by the factorial analysis. Table 6 shows the results of the global spatial autocorrelation indices for the four industrial dimensions found. Moran’s I was calculated considering four matrices of different spatial weights. All indices were positive and significant at the level of 1%. The highest values were obtained with the queen matrix and distance matrices with the five nearest neighbours. Faria (2011) found positive and significant spatial autocorrelation of the intermediate goods industry variable. It is important to note that The LISA used in the rest of this paper is based on the queen matrix.

Table 6: Global spatial autocorrelation index of the industrial dimensions*

Neighborhood Criteria	Factor 1	Factor 2	Factor 3	Factor 4
	Industrial Specialization	Industrial Labour Productivity	Income and Schooling	Urban Agglomerations
Queen	0.521	0.155	0.177	0.263
K5	0.536	0.143	0.181	0.273
K10	0.515	0.092	0.170	0.258
K15	0.499	0.076	0.161	0.249

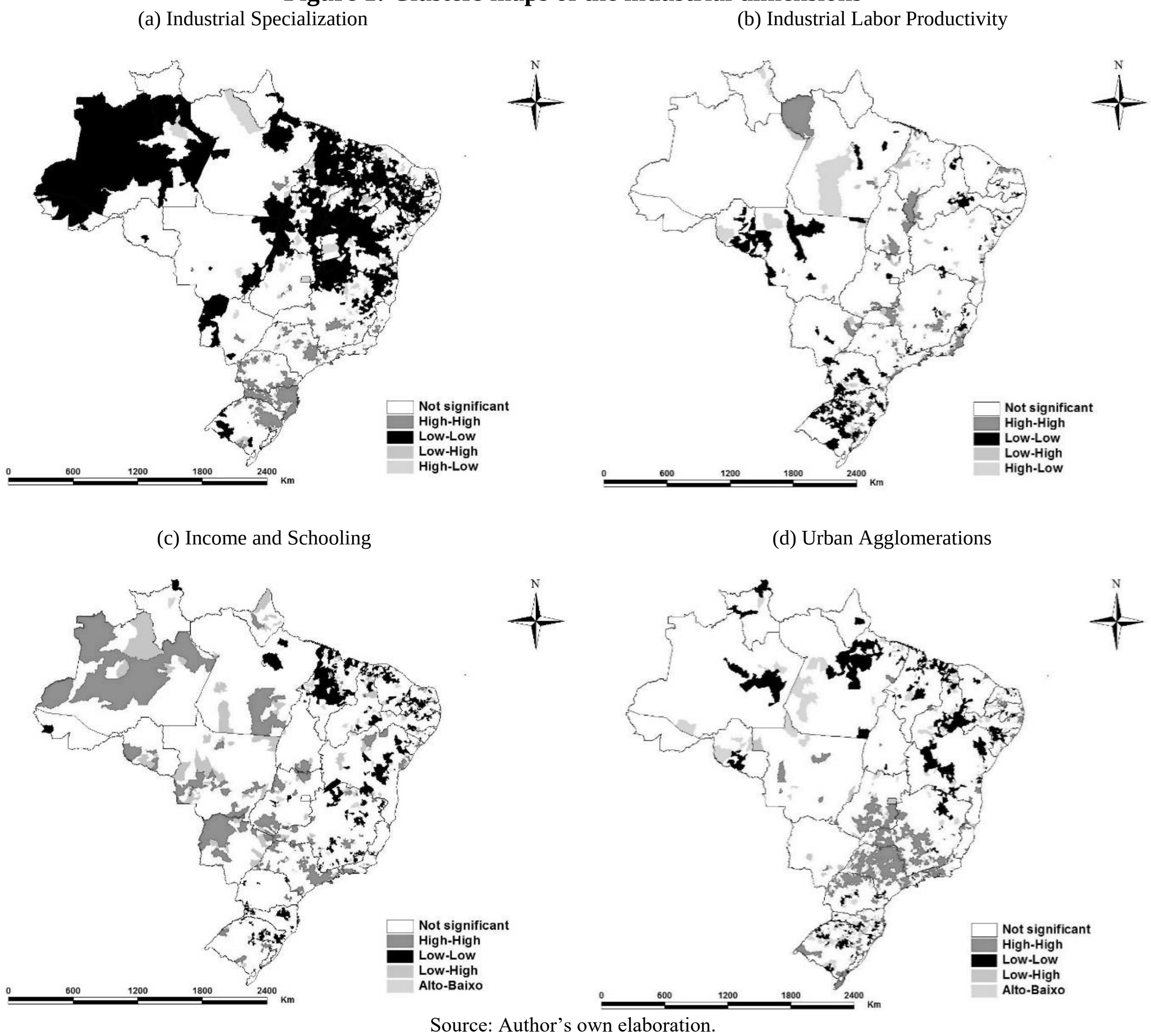
Note: * All of the Moran´s I were significant at the level of 1%.
Source: Author´s own elaboration.

