ECONOMIES OF AGGLOMERATION AND THEIR RELATION WITH INDUSTRIAL PRODUCTIVITY IN BRAZILIAN MUNICIPALITIES [1]

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Resumo: Este artigo teve como objetivos analisar os efeitos das economias de aglomeração (efeitos de localização e de urbanização) na produtividade industrial dos municípios brasileiros entre 2010 e 2017, identificando seus possíveis efeitos de transbordamento para a vizinhança, numa abordagem geral e também para grupos de regiões. Além disso, analisou-se separadamente os efeitos das economias de localização da indústria de alta/média-alta e da baixa/média-baixa tecnologia na produtividade. Para isso, construiu-se um índice de desenvolvimento da indústria como proxy para a produtividade e as estimativas foram efetuadas por painel dinâmico espacial. Como corolário, houve aumento da produtividade ao longo dos municípios brasileiros, com um processo de homogeneização espacial. Identificou-se efeitos das economias de especialização para o Brasil como um todo, especialmente da indústria menos intensa em tecnologia. Quando se analisou por regiões, predominou os efeitos de especialização no Sul/Sudeste e efeitos de diversificação no Norte/Nordeste/Centro-Oeste.
Palavras-chave: Economias de aglomeração; especialização; diversificação; painel dinâmico espacial.

Abstract: This paper aimed at analyzing the effects of economies of agglomeration (location and urbanization effects) on the industrial productivity of Brazilian municipalities between 2010 and 2017, identifying their possible spillover effects on the neighbourhood as a general and also regarding regional groups. In addition, the effects of location economies of the high/medium-high and low/medium-low technology on productivity. To achieve the aims proposed, an index of industrial development was built as a proxy for the productivity and estimates were calculated using the spatial dynamic panel. As a results, increase in productivity was seen in the Brazilian municipalities along with a spatial homogenization process. The effects of specialization economies were identified in the country as whole, mainly in the industry with less intense technology. When regions were analyzed, the effects of specialization outstood in South/Southeast, while the diversification effects prevailed in the North/Northeast/Center-West.
Keywords: Economies of agglomeration; specialization; diversification; spatial dynamic panel.

Classification JEL: R1

ÁREA TEMÁTICA: Localização e concentração das atividades econômicas

[1] This paper is part of the project “Productive agglomerations in Brazilian municipalities and their relationship with industrial productivity”, funded by the *Conselho Nacional de Desenvolvimento Científico e Tecnológico* (CNPQ) (National Council for the Scientific and Technological Development).
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1 INTRODUCTION

When certain region increases its competitiveness, its economic results are accelerated, intensifying the demand for its goods and services. Productive agglomerates show characteristics that promote such regional efficiency. Theoretically, the direct or spatial contact between industries tend to produce knowledge spillovers that either directly or indirectly affect productivity. In addition, when there is a concentration of firms, centripetal forces act attracting qualified workforce, specialized services, infrastructure, etc. These elements lead to the efficiency of the productive activities in a cumulative process (Wheaton e Lewis, 2002).

The economies of agglomeration basically derive from two categories: location or specialization economies, resulting from the concentration of similar economic activities in the same space, and; urbanization or diversification economies, with the centralization of firms belonging to different industries.

Location economies originate from the increase in the production scale, resulting from the geographical concentration of firms of the same industry. They are economies external to the firm and internal to the industry, whose increase in the productivity of factors results from the specialization gains (hereinafter referred to as specialization economies) Marshall (1890) highlights three sources of these externalities: concentration of qualified workforce, promoting collective learning processes; centralization of services, with inter-sectorial chain and, technological spillovers, which create an industrial innovative atmosphere, leading to more efficient technological and organizational combinations with intra-industry technological spillovers.

The higher the concentration of firms of the same industry is in a certain space, the higher the attraction of specialized workforce available for them tends to be, increasing industrial efficiency and the lower the global costs of each company are, due to the proximity between the industry links, also presenting locally a significant offer of specialized services. Another factor is the creation of an industrial atmosphere that tends to lead to more efficient technological and organizational combinations, with technological spillovers to the firms concentrated in such space. The hypothesis is that these externalities attract new firms, intensifying even more the spatial concentration and improving the productivity of all activities in those locations.

Regarding diversification economies, the increase in productivity comes from the availability of public goods and specialized services (in the organizational, technological and financial fields as well as in transportation, entrepreneurial qualification, etc.), associated to the existence of a large consumer market. In addition, an incubator of productive factors might be created in the region, as an extensive and qualified job market, making university and business education available, as well as research centers. Another hypothesis is that the knowledge spillover transfer between firms of different industries might optimize the diversity of ideas, contributing to an increase in the productivity all over that space.

In this conception, urban concentration would be responsible for the generation of innovations, favoring the exchange of abilities between the different actors, as a consequence of the proximity of several sources of knowledge. This would generate knowledge spilloves, which would impact the regional productivity.

Although theoretically both types of economy of agglomeration impact local efficiency, empirically there is no consensus regarding which type of externality would more intensely affect regional productivity. Glaeser et al. (1992) tested the effects of urbanization and location economies on the local growth of American municipalities between 1956 and 1987, and concluded that knowledge externalities tend to be stronger between firms of diverse industries rather than those in the same industry.

Likewise, Usai and Paci (2003), when evaluating the role of a set of variables in the process of local agglomeration of economic activities and the local growth in Italy in the period 1991-1996, found solid evidence of the positive influence of diversification externalities, and a negative impact of location externalities.

Henderson (1999) analyzed the effect of urbanization and location economies in the USA productivity – with data collected in industrial plants between 1972 and 1992 – and identified a positive effect only in location economies. The author justifies that the firms of the same industry can take advantage of a greater magnitude of industrial activity scale, capturing their externalities strongly and creating a cumulative process. When investigating the effects of past environments (five years before), he found strong impact, mainly in the high technology industry. Also, that author identified that this industry presents economies of larger local external scale and more agglomerates than traditional industries.

Nakamura (1985), when analyzing the relative effect of location and urbanization economies on the productivity in Japan, found out that if the scale of an industry doubles, a 4.5% increase is likely to occur in its productivity, signalling more robust effects of location economies than those of the urbanization economies.

Thus, there is no consensus in the understanding of the relation of agglomerates with regional competitiveness. At a national level, this gap tends to be even larger, with studies addressing the causes and effects of agglomerations in the economy dynamics, however, very few focusing its impact on the regional productivity.

This article addresses exactly this context aiming at analyzing the effect of economies of agglomeration (location and urbanization effects) on the industrial productivity of Brazilian municipalities between 2010 and 2017, identifying their possible spillover effects on the neighbourhood, analyzing separately the effects of location of high/medium-high and low/medium-low technology on productivity. In addition, since productive heterogeneity is seen along the country, the same estimates were calculated for the Brazilian regions: North/Northeast/Center-West and South/Southeast.

Four points differentiate this article from other papers in the area. First, national investigations use salary as a proxy for productivity, while here an index of industry development was built aggregating different variables according to the methodology applied by Sabóia and Kubrusly (2008).

Second, the differentiated effect of types of specialization on productivity was analyzed. In other words, the number of existing agglomerates in each municipality was identified regarding their technological level (high/medium-high technology and low/medium-low technology) and their impact on the regional productivity. The purpose was to investigate whether industrial agglomerates that are more intense in technology generate a higher regional productivity effect than that generated by agglomerates with lower levels of technology. The hypothesis is that higher technology industrial concentration generates a more innovative atmosphere, with more dynamic externalities between the firms. No investigation with this focus was found when national studies were surveyed, and at an international level, only Henderson (1999) approached this focus.

