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The dynamics of industrial geographic distribution: evidence from Brazil (2002-2014)

A dinâmica da distribuição geográfica das indústrias: evidências para o Brasil (2002-2014)

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RESUMO: A distribuição geográfica das indústrias brasileiras mudou entre os anos de 2002 e 2014, e foi mais significativa para alguns setores específicos. Com base em Dumais et al. (2002), exploramos a dinâmica dessas mudanças através da decomposição da variação do emprego e do índice de concentração bruto estimado para as indústrias de transformação, que foram agrupadas por nível de intensidade tecnológica. Adicionalmente, investigamos a direção dos movimentos locacionais das empresas entre as microrregiões. Os resultados indicam que, entre 2002 e 2014, houve uma tendência de convergência entre a participação das microrregiões no emprego industrial., contribuindo para a desconcentração industrial no país, com a exceção do grupo das indústrias de alta tecnologia, que passou a ser mais concentrado. Componentes do ciclo de vida das indústrias, em especial., o crescimento do emprego gerado por novas indústrias em microrregiões não metropolitanas foi o principal impulsionador desta evidência. De maneira geral., as evidências obtidas são consistentes com a importância das economias de aglomeração sobre os acidentes históricos para explicar a concentração industrial no Brasil entre os anos de 2002 e 2014.
PALAVRAS-CHAVE: Concentração da indústria; decomposição da variação do emprego; mobilidade da indústria.

ABSTRACT: The geographical distribution of Brazilian industries changed between 2002 and 2014, and it was more significant for some industries. Based on Dumais et al. (2002), we explore the dynamics of these changes by a decomposition of the employment variation and concentration index for manufacturing industries grouped by technological intensity, and

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we identify the direction of the locational movements of the firms among microregions. In general., the results indicate that between 2002 and 2014, there was a trend of convergence among the microregions' participation in industrial employment, contributing to industrial deconcentration in the country, with the exception of the group of high-technology industries, which became more concentrated. Components of the life cycle of industries, especially the growth of employment generated by new industries in non-metropolitan microregions, are identified as main propelling of this evidence. In general., the results are consistent with the importance of agglomeration economies over historic accidents to explain the industrial concentration in Brazil between 2002 and 2014.
KEYWORDS: Industry concentration; decomposition of employment variation; industry mobility.
JEL Classification: R12; L60.

INTRODUCTION

The geographic distribution of manufacturing industries in Brazil has been changing significantly since the 1990s, with heterogeneity among types of industries (Saboia et al. 2014; Costa & Biderman, 2016; Rocha et al. 2019). In 1999, just 10 microregions concentrated around 44% of the country's industrial production[1], and 15 years later this participation declined to 34%. The empirical evidence indicates that although industry is still significantly concentrated in Brazil, with a Gini index[2] of 0.90, industrial activities have been passing through a process of spatial deconcentration (Resende & Willey, 2005; Lautert & Araújo, 2007; Vignandi et al. 2014; Costa & Biderman, 2016; Rocha et al., 2019). Associated with this trend, manufacturing has been losing economic importance: its share of national GDP fell by half between 1990 and 2013, from 26.54% to 13.13%[3].

A well consolidated empirical literature exists for Brazil regarding measurement of the level of industrial concentration, indicating that the country's industry is more concentrated than would have been the case if the location choices had been random (Costa & Biderman, 2016; Rocha et al. 2019). Based on the seminal contributions about the factors determining the agglomeration/dispersion of productive activity (Marshall, 1890; Krugman, 1991; Duranton & Puga, 2004; Rosenthal & Strange, 2004), advances have been achieved for the country in identifying the determinants

[1] Based on the gross added value in national gross domestic product (GDP) from Brazilian Institute of Geography and Statistics (IBGE).

[2] Gini index calculated from gross added value in municipal GDP (2015), by the IBGE.

[3] Gross domestic product (GDP) – manufacturing industry of the National Accounting System from IBGE. Consulted at: http://www.ipeadata.gov.br/Default.aspx.

of this concentration (Rocha et al. 2013; Silva & Silveira Neto, 2009; Rocha et al. 2019) and/or co-agglomeration (Rezende, 2012; Almeida et al. 2017).

Furthermore, to understand the dynamics of this process of industrial deconcentration that has been occurring in the country in parallel with the decreasing economic importance of industry at least since the 1990s (Nassif, 2008; Oreiro & Feijó, 2010; Monteiro & Lima, 2017), it is necessary to investigate whether this is a result of stronger economic growth of less industrialized cities than those of the traditional industrial belt, or if it is due to a process of spatial redistribution to midsize/small cities. In the first case, the industrial deconcentration might be a result of decreased participation in employment of the traditional industrial centers in relation to less industrialized regions, favoring an industrial convergence process. In the second case, it is possible that recent improvements in the connection among cities has resulted from investments in transport infrastructure, providing better market access to medium and small cities, among other factors (e.g., tax incentive policies). This, together with an increase of agglomeration diseconomies from large urban centers (push factors), has favored the relocation some industries to midsize/small cities.

To investigate these questions, Dumais et al. (2002) from decomposition of the variation of employment and a concentration index found that the employment generated by new industrial firms outside the traditional industrial centers favored the spatial deconcentration of industry in the United States between 1972 and 1992. But they also remarked that the closing of plants acted to favor concentration. For Brazil, Costa and Biderman (2016) repeated the decomposition proposed by Dumais et al. (2002) to analyze the dynamics of the geographic concentration of manufacturing between 1991 and 2011 and found that the employment generated by opening of new factories made industrial activity less concentrated in Brazil.