A typical interpretation of positive Moran's I, as found for the "Industrial Specialization" dimension, for instance, indicates that industrially specialized municipalities tend to have neighbors with the same characteristic. It was also found that this dimension was the one with the highest Moran’s I value (0.521). It is important to remember that the dimension "Industrial Specialization" is made up of variables such as industry LQ and market potential. These variables tend to draw distinct spatial patterns and, in many cases, well-defined spatial patterns, which may reveal spatial autocorrelation both in terms of spatial heterogeneity and spatial dependence. In other words, this dimension indicates that the industrial activity associated with market potential tends to spread more in space, but in a heterogeneous way.

The second dimension had the lowest Moran´s I value (0.155). Such an outcome is intuitive as labor productivity tends to be more locally specific. Productivity is higher in locations with more modern industrial plants and which are highly capital intensive in many cases. The proximity of the Moran's I value of the dimension "Income and Schooling" is also intuitive because of the relationship between labor productivity, remuneration and schooling. Finally, the fourth dimension "Urban agglomerations" has a Moran's I equal to 0.263. Such a level of spatial autocorrelation is expected, given that urban agglomerations are also phenomena that tend to spread in space, mainly in response to the development of economic activities.

To identify spatial autocorrelation at the local level, the LISA statistic was used. The local indicators identify significant spatial clusters and the results can be seen in maps according to the different patterns of association. Figure 1 shows the clusters maps for the different dimensions found in Brazilian municipalities.

Figure 1: Clusters maps of the industrial dimensions



Source: Author's own elaboration.

Panel (a) describes the spatial patterns found for the "Industrial Specialization" dimension. Two dominant patterns can be seen. The most comprehensive in Brazil refers to the Low-Low type. In this cluster, municipalities with low industrial specialization are neighbors of municipalities that also present low industrial specialization. This cluster includes municipalities located mainly in the Northeast, north of Minas Gerais, Maranhão, Tocantins, Acre and Amazonas states. These municipalities have, in relative terms, low industrial LQ associated to a smaller number of industrial establishments, fewer jobs in industry and less urban market potential.

On the other hand, the formation of High-High clusters can be seen, in which municipalities with high industrial specialization are neighbors of municipalities that have high industrial specialization. The clusters of this pattern are located mainly in the South and Southeast regions of the country, more specifically throughout the state of Santa Catarina, in municipalities in the north of Rio Grande do Sul, Paraná, Metropolitan Region of São Paulo and others in the interior of the state of São Paulo and Metropolitan Region of Belo Horizonte. The LISA result in Figure 1 (a) is intuitive in the sense that it portrays the issue of industrial specialization in Brazil and its distribution throughout Brazil.

Figure 1 (a) indicates that even with the industrial deconcentrating process experienced by the Brazilian economy (Diniz, 1993; Guadares Neto, 1997; Haddad, 1999; Suzigan, 2000), the South and Southeast regions have the most specialized industry in Brazil. According to Lima and Lima (2010), in the 1990s there was an intensification of public policies based on tax incentives to attract industries to poorer regions, the Northeast in particular. For these authors, this was an alternative in the absence of national development policies. It can be seen, however, that this alone was not enough to stimulate a competitive and specialized industrial sector in the Northeast region, for example. Ribeiro *et al.* (2018) argue that this type of policy must be associated with strategies to strengthening the production chain and develop the consumer market on a regional scale.