The third point refers to the methodology employed for the estimates, using the spatial dynamic panel, controlling the structural heterogeneity via fixed effects to identify their cumulative effect on the local productivity performance and its externality to the neighborhood. Finally, other studies approaching this theme usually present estimates within the segments of the productive activity, analyzing the impact of externalities of agglomeration on individual segments. The objective of this study is to analyze the effects of economies of agglomeration on the general productivity of the municipality since, theoretically, both diversification and specialization economies would have some potential to affect productivity.

This paper is divided into four sections including the introduction. The second section presents the methodology and the theoretical model used as well as the empirical strategy employed. The analysis is presented in the third section and the final considerations in the fourth section.

2. Methodology

Bearing in mind the objective of investigating the effect of economies of agglomeration on the productivity of Brazilian municipalities between 2010 and 2017, an index of the transformation industry development was built (*proxy* for productivity) and the effects of economies of agglomeration on productivity were measured using the spatial dynamic panel. Such impact was tested using the theoretical model by Klein and Crafts (2015) as presented in the following sub-sections, presenting estimates for the country as a whole and also for specific regions of the country, due to the heterogeneities identified in the development of the study.

2.1 Productivity and Economies of Agglomeration: Theoretical Model

In the model proposed by Klein and Crafts (2015) the industrial productivity growth in a region is directly related to the sectorial specialization and the existing level of inter-sectorial diversification. With this purpose, they admit the incorporation of agglomeration spillovers within and through the industry. From the Cobb-Douglas production function, the authors considered an industry in the sector **s** in a municipality **c**, as presented in (1).

$$y_{cst} = A_{cst} l_{cst}^{\mu} k_{cst}^{1-\mu} \qquad (1)$$

Where: **A** is the technological level; **l** is the work, **k** is the number of other inputs; **t** is time, and; **y** is the amount produced by the municipality **c**.

Profit is expressed as:

$$\pi_{cst} = \sum_c p_{cst}\, y_{cst} - w_{st} l_{cst} - r_{st} k_{cst} \qquad (2)$$

Where: **p** is the price; **w** is salary and, **r** is the cost of other inputs.

Assuming that $p_{st} = \sum_c p_{cst} \, {}^{y_{cst}}/_{y_{st}}$, then (2) could be rewritten as:

$$\pi_{cst} = p_{st} y_{st} - w_{st} l_{cst} - r_{st} k_{cst} \qquad (3)$$

Therefore, $p_{st} y_{st}$ is the aggregated value of the sector, since the costs of intermediate inputs is discounted from the unitary value of the goods produced. By applying the first order condition to (1), the work mean productivity appears as the aggregated value per worker:

$$\frac{p_{st} y_{st}}{l_{cst}} - (1-\mu)^{(1-\frac{\mu}{\mu})} \left(\frac{p_{st}{}^{1-\mu} A_{cst}}{r_{st}^{1-\mu}} \right)^{1/\mu} \qquad (4)$$

Klein and Crafts (2015) also considered that the technology growth rate is given by (5).

$$ln\left(\frac{A_{cs\,t+m}}{A_{cst}}\right) \equiv E_{cst} \qquad (5)$$

Where: **E** is the number of *spillovers* found in industry **s** of the municipality **c**.

Since in theoretical approaches to agglomerations there is no functional way to link the technology growth rate to the externality of agglomerations, those authors assumed that E_{cst} is a linear function of the location/specialization economies (also called *marshallians*) and the urbanization/diversification economies (also known as *jacobians*). Thus, through (5), they derived the growth rate of the industry aggregated value per worker (*proxy* for productivity) as a function of technology growth. They also transformed equation (4) by applying the logarithm, expressing for the period *t+m*, and connecting both equations, according to (6).

$$ln\frac{VapW_{cs\,t+m}}{VapW_{cs\,t}} = \frac{1}{\mu} E_{cst} + \left(\frac{1-\mu}{\mu}\right)\left[\left(ln\frac{p_{s\,t+m}}{p_{s\,t}}\right) - \left(ln\frac{r_{s\,t+m}}{r_{s\,t}}\right)\right] \qquad (6)$$

Where: $VapW$ is the value added per worker.

Using (6) one can infer that the growth rate of the value added per worker depends on specialization economies (Marshallian externalities), urbanization economies (Jacobian) and on the difference between the production cost and the input cost. Also, Marshallian externalities are captured by the degree of specialization, while the Jacobians by the degree of variety of the industrial sector outside sector **s** in the municipality **c**.

From these theoretical models, Klein and Crafts (2015) determined the regression equation as represented by (7).

$$ln\frac{VapW_{cs\,t+m}}{VapW_{cs\,t}} = \alpha + \beta_1 Marshaliana_{cst} + \beta_2 Jacobiana_{cst} + \beta_3 X_{cst} + \theta_s + \gamma_c + \varepsilon_{cs} \quad (7)$$

Where: X_{cst} refers to the vector of the control variables; θ_sé is a vector of *dummies* to control the input and product prices at the industrial level; γ_c refers to a vector of *dummies* to control any non-observable effect in the municipality.

Klein and Crafts (2015) applied the model (7) for the municipalities of the United States between 1880 and 1930. As a corollary, they found a positive effect that was statistically significant for the Marshallian externality, demonstrating how important the industry specialization is for increase in productivity. However, regarding the Jacobian, the impact occurred only in some years, showing it as inversely related to productivity. Thus, those authors reformulated (7), considering a quadratic function for the Jacobian externality, assuming the existence of diseconomies of agglomeration. With such procedures, for some periods, they captured a negative initial effect which was turned positive as the municipality developed. Therefore, the empirical evidence put forward by Klein and Crafts (2015) demonstrated that, regarding the Marshallian externality, it always affects productivity positively, while the Jacobina's impact depends on the size of the municipality.

2.2 Industry Development index (IDI)

In the model by Klein and Crafts (2015), productivity was measured through the value added per worker. In Brazilian studies, the mean salary is usually used as a determining factor for productivity. For example, Dalberto and Statuto (2013) investigated the influence of economies of agglomeration on the Brazilian industry salaries between 2001 and 2010. Likewise, Galinari et al (2007) investigated the effect of economies of agglomeration in the Brazilian industry salaries in the 1990s. Amarante and Silva (2016) analyzed Brazilian municipalities between 2000 and 2009 and tested economies of agglomeration on the mean industry salary in the country. That is, the municipal investigations carried out in Brazil basically used the worker's mean salary as a proxy for productivity.

This paper proposes a methodological advancement, by using an industrial development index (IDI) devised by Sabóia and Kubrusly (2008). Those authors assumed that the most productive segments pay the best salaries, employ better educated workforce and present the highest percentage of technical and scientific workers. Those authors used these indicators for being available in relation to smaller spatial disaggregation such as municipalities. They recognize, however, that they are not result indicators. Aiming at demonstrating that, even not being result indicators, they might represent the productivity of a sector/region, Sabóia and Kubrusly (2008) calculated the productivity for Brazilian regions through the division of the industrial transformation value and the personnel employed and then compared the results obtained with the IDI that they had devised. As a result, they found a positive and statistically significant association (correlation that ranged between 0.71 and 0.84), demonstrating the robustness of the index they had built, inferring that it could represent the sectorial/regional productivity.