To contribute to this theme in Brazil, we conducted empirical investigation of the dynamics of the geography of industry from three dimensions, temporal., sectorial and regional. First, we examined the sources of industrial employment growth by technological intensity, since these industries can have different spatial distribution patterns and dynamics, so sources of variation can differ among them. Based on Dumais et al. (2002), we decomposed the growth rate of industrial employment into five sources: increase (j1) or decrease (j2) of employment generated by existing industries in the initial year; establishment of industries that generate new jobs (j3); loss of jobs due to closing of factories that existed in the initial year (j4); and changes in the main industrial activity (j5). Second, we analyzed evidence of the contribution of industrial mobility to explain the process of spatial distribution in Brazil. For this, all firms that moved to a new microregion were mapped to identify the direction of the relocation, if it was from a metropolitan microregion to a non-metropolitan microregion, or vice versa. This analysis was important to support the interpretation of the empirical results of decomposing the industrial concentration index. And, as proposed by Dumais et al. (2002), the gross concentration index was decomposed between the "mean reversion effect" and the "random effect" by group of technological intensity, with the objective of verifying which effect was

more relevant to explain the changes in the level of the industrial concentration in Brazil. So, we used the establishment-level microdata from the Ministry of Economy (RAIS-ME), which include all formally established industries. The study was covered the interval from 2002 to 2014, considering two sub-periods, 2002-2009 and 2009-2014.

GEOGRAPHIC DISTRIBUTION OF MANUFACTURING IN BRAZIL

The initial process of industrialization in Brazil was very concentrated, restricted to some microregions along the coast and in the South and Southeast regions of the country. Greater industrialization of other microregions only happened starting in the 1970s, which favored the deconcentration of productive activity in the country in subsequent decades. The reversal in the geographic distribution of industry was probably the result of greater regional integration, due to improved infrastructure in less industrialized regions, especially transportation. The maturation of these investments was stimulated by national and regional economic development programs, such as the Second National Development Plan (PND) (Coronel, Azevedo & Campos, 2014). Evidence indicates that this deconcentration process was characterized by relative loss of importance of industry for the economies of the traditional industrial microregions (the metropolitan areas of São Paulo, Rio de Janeiro, Porto Alegre and Belo Horizonte) to microregions that had infrastructure compatible with the industrial activity with lower production costs (Alonso & Bandeira, 1988; Crocco & Diniz, 1996; Pacheco, 1999).

However, the continuation of the industrial deconcentration process that occurred from 1970s through the end of the 1980s, notably considering its level of intensity, was not the same as what happened in the 1990s (relatively less). The 1990s was marked by the country's trade opening, and privatization of some important government-controlled companies, which served as an instrument of development policies (Biderman, 2004). Consequently, that decade saw productive restructuring of the Brazilian economy, propitious to the adoption of new technologies and management models. As a result of the increase in the productivity of capital., there was a reduction of production costs and an increase in the relevance of the "qualified labor" input for the location of industrial concerns (Coronel, Azevedo & Campos, 2014). Despite the small changes in the distribution of employment in the 1990s, Cruz and Santos (2011) found that in this period the geographic center of industrial employment shifted slightly to the central part of the country, significantly favoring states of the Midwest region. They also highlighted that the south of the state of Minas Gerais and north of the state of Paraná became more industrialized, while the participation of industry in the nation's total employment declined. In turn, Andrade and Serra (2000) demonstrated the strong relevance of the so-called Center-South Polygon with respect to the ongoing deconcentration observed in the 1990s, although this was not homogeneous within this area, because it started earlier in some regions where industry did not previously exist.

However, according to Lautert and Araújo (2007), manufacturing in Brazil became less concentrated in the 1990s, mainly for firms with less technological intensity, and this pattern continued into the 2000s (Resende & Willey, 2005; Lautert & Araujo, 2007; Vignandi et al. 2014; Costa & Biderman, 2016; Araujo et al. 2017).

For recent years, Table 1 presents the raw concentration index *(G)* for three periods (2002-2009, 2009-2014, 2002-2014) and four industrial categories grouped according to technological intensity[4]. This index is defined in the fifth section, indicating the level of concentration of industry (higher values are associated with more concentration).

The decline of the raw concentration index (14.73%) between 2002 and 2014 indicates that industry deconcentrated in this period, but this movement was limited due to the tendency of concentration of the group of industries with high technological intensity. The deconcentration observed in this period was strongly driven by changes in the spatial distribution of industries with low and medium technological intensity, which was near the average for the industrial sector as a whole. According to Pacheco (1999), these industries were subject to a stronger geographic deconcentration trend compared to industries with greater technological intensity.

Table 1: Raw concentration index by technological intensity – Brazil

Categories	Raw concentration index(G)			Growth (%)		
	2002	2009	2014	(2002-2009)	(2009-2014)	(2002-2014)
General (22)	0.0300	0.0244	0.0256	-18.83	5.06	-14.73
High (3)	0.0160	0.0190	0.0263	18.55	38.62	64.34
Medium high (5)	0.0212	0.0205	0.0170	-3.63	-16.89	-19.91
Medium (4)	0.0074	0.0057	0.0053	-23.49	-6.88	-28.75
Low (10)	0.0313	0.0233	0.0242	-25.56	3.85	-22.70

Source: Elaborated by the authors based on data from RAIS-ME (2002, 2009, 2014).

This industrial deconcentration movement was more pronounced in the first period analyzed (2002-2009), which was characterized by growing participation of the North, Northeast and Midwest regions in national industrial employment, especially in industries with low technological intensity (Saboia et al., 2008; Campolina, Rezende & Paixão, 2012; Azzoni & Sobrinho, 2014). Cruz and Santos (2011), applying spatial analysis methods, found that the geographic center of employment concentration of the country in this period shifted in the northeast direction.