Figure 1 (b) shows the LISA result for the "Industrial Labor Productivity" dimension. There are few associations of the High-High clusters throughout the country. The occurrence of the Low-Low pattern is higher, mainly in the states of Rio Grande do Sul and Rondônia. This indicates that the municipalities that are part of these clusters have low added value from the industry associated with low added value per worker. The lower number of significant clusters with respect to this dimension corroborates the Moran's I result, which presented a smaller, though significant, value than the other dimensions. Therefore, the industrial added value has the most local profile.

Britto *et al.* (2015) analyzed industrial labor productivity in the Brazilian microregions in 1996 and in 2011. Their results show that the microregions of higher productivity, measured by the ratio between the industrial transformation value and employment, are concentrated in the Midwest, Southeast and South. However, they noticed that there was a reduction in the area formed by the grouping of microregions of high productivity. This space, markedly in the interior of the states of São Paulo and Paraná, was reduced between 1996 and 2011, evidencing the loss regional productivity. In spite of the use of different spatial units and variables, our results are similar to those of the above-mentioned authors, insofar as there is a relative difficulty in identifying patterns of groups of municipalities with high industrial labor productivity.

Figure 1 (c) shows the LISA of the dimension "Income and Schooling". It is easy to see the clear formation of significant spatial clusters regarding this dimension. High-High clusters cover part of the state of São Paulo, the states of the Midwest and south of Rio de Janeiro. In these locations, industrial income associated with formal jobs is higher in relative terms. Low-Low associations are also observed in the states of the Northeast and South regions and the state of Minas Gerais.

From the factor "Income and Schooling" it can be seen that the formation of groups of municipalities in the North region classified as High-High. On this, it is worth mentioning the work of Saboia and Kubrusly (2008), who studied regional and sectoral differences in Brazilian industry. The authors found that the values of workers' incomes vary greatly according to the industrial sector. For example, an average wage of R$ 5,492 was found in the oil and gas extraction sector and R$ 514 in the Clothing goods' sector. Considering only the North region, it was noticed that the average income of workers in the oil and gas extraction industry reached R$ 7,072 - the highest value observed among all regions. On the other hand, the average remuneration of workers in coal mining in the Northeast was no more than R$ 381. Still on this finding, the authors argue that the average levels of workers' wages and schooling in the North are close to those in the South. However, in relative terms, there are more technical and scientific workers in the North than in the South (Saboia and Kubrusly, 2008).

Figure 1 (d) shows the LISA of the dimension "Urban Agglomerations". This result corroborates Moran's I because it presents significant clusters with more spatial units than the last two dimensions analyzed. Basically, there is a large High-High cluster that covers almost all the state of São Paulo, South region, Zona da Mata and Minas Triangle in Minas Gerais, south and east of Goiás, north of Paraná and south of Rio de Janeiro. This was expected as in these regions there is a greater proportion of urban population and industry tends to be less specialized, i.e. more diversified. In the states of São Paulo and Rio de Janeiro, for instance, the largest urban-economic centers in the country, the average urbanization rate among its municipalities is 84%. In this line, Ying (2011) argues that the urbanization process favors the development of the services segment, which reinforces the loss of industry specialization in these locations. Moreover, the service sector tends to be concentrated in large cities (Jacobs, 1969; Noyelle and Stanback, 1983; Clark, 1985).

The results of Moran's I, analyzed in conjunction with LISA, indicate that industrial factors related to specialization/diversification tend to spread more in space. Urban agglomerations are also related to this process. On the other hand, industrial labour productivity tends to be a more local phenomenon, since it depends on the type of industrial activity developed regionally. More capital-intensive industrial activities that require more specialized and skilled labor tend to generate lower spillover effects.