Therefore, this paper proposes the calculation of the IDI of Brazilian municipalities (8) using it as a proxy for productivity. It seems relevant to highlight that all information needed for the construction of these indicators were collected from the Rais (CNAE 2 digits).

$$IDI_{i,t} = \phi ESC_{i,t} + \phi SAL_{i,t} + \phi OT_{i,t} \quad (8)$$

Where: ***IDI*** refers to the industry development index; ***ESC*** is the mean schooling in the industry; ***SAL*** refers to the industry mean salary, deflated by INPC; ***OT*** is the percentage of technical and scientific jobs; *i* is the municipality; ***t*** is time; ϕ refes to the weight.

The weight (ϕ) of each of the indicators in (8) was obtained through the principal component analysis. Following the methodology proposed by Crocco et al. (2006), for the construction of the weights in (8) the values of the components will not be used, but the results prior to the principal component analysis will throughout the following phases:

a) Obtaining the eigenvalues of the correlation matrix, via the principal component analysis (PCA). Each one provides an explanation in the variance, highlighting that the sum of betas corresponds to the total variance of components and, therefore, to the total variance of the indicators selected.
b) Recalculating the eigenvalues of the correlation matrix, seeking to find the relative participation of each of the elements in each of the components. Firstly, each eigenvalue is adopted in a modulus and divided by the sum of absolute eigenvalues of its component, obtaining its participation in the corresponding component.

c) Building weights through the multipliation of the relative participation of the indicators in the components with the variation characterized by the component. The sum provides the weight of each indicator.

Teh sum of weights $\phi_1 + \phi_2 + \phi_3$ is equal “one”, which creates a linear combination of the properly standardized indicators (Appendix A presents the weights of each of the indicators in (8)).

2.3 Empirical model, source of data and parameter calculation strategy

In the analysis of the existing relationship between externalities of agglomeration and the productivity of Brazilian municipalities, the Klein and Crafts’ (2015) model was used. In this model, the growth of the industrial productivity in a region is directly related to the sectorial specialization and the level of inter-sectorial diversification. Bearing that in mind, the incorporation of spillovers of agglomeration is admitted within and through the industry. In such hypothesis, the productivity growth rate in each sector depends on the effects of specialization externalities and sectorial diversification.

Regarding this paper, the model by Klein and Crafts (2015) was estimated for the industry in general and for each technological level. For the industry in general, (11) was estimated presenting the explaining variables that follow:

1) **Hirschman-Herfindal Index** (9), representing urbanization economies.

$$HH_i = \sum_{j=1}^{n} \left[\left(\frac{E_{ij}}{E_i} \right) - \left(\frac{E_j}{E_p} \right) \right]^2 \quad (9)$$

Where: **HH** is the Hirschman-Herfindal Index; $\boldsymbol{E_{ij}}$ is the employment in the municipality **i** employment in the sector **j**; $\boldsymbol{E_i}$ is the total employment in the industry in the municipality **i**; $\boldsymbol{E_j}$ refers to the total employment in the sector in the country **j**; $\boldsymbol{E_p}$ is the total employment in the industry in Brazil; **n** are all industrial sectors. The closer the **HH** value is to “2”, the more concentrated the industrial sector is. Since we sought to measure the diversification effect, the HH value was subtracted from the unit and was named modified HH (HH*), so that the higher its value is, the greater the productive diversification in the municipality is.

2) Square modified Hirschman-Herfindal Index, seeking to measure the effects of diseconomies of agglomeration, as inferred by Klein and Crafts (2015).

3) Number of specialized agglomerates, as a *proxy* of specialization economies. The productive activity **j** will be considered specialized in the municipality **i** if it presents three characteristics: locational quotient (10) higher than one; three or more companies in the activity **j**, e; and 0.05% concentration or over of the total employment in the industry (in Brazil) in segment **j** [according to the methodology by Suzigan et al. (2003), adapted to the municipal level by Zissimos (2007)[3]]. The sum of how many specialized productive activities there are in the municipality resulted in this variable.

$$QL_{ij} = \left[\left(\frac{E_{ij}}{E_i}\right) / \left(\frac{E_j}{E_p}\right)\right] \quad (10)$$

4) Industrial concentration, evidencing the density and scale of the industrial activity in each municipality. This variable was used in other studies, such as Galinari et al. (2007), Lira (2015), among others, included as a control variable in the estimates. It was measured through the participation of the local employment in the industry in relation to the total employment in the Brazilian industry.

Therefore, from these variables, the impact of economies of agglomeration on the Brazilian municipalities was estimated using (11).

$$\frac{IDI_{i,t+1}}{IDI_{i,t}} = \beta_0 + \beta_1 CI_{it} + \beta_2 HH^*{}_{it} + \beta_3 HH^*{}_{it}{}^2 + \beta_4 AE_{it} + \varepsilon \qquad (11)$$

Where: **IDI** is the productive activity development index in the municipality **i**, *proxy* for productivity; **CI** is the industrial concentration; **HH*** refers to the modified Hirschman-Herfindal index; **AE** is the number of specialized agglomerates in each municipality **i**; **t** is the year; **T** is the number of years in the interval.

Aiming at identifying whether there are differences of effect of productive specializations resulting from the technological differences between the industries, (11) was recalculated sub-dividing AE into two variables: AE_{alta} (number of specialized agglomerations in the high and medium-high technology); AE_{baixa} (number of specialized agglomerations in the low and medium-low technology)[4]. Therefore, the second estimates were obtained using (12)

$$\frac{IDI_{i,t+1}}{IDI_{i,t}} = \beta_0 + \beta_1 CI_{it} + \beta_2 HH^*{}_{it} + \beta_3 HH^*{}_{it}{}^2 + \beta_4 AE_{alta,i,t} + \beta_4 AE_{baixa,i,t} + \varepsilon \qquad (12)$$

[3] Zissimos (2007) adapted the methodology by Suzigan et al (2003) for having analyzed a smaller spatial unit, referring to municipalities in the State of Rio de Janeiro. In this paper, the adaptation was used for being analyzing all Brazilian municipalities.

[4] The classification by Furtado and Carvalho (2005) was considered: high technological intensity (aeroespacial; pharmaceutical; computing; electronics and telecommunication sectors); medium-high technological intensity (electrical material; automobile; chemical, excluding the pharmaceutical sector; railway and transportation equipment; machinery and equipment sectors); medium low technological intensity (naval construction; rubber and plastic products; oil coke, petroleum processing and nuclear fuel; other non-metallic product; basic metallurgy and metallic product sectors); low technological intensity (other sectors and recycling; wood, paper and cellulose; editorial and graphic; food, beverages and cigarettes; textile and clothes manufacture, leather and shoes manufacture sectors); non-industrial products (live animals; live plants and flower products; fruit, citric fruit skin and mellon; cereal; in natura product; art works, collection and antiques; special transaction sectors; etc).

Where: **IDI** is the industry development index; **CI** is the industrial concentration; **HH*** refers to the modified Hirschman-Herfindal index; **AE** is the number of specialized agglomerates in each municipality **i** in the technological segment of **high** technology (high and medium-high technology) and **low** technology (medium-low and low technology); **t** is the year; **T** is the number of years in the interval.

It seems relevant to emphasize that model (12), in addition to being estimated for the country (Brazil) was also estimated for the different regions of the country, resulting from the productivity spatiality. Therefore, a regression was obtained for South/Southeast and another for North/Northeast/Center-West.

The empirical strategy to estimate (11) and (12) was the use of spatial dynamic model of panel data using the estimated *system Gmm* (13), a method that results from an extension of the original estimator by Arellano-Bond (1991), proposed by Arellano-Bover (1995) and developed by Blundell-Bond (1998), in which the determining effects of the municipal productivity growth were captured, as well as the productivity spatial spillovers. In this way a spatial-temporal model is specified (Anselin, Le Gallo and Jayete, 2008), in which local externalities are admitted to affect the efficiency growth, that the current productivity influences the future one, and that there are productivity externalities that overcome geographical limits of a given municipality and affect the competitiveness of the neighboring areas.