However, unlike the pattern observed for the other industries, the high-technology group – which requires more qualified labor and higher research and develop-

[4] See the classification in the Appendix.

ment investments – became more concentrated between 2002 and 2009 (*G* grew by 18.55%). In this respect, Garcia, Araújo and Mascarini (2009) pointed out that in this period, the regions that attracted the most investments in sectors with high technological content were precisely those with locational advantages, such as greater concentration of qualified labor. Furthermore, the group of high-technology industries was favored by tax incentives for regional development, such as the Manaus Free Trade Zone.

Consequently, in the second period (2009-2014), there was a reversal of the industrial deconcentration trend of the previous period, with increasing concentration. This was due to the increased in the concentration of the high-tech industries (*G* grew by 38.62%) and industries of low technologic (*G* grew by 3.85%).

Therefore, to shed light on the dynamics of the changes of the concentration indexes, the sources of variation in employment and the direction of the locational movements of firms, the following analysis investigates the sources of variation of industrial employment; the direction of the locational movements of firms; and the components of the variation of the raw concentration index.

DATA

The database used included all formal establishments that exist in Brazil and that submitted the Annual List of Social Information (*Relação Anual de Informações Sociais*, or RAIS) to Ministry of Economy (ME). Every year, all formal establishments[5] are required to fill out the RAIS form[6]. The information obtained is used by the ME to oversee compliance with labor obligations, including payment of deposits into the Guarantee Fund for Time of Service (FGTS – a severance indemnity fund) and salary bonus (a yearly benefit for workers earning under a certain threshold), and is also used to keep track of social security contributions and payout of benefits. The database is important to support studies to diagnose the labor market by public authorities, and for academics for a wide range of research purposes[7]. It is the only source of nationwide data at the establishment level, with a long time series, disaggregated according to the National Classification of Economic Activities (CNAE) and to the smallest geographic level desired for analysis, based on the location of firms. In addition, through a unique identifier it is possible to follow the movements of the firms over time.

The analysis period (from 2002 to 2014) considered the years in which the microdata was available for this study. However, since a 12-year period can contain

[5] There are in the Brazil a substantial portion of informal companies that do not report information because do not pay taxes, but the majority are small and are more commonly in the service sector.

[6] For more details about the RAIS report, consult: http://www.rais.gov.br/sitio/quem_deve_declarar.jsf.

[7] Access to the database was granted to us by the Ministry of Labour (now, Ministry of Economy) upon signing a commitment to preserve data secrecy.

an atypical year, when the patterns of industrial employment differed substantially from the average for the entire period (outlier year), we conducted the analysis separately for two sub-periods, 2002 to 2009 and 2009 to 2014. The first period ended with an international economic crisis in 2008. And the second period was finalized with a recession economic followed of a political crisis which led to credit and consumption restrictions in Brazil.

The study is disaggregated by the divisions of the manufacturing industry (2 digits of CNAE code 95)[8]. This classification was chosen because the database contains information broken down according to two-digit CNAE codes for the entire period analyzed. Besides this, since manufacturing industries differ regarding technological intensity level, which may explain their different spatial distribution patterns, the analysis considered four groups of industries classified by technological intensity (see Table A1 in the Appendix) – low, medium, medium-high and high – according to the classification proposed by Cavalcante (2014) based on OECD (2011).

The geographic reference unit is the microregion (groups of municipalities[9]), since for a more disaggregated level there would be many industries without presence, which would skew the analysis. On the other hand, for a more aggregated level, such as Federation Units (26 States plus Federal District), there would be loss of information regarding the differences of the distribution of industries within of the 27 Brazilian Federation Units. Finally, microregions are an intermediate size, composed by municipalities that present similarities and inter-dependence productive, in relation to distribution of production, exchange and consumption of products and worker mobility (DGEO/DITER, 1990)[10].

REGIONAL DIFFERENCES OF THE DYNAMICS OF MANUFACTURING EMPLOYMENT

The geography of industrial distribution can change even if concentration levels remain relatively stable (Dumais et al., 2002). For example, the employment generated by new industries in less industrialized locations can only compensate, with a certain lag, the loss of jobs resulting from the closure of other industries in these locations. Thus, it is possible that the concentration level to remain stable while

[8] The category including manufacture of coke, refining of crude oil, production of nuclear fuels and alcohol (CNAE 23) was removed from the aggregated analysis because we found errors in the records of the RAIS reported by the establishments of this group.

[9] The municipality is "autonomous unit of lower hierarchy within the political-administrative organization of the Brazil" that has a representation of the executive government, the mayor. In 2014 existed in Brazil 5.570 municipality divided in 558 microregions.

[10] For more general information (in Portuguese), access http://www.ngb.ibge.gov.br/Default.aspx?pagina=divisao.

the spatial distribution patterns of industries to present changes. To investigate these questions, Dumais et al. (2002) decomposed the variation of employment into five sources: increase (j1) or decrease (j2) of employment generated by existing industries in the initial year; employment from new firms (j3); loss of jobs due to closing of companies (j4); and changes in the main industrial activity (j5). Considering there can be regional and sectoral differences among the sources of employment variation, Table 2 presents the decomposition of the employment growth for four groups of industries classified according to the technological intensity and for the two periods (2002-2009 and 2009-2014), by metropolitan microregions and non-metropolitan microregions.