Domingues and Ruiz (2006) also used LISA statistics, however, to find industrial agglomerations based on the variable used (value of the industrial transformation of firms that innovate and firms that do not innovate). Their results indicated the formation of 15 industrial agglomerations, 11 of which were in the Southeast and South regions of the country. In addition, only these agglomerations were positively associated with the agglomerations of industries that innovate. Assuming that the technological base is one of the main determinants of industrial activity, this result indicated the tendency to maintain the industrial scale of the Southeast and South regions and weaken the other regions of Brazil. An analogous result was found by Faria (2011). Significant high-high clusters, that is, municipalities that held a high proportion of the intermediate goods industry that had neighboring municipalities that also held a high proportion of the intermediate goods industry, were located mainly in the Southeast and South regions of the country. In other regions, high-low spatial associations have been identified, which indicates the existence of spatially isolated industries. The results of these studies show the contributions of this paper regarding the spatial analysis performed. Those studies performed the spatial analysis on the industrial variable of interest, not on the factors associated with industrial activity (factors) as this paper did.

5. FINAL REMARKS

The objective of this paper was to analyze the spatial pattern and concentration of industrial development in Brazilian municipalities in 2014. In order to do so, FA and LISA were used to construct synthetic indicators that capture characteristics of the industry and to verify the spatial patterns of these indicators, respectively. As argued along the work, there are special features concerning manufacturing activities on productivity and, therefore, on economic growth. Therefore, it is very important to understand its spatial pattern and concentration in Brazil because firms are more likely to gain advantages from agglomeration and specialization in the regions analyzed.

Factorial analysis generated four coherent indicators that together account for 75% of the data variance, namely: i) "Industrial specialization"; (ii) "Industrial labour productivity "; iii) "Income and schooling"; and (iv) "Urban agglomerations". Moran’s I, in turn, indicated spatial autocorrelation in all four generated indicators, which means that they have significant spatial patterns.

In general, regarding industrial specialization, LISA indicated the presence of High-High clusters in the South and Southeast regions of Brazil, whereas in the North and Northeast regions, mainly, the presence of Low-Low clusters. Except for the municipalities of the South region, where there is a Low-Low pattern in relation to the clusters formed by industrial labor productivity, it does not seem to be any other significant groups of municipalities with any pattern in the rest of Brazil.

The industrial sector in the poorer regions, therefore, does not appear to be competitive, since it has a relatively poorly educated and poorly paid labor force, which reflects low industrial labor productivity. In order to try improving this scenario, public policies should be introduced with a focus on the industrial sectors of the poorest regions. An important aspect of these policies would be, for example, programs for the continuous qualification of the workforce.

It is important to mention that this work has some limitations. The first is that the methods used in this paper do not explain the spatial patterns identified, that is, there is no causal relationship between the variables used. In an attempt to deepen this discussion, an interesting follow up of this work would be to seek to explain the causes of these patterns in space. The second limitation is that the method used is not appropriate for a dynamic analysis of the indicators. Thus, if the objective is to understand the dynamics of the Brazilian economy from the variables used, other methodologies should be used. Finally, this paper is descriptive and its main objective is to provide elements of the Brazilian economy for further studies.

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APPENDIX 1: Correlation matrix and statistic significant level

	VAB	QL	PROD	EMP	EST	REND	EDU	CE	URB	MERC
VAB	1.00									
QL	0.55	1.00								
PROD	0.69	0.14	1.00							
EMP	0.23	0.67	-0.11	1.00						
EST	0.17	0.45	-0.08	0.66	1.00					
REND	0.22	0.46	0.00	0.36	0.23	1.00				
EDU	0.10	0.22	0.03	0.12	0.06	0.38	1.00			
CE	0.29	0.04	0.20	-0.28	-0.24	-0.05	-0.01	1.00		
URB	0.13	0.37	-0.05	0.34	0.30	0.35	0.16	-0.25	1.00	
MERC	0.29	0.45	-0.01	0.51	0.43	0.35	0.18	0.01	0.02	1.00
VAB										
QL	0.000									
PROD	0.000	0.000								
EMP	0.000	0.000	0.000							
EST	0.000	0.000	0.000	0.000						
REND	0.000	0.000	0.491	0.000	0.000					
EDU	0.000	0.000	0.005	0.000	0.000	0.000				
CE	0.000	0.001	0.000	0.000	0.000	0.000	0.157			
URB	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		
MERC	0.000	0.000	0.143	0.000	0.000	0.000	0.000	0.314	0.120	

Source: Author´s own elaboration.