Thus the estimation in spatial dynamic panel seems to be important when the purpose is to control the heterogeneity not observed in Brazilian regions which is invariant of time, spatial spillover and the productivity path dependence character[5].

$$txIDI_{i,t} = b_0 + b_1 txIDI_{i,t-1} + \rho\, W\ txIDI_{i,t} + b_2 Z_{i,t} + b_3 W\ Z_{i,t} + b_4 D_t + \alpha_i + \varepsilon_{i,t} \quad (13)$$

Where: **txIDI** is the productivity growth rate; **W** is the matrix of spatial weights; **Z** representes the set of explaining variables of (11) and (12); **D** are annual dummy variables, aiming at capturing the temporal effects common to all municipalities; $\boldsymbol{\alpha_i}$ refers to the non-observable effect in the municipality **i**; $\boldsymbol{\varepsilon_{i,t}}$ is the idiosyncratic error, independently and identically distributed , with zero mean and variance, of municipality **i** in time **t**.

If (13) is estimated using traditional techniques, some bias resulting from simultaneity might occur. A way of eliminating this problem would be an estimation using the generalized method of moments (GMM), which eliminates the fixed effects through the first difference of (13). The endogeneity would be controlled through the instrumental variables, resulting from the temporal mismatch of the variables. When the dependent and explaining variables present strong persistency, even the GMM estimator might not be consistent, but biased, especially for panes with short T (times). In such cases, Arellano and Bover (1995) and Blundell and Bond (1998) proposed a system that combines the set of equations in difference with the set of level equations, called generalized method of moments system (*system GMM*). Regarding equations in differences, the set of instruments continues to be the same mismatch of variables, for the level regression, the instruments correspond to the mismatched differences of the respective variables.

As a way of testing the robustness and consistency of the model, the Sargan test was used for each estimates, aiming at verifying the validity of the instruments. In addition, as the error had initially been assumed as not autocorrelated, a serial correlation test of first order and another of second order were carried out on the residual in first difference, expecting that the errors were correlated in the first order, but not autocorrelated in the second order (results in Appendix D).

It seems relevant to emphasize that (13) is the specification of a spatial-Durbin model (SDM), in which the dependent variable is specially mismatched and the explaining variables too. In addition to this, the Spatial Lag Model (SAR) was estimated, in which the only difference is that b_3= 0, that is, only the dependent variable mismatch was considered. As a procedure to choose between SAR and SDM the Akaike criterion was used (results shown in the estimates table), besides considering

[5] By the Hausman test, the fixed effect was, in all the estimates, as the most indicated.

that the spatial autocorrelation of residuals in the model chosen were statistically significant (as shown in Appendices B and C).

For both, the SAR and SDM models, it was necessary to determine the spatial weight matrix. The one chosen corresponded to the tower, which presented the highest I Moran coefficient for both the distribution of the relevant variable in this study and the original regression residual (without space).

4 RESULT ANALYSIS

Theoretically, the concentration of the productive activity (intra or inter-industrial) produces externalities that feedback agglomeration and result in increase in the regional productivity. As a consequence, competitiveness is improved, affecting directly local economic indicators. This is the importance of increasing regional efficiency identifying its main inducers.

In Brazil, the inertial of productivity values was visible, being stable for several years and restarting to growth from the previous point, that is, the productivity trajectory was apparently dependent on previous characteristics (path dependence). The analysis of the period between 2010 and 2017 evidenced an increase in efficiency up to 2013, getting stable in the years of the Brazilian economic crisis, followed by certain growth in 2016 (Table 1).

The same tendency was verified in Brazilian regions, which kept their productivity, evolving slowly, from the initial point where they were. In terms of magnitude, there were regional differences of productive efficiency, presenting greater competitiveness for the South, Southeast and Center-West, the regions where the Brazilian greatest industrial centers were located.

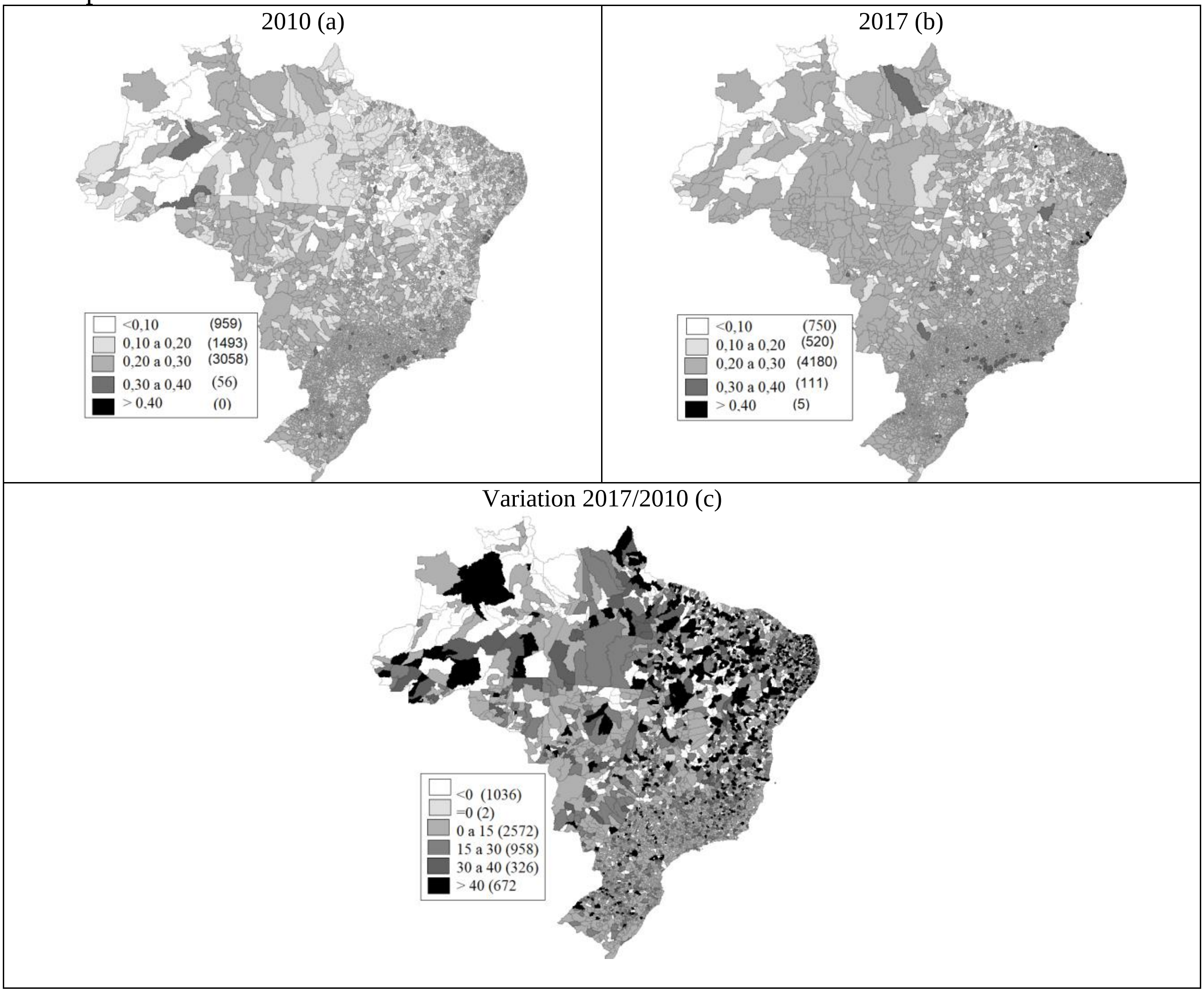
Table 1: Industrial Productivity (IDI) mean – Brazilian regions – 2010 to 2017