Table 2: Decomposition of the growth of industrial employment by sources of variation (according to technological intensity)

Technological	2002-2009						2009-2014					
Intensity	Tx. (%)	j1	j2	j3	j4	j5	Tx. (%)	j1	j2	j3	j4	j5
Metropolitan Microregions												
Low	21.1	23.0	(14.8)	52.6	(39.7)	0.3	0.4	16.1	(14.8)	28.4	(29.3)	0.2
Medium	33.9	26.3	(11.0)	54.9	(36.3)	1.2	4.4	17.9	(13.8)	24.6	(24.2)	0.1
Medium-High	40.5	31.7	(10.0)	48.6	(29.8)	0.7	10.9	17.9	(13.0)	24.6	(18.6)	(0.1)
High	43.0	36.0	(14.8)	60.9	(39.1)	4.0	12.6	24.3	(15.9)	32.6	(28.4)	(0.1)
Industry	29.6	27.8	(13.2)	48.7	(33.6)	1.6	4.7	17.8	(14.5)	25.1	(23.7)	0.2
Non-Metropolitan Microregions												
Low	38.3	28.7	(13.9)	58.2	(34.7)	0.3	8.1	19.3	(14.9)	28.4	(24.7)	0.1
Medium	43.4	29.0	(10.4)	57.1	(32.3)	0.8	15.1	20.6	(13.2)	28.8	(21.1)	0.2
Medium-High	61.9	35.8	(9.8)	66.0	(30.0)	0.7	37.6	22.0	(11.0)	44.4	(17.8)	0.0
High	71.6	32.1	(8.3)	91.9	(44.2)	0.5	26.8	25.4	(15.4)	39.8	(22.9)	0.7
Industry	43.8	31.3	(12.9)	56.5	(31.1)	1.2	15.4	20.6	(14.1)	30.2	(21.2)	0.2

Source: Elaborated by the authors based on RAIS-ME microdata on establishments (2002; 2009; 2014).

Some generalizations can be highlighted from the decomposition statistics in Table 2. From 2002-2009 to 2009-2014, there was a tendency of declining industrial employment growth, including all technological intensity and microregions groups. However, for both periods the growth of industrial employment was greater in non-metropolitan microregions, which is consistent with the process of interiorization of industrialization in Brazil. In addition, in general., there was a positive association between the level of technological intensity and the employment growth rate of industries grouped by technological intensity. But, in Brazil, the industries of low technological intensity represent more of the half of total industrial employment (see Table A1 in Appendix).

To regard to the sources of employment growth, for both periods and microregions, the greatest contribution was from employment due to the birth of firms, which was offset by the losses generated by the closure of firms. Similar evidence was also reported by Costa and Biderman (2016) for Brazil and Dumais et al. (2002)

for the United States. Dumais et al. (2002) argued that the employment generated by the opening of new plants contributed to the industrial decentralization in the United States, while the closing of factories was a source of variation of employment, favoring concentration. From our results, we can observe that the contribution of the birth of firms to job growth was proportionality higher in non-metropolitan microregions than metropolitan microregions. The other sources of decomposition had closer values.

With respect to the decomposition by technological intensity, the highlight is the significant contribution of the employment generated by the new high-tech industries in the non-metropolitan microregions in the period of 2002 to 2009, with a weight of 91.9% on the employment growth rate (71.6%), which fell to 39.8% in the second period.

On the other hand, it is also possible that the spatial mobility of industries also contributed to the changes in geographic location. Besides this, depending on the technological intensity of industries, these movements can be more intense, in different directions (from metropolitan to non-metropolitan microregions, or vice versa). Therefore, in the two periods, 1.4% to 2% of the industrial firms changed microregion. Table 3 presents the percentage of the firms that changed of the location between non-metropolitan and metropolitan microregions (Non-MRs and MRs, respectively) by technological intensity group. In general., the results indicate that firms located in Non-MR were more mobile, and this movement was most intense among high-tech industries. In addition, the migratory flows from Non-MRs to MRs were more intense in the second period (2009-2014) and were significantly higher for high-technology industrie. (Table 3).

Table 3: Migration interaction matrix by technological intensity

Technological Intensity	Origin/ Destination	2002-2009			2009-2014		
		Non-MRs	MRs	Total	Non-MRs	MRs	Total
Low	Non-MRs	79%	21%	806	78%	22%	915
	MRs	98%	2%	275	94%	6%	251
Medium	Non-MRs	80%	20%	389	75%	25%	508
	MRs	98%	2%	244	98%	2%	164
Medium-High	Non-MRs	81%	19%	283	72%	28%	401
	MRs	97%	3%	221	99%	1%	169
High	Non-MRs	73%	27%	22	66%	34%	56
	MRs	93%	8%	40	97%	3%	29
Manufacturing Industry	Non-MRs	79%	21%	1.500	75%	25%	1.880
	MRs	97%	3%	780	97%	3%	613

Source: Elaborated by the authors based on RAIS-ME microdata on establishments (2002; 2009; 2014).

Table 4 presents the ranking of the microregions with the 10 largest and smallest migratory balances: immigrant industries (total of industries that moved from microregion j to i) less emigrant industries (total of industries that left from microregion i to j). These results show that for the 2002-2009 period, of the 10 microregions with the largest net migratory flux, nine are located in the state of São Paulo, are close to the city of São Paulo and have significant economic importance for the state. The tenth, the Itajaí microregion in Santa Catarina (SC), is a port microregion of great economic importance for the South region and includes municipalities with high HDI[11].

In the second period, in addition to the migratory balances having declined significantly regarding the first placed in the ranking, other microregions outside the state of São Paulo emerged in this ranking, although nine are still located in the Southeast Region. In addition, it should be noted that all microregions with the highest positive net balances, in both periods, except for Rio de Janeiro, are non-metropolitan microregions. These results are consistent with what has been observed in the country, the economic rise of medium-sized cities close to the country's urban centers, which have had more intense economic growth since the 1990s (Andrade & Serra, 1998; Saboia et al. 2014).

Among the microregions with the largest negative migratory balances in the two analysis periods, there is a large representation of the metropolitan microregions, with the São Paulo microregion leading the ranking (see Table 4). It is also noteworthy that the first period was marked by a greater negative migratory balance in the São Paulo microregion (-492), which may have contributed to a greater industrial deconcentration in the country, a process that started in the 1970s (Azzoni, 1986; Crocco & Diniz, 1996; Pacheco, 1999; Garcia, Araújo & Mascarini, 2009). Once again, such evidence is consistent with the loss of importance of industrial activity for the economy of the country's large urban centers, which have become more specialized on the provision of services that require greater investment in human capital and urban infrastructure.

The interaction matrix of origin and destinations in Table 5 shows that the most intense migratory flows were among the microregions of the state of São Paulo, with a distance radius that can reach up to 100 km. However, the 2002-2009 period was marked by a greater displacement of industries from the São Paulo microregion to surrounding microregions. These data only reinforce what was indicated in past decades, the industrial depolarization of the São Paulo Metropolitan Region to medium-sized cities that are close to the capital. In these microregions, like Campinas, there are important teaching and research institutions and some transport infrastructure and urban service networks compatible with industrial activities (Azzoni, 1986; Caiado, 1995; Betarelli Junior & Simões, 2011).

[11] Data about the Human Development Atlas of Brazil (PNUD) are available at: http://www.atlasbrasil.org.br/2013/pt/ranking.

Table 4: Ranking of the 10 biggest and smallest net migratory flows

Microregion	2002-2009	Microregion	2009-2014
Ranking of the 10 largest net migratory flows			
Guarulhos-SP	96	Sorocaba -SP	37
Osasco-SP	76	Campinas – SP	32
Itapecerica da Serra-SP	64	Bragança Paulista – SP	28
Jundiaí-SP	50	Rio de Janeiro – RJ	25
Sorocaba-SP	42	Jundiaí – SP	24
Mogi das Cruzes-SP	36	Divinópolis – MG	23
Campinas-SP	34	Montenegro – RG	15
Franco da Rocha-SP	32	Patrocínio – MG	14
Bragança Paulista-SP	31	São João da Boa Vista – SP	13
Itajaí-SC	11	Macaíba – RN	12
Ranking of the 10 smallest net migratory flows			
São Paulo – SP	-492	São Paulo -SP	-102
Blumenau-SC	-17	Osasco – SP	-48
Natal-RN	-12	Guarulhos – SP	-42
Fortaleza-CE	-11	Belo Horizonte -MG	-38
Juiz de Fora-MG	-11	Porto Alegre – RS	-26
Ipatinga-MG	-9	Natal – RN	-22
Divinópolis-MG	-9	Recife – PE	-16
Porto Alegre-RS	-9	Ipatinga – MG	-13
Maringá-PR	-7	Itapecerica da Serra -SP	-13

Source: Elaborated by the authors based on RAIS-ME microdata on establishments (2002; 2009; 2014).

Table 5: Ranking of the 10 largest migratory interactions (2002-2009 and 2009-2014)

Origin microregion (2002)	Destination microregion (2009)	Frequency	Origin microregion (2002)	Destination microregion (2009)	Frequency
São Paulo	Guarulhos	127	Osasco	São Paulo	92
São Paulo	Osasco	126	Guarulhos	São Paulo	80
São Paulo	Itapecerica da Serra	77	São Paulo	Osasco	55
São Paulo	Campinas	58	São Paulo	Guarulhos	54
São Paulo	Mogi das Cruzes	56	Itapecerica da Serra	São Paulo	46
São Paulo	Jundiaí	42	São Paulo	Itapecerica da Serra	45
São Paulo	Bragança Paulista	35	São Paulo	Mogi das Cruzes	43
São Paulo	Sorocaba	35	São Paulo	Campinas	42
São Paulo	Franco da Rocha	33	São Paulo	Sorocaba	33
Osasco	São Paulo –SP	31	Mogi das Cruzes	São Paulo	33

Source: Elaborated by the authors based on RAIS-ME microdata on establishments (2002; 2009; 2014).

DYNAMICS OF INDUSTRIAL CONCENTRATION

To make inferences about the dynamics of industrial concentration, Dumais et al. (2002)[12] proposed the decomposition of a simple concentration index that was well-consolidated in the literature, the raw concentration index, into two components: "mean reversion effect" and "random effect". The mean reversion effect is related to the initial level of employment in the region, and when negative indicates the existence of convergence between the shares of the regions in industrial employment: less industrialized regions, growing faster than the traditional industrial regions. In this case, industry becomes less concentrated. On the other hand, if the effect is positive, regions that for some reason (e.g., historical accident à la Krugman, 1993) have a larger stock of industrial employment in the initial period should grow faster than the average. This second situation is possible when these regions, which initially have a larger industrial sector, manage to generate self-sustained growth with circular and cumulative causation (Myrdal., 1957).

In contrast, the random effect captures the change in the level of industrial concentration due to random factors that always act in favor of concentration. In this case, regions that have industrial sectors of the same size in the initial period respond asymmetrically to random shocks and present different growth rates, straying from the mean. The random shocks (e.g., monetary policy, pandemics, wars) can asymmetrically affect the growth of regions with industrial bases of similar size, but with different productive structures (Carlino & Defina, 1999; Rocha et al. 2011). Consequently, spatial redistribution can occur in favor of more dynamic regions or those that are more specialized in the sectors that are less sensitive to changes in the basic interest rate. Furthermore, it is also possible that in periods of monetary tightening, these regions would present a lower mortality rate of industrial establishments in relation to others, which also would increase industrial concentration.