	2017	2016	2015	2014	2013	2012	2011	2010
North	0.17	0.18	0.17	0.17	0.16	0.16	0.15	0.15
Northeast	0.17	0.17	0.17	0.17	0.16	0.15	0.15	0.14
Southeast	0.23	0.23	0.23	0.22	0.22	0.21	0.21	0.21
South	0.24	0.23	0.23	0.23	0.22	0.22	0.22	0.21
Center-West	0.22	0.22	0.21	0.21	0.20	0.20	0.19	0.19
Brazil	0.21	0.21	0.20	0.20	0.20	0.19	0.18	0.18

Source: Research results

At a municipal level, an expressive improvement was observed, with a process of homogenization of efficiency throughout the country, reducing the number of municipalities with low IDI (IDI up to 0.20 – first and second quartiles in Figures 1a and 1b), going from 2,452 in 2010 to 1,279 in 2017. Also, some proximity was seen between those that presented high productivities, evidencing an efficiency spillover process in the space with time. Moreover, in the evolution process (Figure 1c), the highest values were mainly located in those regions with lower initial efficiency, which again signals the homogenization of productivity with time.

Figure 1: Productivity (IDI) in 2010 (a), in 2017 (b) and productivity variation (b/a) – Brazilian municipalities



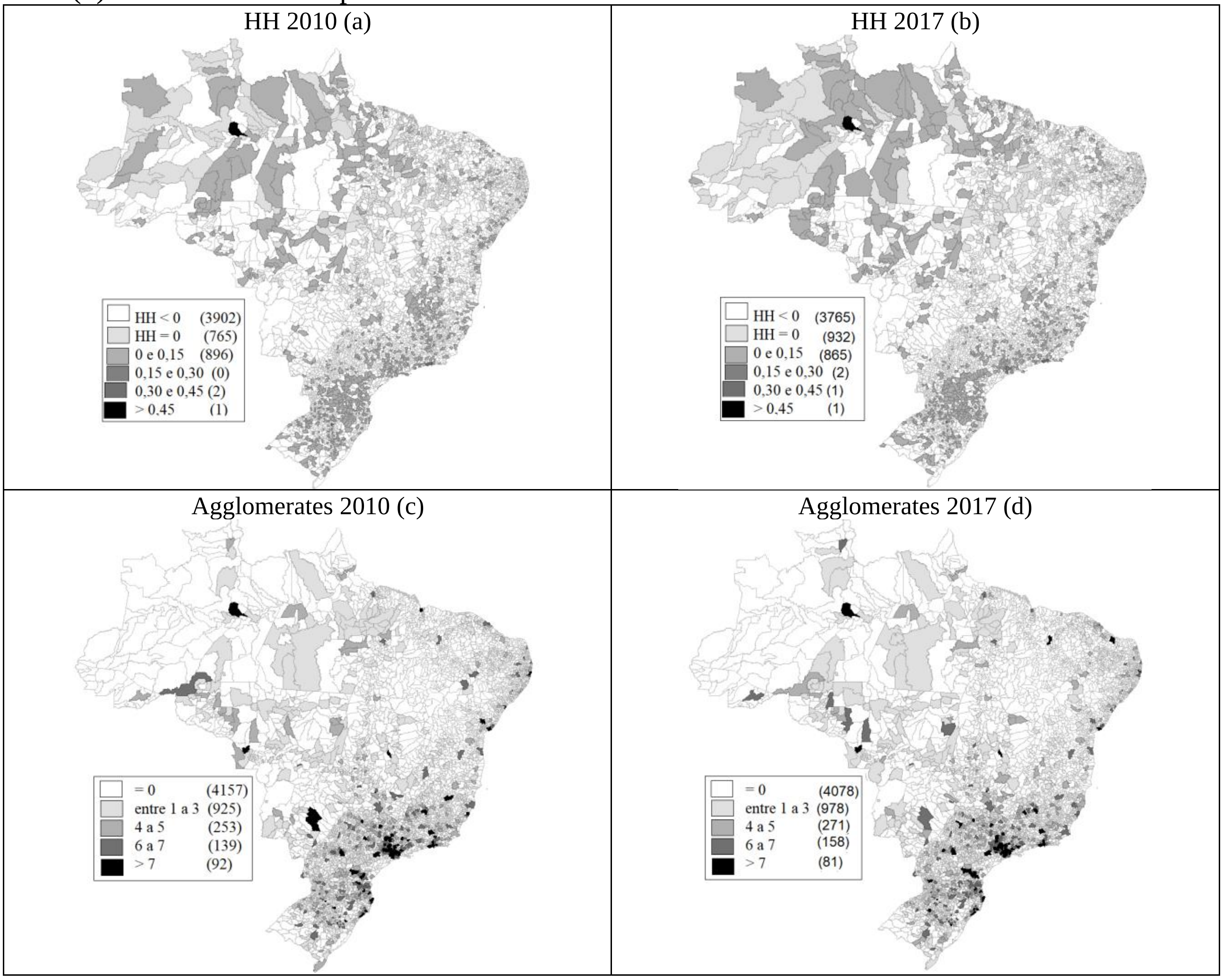
Source: Research results

Theoretically, the presence of productive agglomerations could explain this increase in productivity in Brazilian municipalities. In fact, even if Brazil reduced the job offer in industry between 2010 and 2017 (801,512 fewer positions in this period), as a result of the economic crisis in the country, the standard deviation of the number of employees in the municipalities shrank, going from 9,402 to 6,930, which indicates that the number of jobs in the industry became more homogeneous in the Brazilian space. In addition, the fact that 4,633 municipalities had some industrial employment in 2010 and in 2017 this number increased to 4,816, that is 87% of the municipalities started to have productive activities.

When a company opens in certain point, positive feedback might be generated, reinforcing local externalities, attracting new firms (KRUGMAN, 1991). This positive process leads to the formation and broadening of the agglomerate, a direct consequence of the workforce concentration, presence of infrastructure, centralization of specialized services, technological spillovers, among other factors. All of this generates economies of agglomeration that impact the local productive efficiency. The great theoretical battle is in the type of economies of agglomeration that generate greater impact in productivity: the specialization/location economies or the diversification/urbanization ones.

Figure 2 shows the distribution of the Hirschman-Herfindal Index, in which the higher it value is, the more concentrated the industrial sector is. An increase in the number of municipalities with indices below 0.15 was noticed with time, demonstrating a decrease in the industrial concentration. At the same time, an increase in the municipalities with certain type of specialized agglomerate could be verified: 4,157 municipalities did not have any agglomerates in 2010 and this number reduced to 4,078 in 2017.

Figure 2: HH Index in 2010 (a), HH index in 2017 (b), number of agglomerates in 2010 (c) and in 2017 (d) – Brazilian municipalities



Source: Research results

Regarding productivity and specialized agglomerates, the phenomenon of spatial concentration was observed (see Moran I statistics, Table 2). That is, municipalities with high (low) productivity, on average, were surrounded by other municipalities with high productive efficiency (low); likewise, those with a high (low) number of agglomerates tended to have neighbors with the same characteristics.

Table 2 – Moran I statistics – Brazilian municipalities – 2010 and 2017

Variables analyzed	Convention				
	Queen	**Tower**	4 neighbors	5 neighbors	6 neighbors
Productivity growth rate 2017/2010	0.09*	**0.09***	0.05	0.04	0.04
Productivity 2010	0.26*	**0.26***	0.0001	0.0002	0.0002
Productivity 2017	0.24*	**0.24***	0.00001	0.0002	0.0001
Agglomerates 2010	0.36*	**0.37***	0.001	0.002	0.001
Agglomerates 2017	0.37*	**0.38***	0.002	0.002	0.002

HH 2010	0.01	0.02	-0.00001	-0.00001	-0.00001
HH 2017	0.02	0.02	0.00001	0.00001	0.00001

Source: Calculated by the authors using the *software* GeoDa, based on the research data.
Note: An empirical pseudo-significance baed on 999 random permutations; * significant at a 5% level of significance.

Therefore, one can understand that productivity was not dispersed all over the Brazilian space, and those municipalities that achieved the highest productivity growth rate tended to be close to other municipalities with similar characteristics (see Moran I of the productivity growth rate 2017/2010 – Table 2).

In the next section, the effects of diversification and specialization economies on the Brazilian municipal productivity will be analyzed.

4.1 Effect of Economies of Agglomeration in the Productivity of Brazilian municipalities

The literature presents two types of economies resulting from agglomerations that impact regional efficiency: specialization and diversification economies. A test was carried out to identify which of these two effects would impact more significantly Brazilian municipalities. Table 3 presents the results, highlighting that SDM was the most indicated model (estimates II), However, the authors opted to present all estimates aiming at demonstrating the robustness of the results found.

Table 3- Spatial dynamic panel –Fixed effect – Brazilian municipalities

	Modelo (11)		**Modelo (12)**	
Variable	SAR (I)	**SDM (II)**	SAR (III)	**SDM (IV)**
Dif. Produ. (t-1)	0.40*	**0.40***	0.42*	**0.42***
	(0.01)	**(0.12)**	(0.02)	**(0.01)**
AE	1.54*	**1.54***	-	-
	(0.12)	**(0.12)**		
High AE	-	**-**	-0.0005	-0.0005
			(0.0003)	(0.0005)
Low AE	-	**-**	0.08*	**0.08***
			(0.04)	**(0.04)**
HH	3.13	3.22	1.97	2.12
	(4.55)	(4.54)	(2.64)	(2.70)
HHq	-1.96	-1.99	-1.55	-1.24
	(2.56)	(2.56)	(1.49)	(1.54)
CI	-0.31*	**-0.31***	-0.08*	**-0.07***
	(0.03)	**(0.03)**	(0.008)	**(0.009)**
W AE	**-**	**0.26***	-	-
		(0.13)		
High W AE	**-**	**-**	-	-0.0006
				(0.001)
Low W AE	**-**	**-**	-	**0.003***
				(0.001)
W HH	**-**	7.72	-	-0.77
		(8.47)		(9.57)
W HHq	**-**	-4.34	-	0.36
		(4.77)		(5.35)
W CI		**-0.08***	-	**0.01**
		(0.009)		**(0.001)**
ρ	0.07*	**0.06***	0.07*	**0.07***
	(0.008)	**(0.008)**	(0.09)	**(0.008)**
Crit. inf. Akaike	-151292	**-151297**	150104	**-150197**

Source: Research results.
Note: The robust standard error is reported in brackets. * estatically significant at 5%; **HH** is the modified Hirschman-Herfindahl index; **AE** refers to the number of specialized agglomerates; **CI** is the industrial concentration; **Dif. Produ. (t-1)** is the productivity growth in the previous period; $\boldsymbol{\rho}$ is the dependent variable spatial gap coefficient.

The coefficient related to the one-year delay in the dependent variable was seen to be positive and statistically significant, indicating the existence of a productivity dependence process, corroborating previous evidence, identifying a process of path dependence.

When diversification economies were analyzed, the results evidenced absence of effects. That is, the diversification of the productive activity is not the element leading to an increase in the efficiency of Brazilian municipalities. This might be associated to the size of most of the municipalities (small), which do not generate enough externalities to result in increased productivity and, at the same time, those that present diversification might already be at a level that presents diseconomies of agglomeration. That is indicated by the coefficient signals, however, they are not statistically significant.

Economies of specialization (represented by the "number of specialized agglomerates), in turn, were seen to be statistically significant, with a positive impact on productivity. Therefore, the spatial concentration of firms of the same industry increases the efficiency of the Brazilian municipalities, generating externalities, emphasizing that the larger the number of specialized industries is, the higher this impact is.

Lira's (2016) report confirms this study, inferring that specialization externalities affect productivity in the Brazilian microregions, mainly in the low and medium-low technology sectors. Since over 77% of the productive specialization of the Brazilian municipalities include low and medium-low technology, it confirms the results found in this study.

At an international level, Henderson (1999) analyzed the effect of urbanization and location economies on productivity in the USA – collecting data from industrial plants from 1972 to 1992 – and identified a positive effect only for location economies. That author explains that companies in the same industry took advantage of a greater magnitude of the industrial activity scale, capturing their externalities strongly, creating a cumulative process. Nakamura (1985), when analyzing the relative effect of location and urbanization economies on the productivity in Japan, found out that if the scale of one industry doubles, it tends to increase its productivity in 4.5%, signalling more robust effects of location economies than those of the urbanization economies.

Theoretically, Marshall (1890) pointed out that through specialization, the concentration of companies produces externalities, mainly via increase in the production scale, through flows of technology, and also that the chain formed between firms intensifies the joint efficiency due to lower global costs, resulting in competitive advantages and higher growth rates. Moreover, transactional economies appear, as a result of the proximity between firms of the same industry, intensifying personal relationships and facilitating the execution of contracts. The formation of a specialized workforce market would be another source of increase in efficiency, with accumulation of technical competences directed to the firms of the same industry, fostering collective learning processes, which might optimize productivity. In addition, Marshall (1890) also addresses the existence of a series of locally concentrated services, intensifying the local production value, with sinergy effects on the image of that economy.

All these factors justify the importance of specialization economies in the productivity of Brazilian municipalities. And the coefficient obtained for the spatial gap in productive specialization (ρ) indicates an effect that goes beyond the geographical borders of each municipality. That is, when there is an increase in the number of productive agglomerates in a municipality, it does not only benefits that municipality, but also the neighboring areas, increasing productivity in the municipalities close to it. Hirschman (1958) emphasized that when there is an agglomerate, its effects might go beyond borders, through the chain of firms inside this agglomerate and the neighbor municipalities and/or through externalities originated in the technological spillovers, etc.

This confirms the hypothesis that the relationship between firms of the same industry tends to result in a series of spillovers (technological, transportation cost reduction, common use of infrastructure, specialized workforce, etc.) which impact the competitiveness of the whole intrafirm productive chain, also producing externalities for other productive activities concentrated in that space, besides reaching productive processes beyond their municipal borders.

The empirical model estimated in Table 3 also allows the identification of the industry competitiveness degree and its effect on productivity. Theoretically, Porter (1990) emphasizes that greater competition (that is, a larger number of firms belonging to certain industry) generates greater benefits for the industrial development than a monopolist structure, since competitiveness accelerates imitation and improves the innovator's ideas and, even if it reduces innovation returns due to the competition, it intensifies the demand for innovation. On the other hand, Marshall (1890) defends an industry with greater monopoly as the driving force of economies of agglomeration, considering that its impact in the industrial dynamics tends to be higher due to the certainty of innovation profits.