Decomposition of the raw concentration index

Assuming that the share of industry i employment in region s at time t is S_{ist} and his mean is S_{st}, by definition, the raw concentration index (G_{it}) is equivalent to the variance of S_{ist}, which indicates how far the geographic distribution of industry i is from the mean S_{st}:

$$G_{it} = \sum_s (s_{ist} - s_{st})^2 \qquad (1)$$

Where S_{ist} is the quotient between the employment of industry i in region (E_{ist}) and the total employment of i in year t (E_t); S_{st} is the mean of S_{ist} for each region s [$s_{st} = (\frac{1}{I}) \sum_i s_{ist}$], with I being equal to the number of divisions of industries. The

[12] Due to space limitations and considering the scope of the paper, we explore the decomposition of the raw concentration index from Dumais et al. (2002). For a broader analysis to Brazilian case, we recommend reading Costa and Biderman (2016), who repeated the entire decomposition proposed by Dumais et al. (2002).

higher the index is, the greater is the degree of dispersion of S_{ist} around its mean, and thus the more geographically concentrated industry *i* will be.

Dumais et al. (2002) proposed a decomposition of the raw concentration index (G_{it}) based on the estimation of equation (2) by the ordinary least square's method. According to the specification of equation (2), the variation between t+1 and t of the share of industry *i* employment in region *s* [ΔS_{it}] is a function of the its initial value [S_{ist}] and of the mean of S_{is} in *t+1* [$S_{st\ +\ 1}$], both normalized by the mean of S_{ist} [S_{st}].

$$\Delta S_{is} = S_{ist+1} - S_{ist} \ = \hat{\alpha} + \hat{\beta}\ (S_{ist} - S_{st}) + \ \hat{\gamma}\,(S_{st+1} - S_{st}) + \ \hat{\epsilon}_{ist} \qquad (2)$$

The main parameter of interest of equation (2) for the decomposition is $\hat{\beta}$, which when negative indicates that regions with a smaller participation in employment in the initial period have grown faster than the average, in line with an industrial deconcentration process. The estimated error term [$\hat{\epsilon}_{ist}$], which is orthogonal to the regressors of equation (2), is associated with the changes in the dependent variable, which are attributed to the heterogeneity of the increase of the participation of the regions in industrial employment. Furthermore, given the specification of equation (2), $\hat{\alpha}$ is equal to zero and $\hat{\gamma}$ is equal to 1.

From the definition of the raw concentration index (G_t) in (1), it is possible to specify its variation as:

$$G_{t+1} - G_t \ = \frac{1}{I}\,[\textstyle\sum_{is}(S_{ist+1} - S_{st+1})^2 - \sum_{is}(S_{ist} - S_{st})^2] \qquad (3)$$

After substituting the parameters estimated from equation (2) in equation (3), with some algebraic manipulations we obtain the decomposition of the variation of G_t proposed by Dumais et al. (2002):

$$G_{t+1} - G_t \ = \underset{\text{(I)}}{(2\hat{\beta} + \hat{\beta}^2)G_t} \ + \ \underset{\text{(II)}}{\frac{1}{I}\sum \hat{\epsilon}_{ist}{}^2} \quad (4) \qquad (4)$$

The component (*I*) is the "mean reversion effect", whose magnitude depends on the value of $\hat{\beta}$ and the raw concentration index (G_t) of the initial period. Since G_t is always positive, if the component (*I*) is negative, it means there is a process of convergence, when the regions that had lower weight in industrial employment in the initial period are growing at a faster rate than the more industrialized regions. In the contrary case, if the sign of $\hat{\beta}$ is positive, the regions with greater participation in industrial employment at *t* are growing at a faster pace than the average of the other places. The component (*II*) is always positive, acting in favor of industrial concentration.

Decomposition Results

Table 6 presents the results of decomposing the variation of the raw concentration index (*G*) – obtained by estimating equation (2) and the deterministic relation

of equation (4) – grouped according to technological intensity for the three time periods (2002-2014, 2002-2009 and 2009-2014).

Table 6: Decomposition of the variation of the raw concentration index (*G*)

Industries (Number of Divisions)	$G_{t+1} - G_t$	$\hat{\beta}$	Standard Error ($\hat{\beta}$)	Growth of *G* (I+II)	Decomposition of G (%)	
					Reversion (I)	Random (II)
			2002-2014			
Total (22)	-0.0044	-0.1870*	0.0039	-14.73	-33.96	19.23
High (3)	0.0103	0.0074	0.0196	64.34	1.47	62.87
Medium high (5)	-0.0042	-0.2501*	0.0093	-19.91	-43.81	23.91
Medium (4)	-0.0021	-0.2040*	0.0060	-28.75	-36.62	7.88
Low (10)	-0.0071	-0.1763*	0.0041	-22.70	-32.19	9.49
			2002-2009			
Total (22)	-0.0057	-0.1776*	0.0033	-18.83	-32.76	13.93
High (3)	0.0030	-0.1991*	0.0182	18.55	-34.16	52.71
Medium high (5)	-0.0008	-0.1105*	0.0078	-3.63	-19.81	16.18
Medium (4)	-0.0017	-0.1612*	0.0052	-23.49	-29.61	6.13
Low (10)	-0.0080	-0.1815*	0.0036	-25.56	-33.08	7.52
			2009-2014			
Total (22)	0.0012	-0.0306*	0.0030	5.06	-6.29	11.35
High (3)	0.0073	0.0216	0.0144	38.62	4.35	34.27
Medium high (5)	-0.0035	-0.1521*	0.0064	-16.89	-28.41	11.52
Medium (4)	-0.0004	-0.0640*	0.0050	-6.88	-12.38	5.50
Low (10)	0.0009	-0.0003	0.0027	3.85	-0.06	3.91

Source: Elaborated by the authors based on RAIS-ME data (2002 to 2014). Note: Coefficients are statistically significant at under 5%.