In the specific case of Brazilian municipalities, results demonstrate that Porter's hypothesis (1990) is more coherent, obtaining a statistically significant negative coefficient for industrial concentration, inferring that the lower the density and scale of the industrial activity is, the higher the local productivity growth tends to be.

And such effect, on average, also impacts the productive efficiency in neighboring municipalities, so that, the lower the industrial concentration in a municipality is, the higher the externalities around it are. Likewise, Glaeser et al (1992), when analyzing some municipalities in the United States, identified a more dynamic industrial growth in the cities where the industries were smaller, with increase in the local competition among companies, generating higher local efficiency.

Finally, the parameter ρ presented positive and statistically significant effect, demonstrating a positive IDI spillover in the productivity growth around that specific area. That is, when certain municipality intensifies its productivity, part of this dynamism also benefits neighboring municipalities, creating a virtuous cycle of competitiveness. The installation of a satellite company and construction of a technological atmosphere are some of the factors that might justify productivity spillover to the neighboring municipalities.

Table 3 (Model IV) shows the estimates of (12), sub-dividing the "variable number of agglomerations" by "number of agglomerations high/medium-high technology" and "number of agglomerations low/medium-low technology". In general, all results were kept, that is: industrial concentration impacts productivity negatively in both the municipality and the neighboring area; past productivity has a positive effect on the future efficiency; there is a spatial effect of productivity, with spillovers to the neighboring areas; and the diversification economies still did not have statistically significant effects.

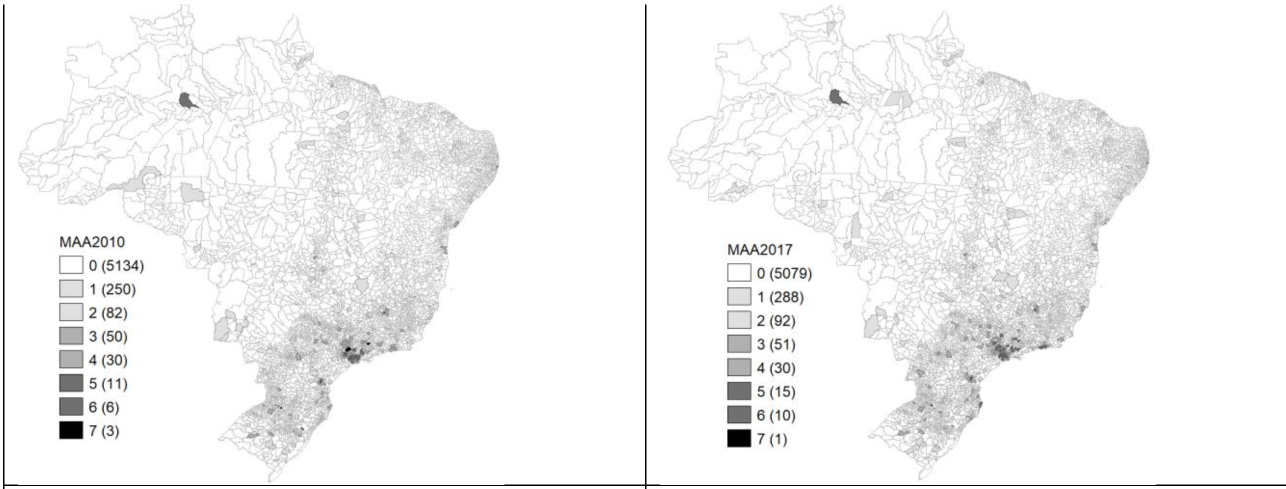
Regarding economies of agglomeration, specializations in less intense levels of technology were seen to produce positive impact in the regional productivity, affecting the efficiency of the municipality and the area around it. Conversely, when specialized agglomerations are observed in the production of high/medium high technology, there were no statistically significant effects. In fact, Brazil presents comparative advantage in the production of primary products (Machoski and Raiher, 2016), and, therefore, having agglomerated firms which are specialized in such raw material means having an increase in efficiency and productivity.

When more intense levels of technology are investigated, theoretically, they present a better innovator environment with potential to lead to a higher productive efficiency in the region. The issue in this case is that great part of the good needed for production in these firms of higher technological intensity are not produced internally and have to be imported (Carmo et al, 2012). This partly justifies the absence of specialized agglomerations effects of high/medium-high technology on the productivity of Brazilian municipalities.

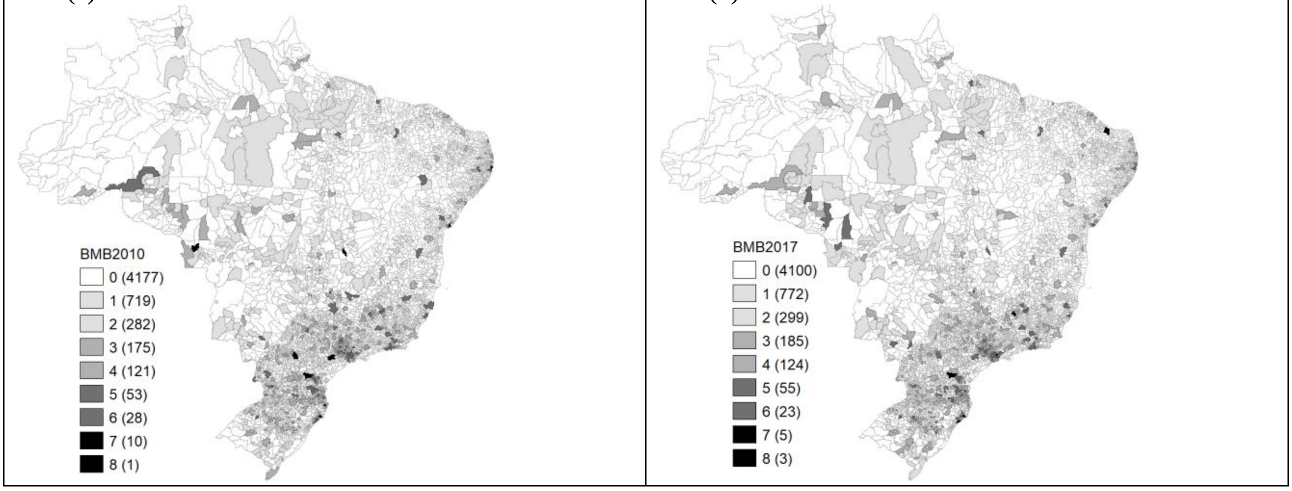
According to Figure 3, the number of municipalities with some specialization either in the industry with higher technological intensity or in the one with lower technological intensity grew, with an increase of 91 and 90 new specialized agglomerates, respectively; however, the specialization of sectors with higher value aggregation was mainly in the South and Southeast of Brazil, not changing its location pattern over the years.

Figure 3: Number of specialized agglomerates of high/medium-high technology and low/medium-low technology – 2010 and 2017

(a) High/medium-high technology 2010	(b) High/medium-high tecnnology 2017



(c) Low/medium-low 2010 (d) Low/medium-low 2010



Source: Research results

Table 4 confirms previous findings, evidencing the concentration of specializations in both low/medium-low and high/medium-high technologies in the South and Southeast of Brazil, since 75% of all productive agglomerations that are less intense in technology and 87% of the agglomerations of high/medium-high technologies were located in the South and Southeast regions.