Manufacturing Industry

For the period between 2002 and 2014, the raw concentration index fell by approximately 15%, indicating that this period was marked by industrial deconcentration. These results corroborate previous empirical evidence obtained in recent decades for Brazil, showing the tendency for manufacturing to become more evenly distributed among the country's microregions (Resende & Willey, 2005; Lautert & Araujo, 2007; Vignandi et al. 2014; Costa & Biderman, 2016; Araujo et al. 2017). In support of the decomposition of the variation of the raw concentration index (*G*) for this period, note that the mean reversion/convergence effect (-33.96%) exceeded the random effect (19.33%): industry in the country became less concentrated because the employment from less industrialized microregions grew faster in relation the national average. However, this effect was counterbalanced by the random factors, which acted in favor of greater concentration. Dumais et al. (2002)

found similar evidence for the United States and contended that the results were inconsistent with arguments that associate the formation of industrial clusters with historical accidents. Likewise, Barrios and Strobl (2004), studying the countries of the European Union, observed that the changes in the levels of concentration between 1972 and 1995 were a response to the random effect, which made industry more concentrated, outweighing the mean reversion effect.

However, there were differences in the change of the pattern of industrial geographic distribution in Brazil between the two periods analyzed. In 2002-2009, manufacturing became less concentrated in the country (G) fell by nearly 18.83%), and the negative value of $\hat{\beta}$ (-0.178), statistically significant, corroborates the importance of the contribution of the mean reversion effect (32.76%) on the reduced the concentration index. But this effect was once again partly counterbalanced by the random effect, which contributed to increase G (13.93%).

The results obtained here for manufacturing are in line with the previous evidence obtained by Costa and Biderman (2016) for Brazil in the period from 1991 to 2011: the mean reversion effect acted in the direction of deconcentration, when less industrialized regions in the initial period grew faster than the national average.

However, new and different evidence was obtained for the second interval (2009--2014): even with the mean reversion effect acting to reduce the concentration index, industry became slightly more concentrated in Brazil, with a slight increase of G (5%). And this increase resulted from the predominance of the random effect (11.35%) over the reversion effect (-6.29%), with the former effect having almost twice the magnitude.

Despite these results, we stress that the dividing line in the two periods was marked by the start of a global economic crisis, beginning in 2008 in the United States, and by changes in the performance of the Brazilian economy. The year 2009 was noteworthy for a decline of 0.3 percentage point[13] in the country's GDP growth, which fell to the lowest level since 1992. According to Oreiro and Feijó (2010), the industrial trade deficit increased between 2004 and 2009. According to Barbosa Filho and Pessoa (2014), this downturn in Brazil's economy was the result of lower total factor productivity in the country, speciality from capital. Further according to the authors, this was due more to changes in the internal economic policies adopted in this period than to external factors. In fact, Fligenspan (2019) showed that between 2007 and 2014, the industrial productivity reached one of its lowest levels in 2009.

The fall of the productive importance of industry in the Brazilian economy in the decade of 2010, together with the different results of decomposing the concentration index for the two periods (2002-2009 and 2009-2014), suggest that periods

[13] Sources: IBGE, Directorate of Research, Coordination of National Accounts and Coordination of Population and Social Indicators. https://ww2.ibge.gov.br/english/estatistica/economia/contas regionais/2009/comentarios.pdf.

of economic crisis – leading to constraints in the capital market – disfavor less industrialized microregions, because they probably have lower productivity of labor and capital in relation to traditional industrial centers. Therefore, industry should be more concentrated when fewer firms are opened, since it is the main source of growth of industrial employment in Brazilian microregions, which is relatively more important to non-metropolitan regions.

Although it is beyond the scope of this study, this issue deserves to be explored in future research, since economic crises with negative consequences on the job market, like the COVID-19 pandemic, can affect the geography and concentration of industry in Brazil.

Results by technological intensity

The results of the decomposition for the industrial subsamples (Table 6), classified according to technological intensity, indicate that the high-technology group differed from the pattern observed for the other groups. This group, unlike the others, tended to become more concentrated (*G*) increased by 64.34%) between 2002 and 2014, and the random component (accounting for 62.87% of the variation of (*G*) was preponderant in this process. Furthermore, the estimate of $\hat{\beta}$ was not significant at under 5%. These results indicate that for this group of industrial firms, the mean reversion effect had a non-significant contribution to the variation of *G*, and therefore no conclusions can be drawn about this effect. The other industrial groups became less concentrated due to the mean reversion effect to the variation of *G*. These results are in line with the productive characteristics of Brazil, where only a few microregions – located mainly in the Southeast region and along the coastline – have the technological and educational infrastructure compatible with development of technology-intensive activities, besides concentrating a significant portion of the specialized labor force with high human capital.

Comparison of the results between the two periods shows that the decline of the raw concentration index between 2002 and 2009 was a result of the deconcentration movement of low, medium, and medium-high technological intensity industries too. The high-tech industries were the exception, becoming more concentrated in this period (the raw concentration index increased by 18.55%). However, the mean reversion effect acted to favor of lesser spatial dispersion for all industrial groups in this period, indicating to a process of convergence among the shares of the microregions in industrial employment. Nevertheless, the random effect for the high-tech group more than offset the negative effect of the mean reversion component, with a contribution of 52.71% in the percentual variation of the raw concentration index.

In the second period (2009-2014), the set of high-technology industries became more concentrated (*G*) increased by 38.62%) and, in lesser magnitude, the low-technology industries (*G*) increased by 3.85%), reversing the trend for industrial

deconcentration observed in the preceding period. These results were due to "random effect", because the "mean reversion effect" was not statistically significant at 5% for both set of industry.

This result reflects those obtained in the previously section. For the high-technological industries: the employment generated by new firms in non-metropolitan microregions dropped considerably (between 2002 and 2009 represented 92% of the growth of employment and pass to 40% in 2009-2014), together with the increase in the migratory movement of firms from non-MRs to MRs microregions, probably contributed to the increase of the concentration of the high-technology industries. And, for the low-technological industries: practically the level of employment remained stable in the metropolitan microregions in relation to the previous period, and the employment generated by pre-existence industries in non-metropolitan microregion was more important than to metropolitan microregions. About to the group of low-technology industries, it is also an important case to be better explored in future research, since it considers industries of great importance for the economy of non-metropolitan microregion, as Food and Textile Industries.

With respect to the role of the mean reversion effect to explain the dynamics of industrial concentration in Brazil, the results reported here are similar to those obtained by Dumais et al. (2002) and Barrios and Strobl (2004), both finding that the mean reversion component is negative for most industries. In the United States, Dumas et al. (2002) obtained evidence of that industry was undergoing process of the deconcentration since the 1970s, and the birth firms outside the traditional industrial centers was contributing to this movement. Consequently, the decomposition of raw concentration in the U.S. indicated that the reversion effect was much stronger and offset the random effect, except in the textile & apparel industry, which became more concentrated between 1972 and 1992. On the other hand, the results of Barrios and Strobl (2004) for manufacturing in the European Union, from region-level gross value added (GVA) data, indicated that industry became more concentrated between 1980 and 1995, with dominance of the random effect.

In general., this evidence weakens the arguments in favor of dominance of the historical accidents to explain the level of industrial concentration, provided that the negative effective of the mean reversion is consistent with the process of industrial deconcentration.

CONCLUSION

This article presents an analysis of the dynamics of the distribution of manufacturing in Brazil, considering three dimensions: temporal., sectorial and regional. From the microdata of the RAIS-ME it was possible to: (i) decompose the variation

of industrial employment; (ii) analyze migratory flows (origin-destination) of firms; and (iii) decompose the variation of the raw concentration index proposed by Dumais et al. (2002). The analysis was broken down by technological intensity of the industries and two sub-periods (2002-2009 and 2009-2014).

From our results, four main conclusions stand out. First, although there was a trend for industrial deconcentration, the high technology manufacturing remained significantly concentrated in Brazil. Second, this tendency to deconcentration in Brazil was interrupted between 2009 and 2014, a period of economic crisis and drop in the growth rate of industrial employment. Third, except for the group of high-technology industries, from 2002 and 2014, the changes in the pattern of industrial distribution resulted more from the mean reversion effect than the random effect. This result indicates that the ascension of less industrialized microregions contributed to the tendency for industrial deconcentration in Brazil, partly, due to the employment generated by new firms from outside traditional industrial centers. And fourth, industries that rely more on technological resources tended to be more concentrated, and the mean reversion effect lost importance to explain changes in the concentration levels, relative to the other industries. This result indicates that the economies of agglomeration generated by spatially concentrated industries in industrial centers were more important to explain the locational choices of high-technology industries.

Among proposals for future studies, a natural continuation of this investigation would be to expand the analysis of the decomposition of the raw concentration index to more disaggregated geographic and sectorial scales. Besides this, given the scarcity of empirical studies in Brazil about firm's mobility, it would be enlightening to investigate the impact of the migration of firms and the tax incentive policies on the location of industries.

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APPENDIX

Table A1: Participation (%) of industries in employment according to technological intensity

CNAE	Description	Intensity	Manufacturing Employment (%)	
			2002-2009	2009-2014
		Low	54.52	51.61
15	Manufacture of food and beverage products	Low	40.30	41.17
16	Manufacture of tobacco products	Low	0.41	0.34
17	Manufacture of textile products	Low	8.64	8.09
18	Manufacture of clothing and accessories	Low	16.50	16.40
19	Preparation of leather and manufacture of leather goods, travel articles and footwear	Low	10.06	9.18
20	Manufacture of woos products	Low	5.03	4.66
21	Manufacture of pulp, paper and paper products	Low	4.26	4.55
22	Editing, printing and reproduction of recordings	Low	5.94	5.52
36	Manufacture of furniture and diverse products	Low	8.13	9.25
37	Recycling	Low	0.71	0.84
		Medium	21.29	21.24
25	Manufacture of rubber and plastic articles	Medium	27.71	27.29
26	Manufacture of non-metallic mineral products	Medium	24.67	27.14
27	Basic metallurgy	Medium	15.39	14.19
28	Manufacture of metal products, except for machinery and equipment	Medium	32.24	31.39
		Medium High	21.61	24.41
24	Manufacture of chemical products	Medium High	23.70	27.36
29	Manufacture of machinery and equipment	Medium High	30.21	30.38
31	Manufacture of electrical machines, apparatuses and materials	Medium High	12.29	11.45
34	Manufacture and assembly of automotive vehicles	Medium High	27.40	23.73
35	Manufacture of other transportation equipment	Medium High	6.40	7.08
		High	2.58	2.75
30	Manufacture of office machines and informatics equipment	High	22.75	21.90
32	Manufacture of electronic material and communication apparatuses and equipment	High	42.81	38.94
33	Manufacture of medical-hospital equipment and precision instruments	High	34.44	39.17

Source: RAIS-ME.