Table 4: Number of specialized agglomerations – high/medium-high and low/medium-low technology – Brazilian municipalities - 2010 and 2017

Region	2010		2017	
	Low/medium-low	Medium high/high	Low/medium-low	Medium high/high
North	134	13	134	19
Northeast	392	56	393	64
Southeast	1159	486	1169	523
South	937	214	999	250
Center-West	181	27	198	31
Brazil	2803	796	2893	887

Source: Research results

In such context, given the existing heterogeneity along the country, it is not possible to imagine that economies of agglomeration have the same effect all over the country. Therefore, equation (12) was re-estimated, analyzing separately South/Southeast in comparison to North/Northeast/Center West. These results are presented in Table 5, where a difference regarding the effect of economies of agglomeration can be seen.

When South/Southeast[6] are observed, the specialization externalities, on average, affected productivity positively, however, not all types of specialization impacted positively, only those referring to the production of goods of lower technological intensity. Also, those agglomerations did not affect only the municipalities where they were installed, but also the neighboring areas. Since great part of the agglomerations in the region present low value aggregation (74%) and are spread throughout the space, so that 37% of the South/Southeast municipalities have some type of low/medium-low technology, the existence of this effect tends to benefit the whole space, tending to the homogenization of the productivity in the long term, specially due to its spatial spillover effect.

Table 5- Spatial dynamic panel – Fixed effect –Model (12) – Brazilian regions

	South/Southeast		North/Northeast/Center-West	
Variable	Fixed effect – SAR (I)	**Fixed effect – SDM (II)**	**Fixed Effect SAR (III)**	Fixed effect SDM (IV)
Dif. Prod. (t-1)	0.40*	**0.40***	**0.43***	0.43*
	(0.03)	**(0.02)**	**(0.015)**	(0.01)
AE high technology	-0.0005	-0.0005	-0.0005	-0.0005
	(0.0005)	(0.0005)	(0.0006)	(0.0007)
AE low technology	0.0007*	**0.0006***	**0.001**	0.0014*
	(0.0004)	**(0.0003)**	**(0.001)**	(0.001)
HH	0.12	0.33	**20.07***	20.82*
	(2.69)	(2.77)	**(8.71)**	(8.90)
HHq	-0.13	0.329	**-11.53***	-11.98*
	(1.52)	(1.58)	**(5.01)**	(5.12)
CI	-0.003	**-0.001***	0.03	0.03
	(0.006)	**(0.006)**	(0.07)	(0.07)
W AE high	-	-0.0008	-	-0.00005
		(0.001)		(0.003)
W AE low	-	**0.004***	-	-0.006
		(0.002)		(0.006)
W HH	-	-2.20	-	-31.77
		(8.03)		(44.52)
W HHq	-	0.87	-	-31.77
		(4.58)		(44.52)
W CI	-	**-0.005***	-	20.12
		(0.009)		(25.83)
ρ	0.12*	**0.12***	**0.06***	0.06*
	(0.02)	**(0.009)**	**(0.01)**	(0.01)
Crit. inf. Akaike	-90055	**-90056**	**-65295**	-65292

Source: Research results.

Note: The robust standard error is reported in brackets. * statistically significant at 5%; **HH** modified Hirschman-Herfindahl index; **AE** number of specialized agglomerates; **CI** industrial concentration; **Dif. Prod. (t-1**) productivity growth in the previous period; $\boldsymbol{\rho}$ coefficiente of the dependent variable spatial gap.

For the North/Northeast/Center-West, productivity specialization did not present statistically significant impacts. At the same time, diversification economies exhibited some effect on the regional productivity, evidencing a concave relation between the urbanization economy and productivity, with a positive effect up to a certain point, from where a greater concentration of firms from different industries starts to generate, on average, negative effects on the productivity growth rate in the municipality. One of the explanations for this result might be the diseconomies of agglomeration, resulting from the decreasing profits that the municipality faces after certain level of urbanization. Such diseconomies are linked to congestion costs, also resulting from the intensification of social conflicts (such as criminality, etc), as well as the increase in the price of rents and the cost of several essential urban services (CAMAGNI, 2005).

Therefore, an inverted U shaped relation was found between urbanization economu and productivity in each municipality of the North/Northeast/Center-West of Brazil.

[6] Considering that the best spatial model corresponded to SDM (Akaike's criterion, and without residual spatial correlation) for South/Southeast. However, for the North/Northeast/Center-West, the bet model was SAR.

Economies of agglomeration were seen not to affect equally the municipalities of the country, since due to the development of the industry – more intense in the South-Southeast than in other regions of the country – a differentiated impact of these externalities was seen in the local productivity.

FINAL CONSIDERATIONS

The objective of this paper was to analyze the impact of economies of agglomeration on the regional productivity of Brazilian municipalities. The high relevance of economies of agglomeration in the process of competitiveness of the Brazilian municipalities was observed. More specifically, urbanization economies presented a higher effect on this process in the regions North/Northeast/Center-West. However, its impact depends on the size of the municipalities: in those where there is low urbanization (and, consequently, not very intense industry diversification), it was possible to affect positively the productivity. In municipalities with high population density, an increase in the number of firms might lead to a greater expansion of the urbanization and, if not supported by infrastructure and spatial organization of the territory, might have negative impacts regarding productive efficiency. Therefore, in addition to implementing industrialization policies in these regions, it is necessary to analyze the urban spaces where such policies are to be applied.

For the regions South/Southeast, specialization economies are important, mainly regarding low/medium low technology industries. There is a predominance of sectors that are less intense in technology in the productive structure of these regions, with high competitiveness of the segments upstream these industries (agriculture and cattle raisin), an element that potentially provokes competitiveness and leads to the existence of externalities for the whole region.

The importance of industries with higher value aggregation in the productivity of the municipalities of these regions cannot be denied, the issue focused on here is that due to the current level of development, there are not sufficient elements to promote efficiency in the municipal economy as a whole with the specialization of industries that are intense in technology. There might not be enough chaining of these industries locally, with leakage of the effects to other countries and regions, along with the lack of sufficient investment in research and development in these areas.

However, general results do not deny the importance of any type of economy of agglomeration – either diversification or specialization – which are also important in specific areas of the country.

It seems relevant to highlight that, despite the methodological effort employed in this research, it does not exhaust the discussion involving the effects of agglomerates on the regional productivity. Some issues are still pending, such as 'would the results be different if a regression had been estimated separately for each group of municipalities, according to their initial development? How much do productive agglomerations and their externalities contribute to productivity convergence in Brazil?' These and other issues should be approached in further studies.

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APÊNDICES

APPENDIX A: WEIGHTS OF IDI INDICATORS

	Schooling	Salary	Technical and scientific jobs
Weights	0.32	0.30	0.28

Source: Research results.

APPENDIX B: Moran I of residuals – Table 2

	Ano							
SDM – Table 2	2010	2011	2012	2013	2014	2015	2016	2017
Column II	-	0.032	0.031	0.031	0.030	0.029	0.002	0.028
Column III	-	0.002	0.001	0.001	0.003	0.002	0.001	0.001

Source: Research results.

APPENDIX C: Moran I of residuals – Table 5

	Ano							
	2010	2011	2012	2013	2014	2015	2016	2017
Column II SDM	-	0.08	0.08	0.09	0.05	0.05	0.009	0.08
Column III SAR	-	0.02	0.01	0.03	0.009	0.04	0.04	0.01

Source: Research results.

APPENDIX D: Sargan Test and AC – Models of Tables 2 and 5

	Table 2- Column II	Table 2 – Column III	Table 4 – Column II	Table 4 – Column III
Sargan test	154.02	75.35	46.85	89.27
AC test	1.42	1.34	0.88	1.22

Source: Research results.