From the local economy to the global market

Municipal-level spatial economic modelling of international trade for Brazil

Abstract

International trade is one of the key spheres of economic policy. It is crucial for a country to understand the dynamics of its export markets to create a coherent strategy to improve its position in global markets. Research in this field is particularly interesting for both economists and policy makers. However, due to a lack of data, most of the well-established literature is focused on the national level. Therefore, there is little evidence on the influence of local characteristics on export markets. This research aims to evaluate the influence of regional factors on the competitiveness of firms in international markets, focusing on the importance of *agglomeration economies* and *location*, among other local factors. To identify this influence, this paper studies the case of Brazil. This country offers rich disaggregated information that allows this type of research and displays enormous differences across rural and urban areas. Given these differences, the assumption of homogeneous effects is too restrictive. Therefore, to study the patterns across different territories around the country, Geographically Weighted Generalized Linear Model (GWGLM) method is applied. The results indicate an interaction between location and the influence of several local characteristics such as human capital, the degree of development and the local economic structure. This relationship creates virtuous circles in a few locations where urban agglomerations create a suitable environment for firms, while opposite patterns appear in other locations.

Keywords: spatial economic modelling, *agglomeration economies*, trade patterns, local analysis, GWGLM and Brazil.

JEL codes: F14, R11 and R12.

1. Introduction

The study of international trade has always drawn the attention of economists. Since Adam Smith, the processes of specialization and competitiveness among countries have been explained by classical and neoclassical authors. For instance, Ricardian theory assumes that trade is advantageous when a country has a comparative advantage in the production of at least one good. The Heckscher-Ohlin model is based on the theorem that a country has a comparative advantage in commodities that make intensive use of its abundant factors (Hewings and Oosterhaven, 2014). Those theories do not take into account the influence of *transport costs* and differences in prices within countries, and they do not usually consider differences in factor compensation across space due to unequal productivity levels of the industries inside a country (Eaton and Kortum, 2002). These theories assume perfect competition and constant returns to scale. As a result, a large degree of trade in similar goods within similar economies are difficult to explain under these assumptions. According to Hewings and Oosterhaven (2014), New Trade Theory (NTT) introduced monopolistic competition and increasing returns to scale to these models, and Ottaviano (2011) notes that general equilibrium analysis was incorporated through Dixit-Stiglitz models. These new developments were responsible for bringing onto the scene the subfield of New Economic Geography (NEG), which merges international trade theory and regional science, with Krugman (1980 and 1991) making some of the first contributions.

Regional analyses of trade are increasingly in vogue, as countries are full of internal contrasts regarding, for example, their economic structure or distribution of inputs. In addition, most competitive regions attract a large share of firms and consumers. This process leads to an agglomeration process, as widely discussed within the framework of NEG (Krugman, 1980 and 1991). Consequently, to understand the internal dynamics within regions, it is necessary to study the underlying dynamics behind an exporting country's performance. This can facilitate progress on policy solutions to strengthen the competitiveness of territories.

In this context, the aim of this paper is to analyse the three pillars of the NEG framework: *location*, *trade*, and *agglomeration theory*. *Location theorists* hold that the industrial location is based on the market power of a given place in addition to the potential to exploit imperfect competition; *international trade theorists* elucidate how a place specializes in a (range of) product(s) as a consequence of the availability of production factors across regions; and finally, *urban economists* understand that externalities are key to the spatial distribution of production and consumption (Ottaviano, 2011). According to NEG, the concentration of industries is explained by the home market effect, because firms locate themselves near large markets to take advantage of increasing returns and decreases in the friction effect of *transport costs* (Krugman, 1980). Agglomeration then, increases real wages in that region and promotes better services and information spillovers, transforming it into a more attractive place to live and do business (Parr et al., 2002). The best representation of these dynamics is found in metropolitan areas that attract firms thanks to their competitiveness, leading to an agglomeration process (Brodzicki et al., 2018 and García et al., 2020). Therefore, NEG framework motivates the decision to investigate location-related aspects of exporting firms since this theory proposes endogenous location decisions of firms that are determined by spatial disparities over space. In this paper we are particularly interested in observing how these elements influence the propensity to international trade of local space units. We do not address a growth analysis in general, but a specific contribution in the understanding of the role of the mentioned aspects in the propensity for internationalization.

Previous studies have reached very interesting conclusions analysing regional aspects of promoting the generation of exports (see Artuc et al. (2014), Brodzicki et al. (2018), Brodzicki and Uminski (2017), Márquez-Ramos (2014), Matthee and Naudé (2008) or, among others, Parr et al. (2002)), but they have paid little attention to the spatial heterogeneity of the process, at least formally in their empirical estimations. The hypothesis in this paper is that *location patterns* of export generation are influenced by spatial characteristics at the very local level. By confirming this proposition, we contribute to the literature and facilitate better planning and implementation of public policy guidelines, in which aspects such as *location* decisions, *trade* specialization and *agglomeration economies* should be considered.

To verify our hypothesis, we apply Geographically Weighted Generalized Linear Model (GWGLM). This technique allows the identification of varying relationships of coefficients across space. The empirical evidence comes from a Brazilian export database of firm-level customs declarations from 2007 and 2017 in the 5,570 Brazilian municipalities. This implies that the data are at a very disaggregated level. As in Tsekeris (2016), dealing with the many zero values poses an estimation challenge. To overcome it without generating a possible bias, GWGLM introduces specific count data modelling in the estimation.

The rest of the paper is structured as follows: section 2 explains the context of this research in terms of the previous theoretical and applied literature. Section 3 summarizes the methodological approach of this analysis. Section 4 describes the database used for the analysis in detail and presents an initial statistical analysis of the problem. The outcome of this research is summarized in section 5, while section 6 focuses on the interpretation, policy implications and conclusions of these results.

2. Brief review of Brazil's integration into the international market

Brazil is a country full of contrasts. On one hand, Brazil has become a major competitor in the global market since it started opening its economy in the 1990s (De Negri & Araújo, 2006). Exports grew by 127% in the period from 2007 to 2017, according to the Ministry of Economy (2020b). For Britto (2006), no conclusions can be drawn as to what caused this increase in exports. However, he points out some possible reasons: (i) late reflection of the liberalization of the Brazilian economy in the 1990s; (ii) a favourable price realignment in 1999; (iii) changes in the mentality and attitude of Brazilian businesspeople in relation to expansion to foreign markets; and iv) the opening of new markets for national (primary) products, especially China. For Borghi and Sarti (2019), the last point is the main factor responsible for the increase in Brazilian exports. In fact, Pimentel et al. (2005) conclude that there is a strong dependence on foreign income for export generation, especially for agricultural products.

On the other hand, despite the growth in exports, Brazil still has low external openness (measured as the sum of exports and imports divided by GDP), the lowest average rate of 25.7% over 2002-2017 among countries classified as upper middle income by the World Bank (2020). According to De Negri and Araújo (2006), the degree of closure in Brazil is justified since Brazilian industrialization has grown through an *import substitution* process. Consequently, industrial parks are diversified while local industries received state subsidies and are protected under tariffs. At the same time, an anti-export bias has been created (Borghi and Sarti, 2019).

A second contrast relates to what is exported and what are the necessary production endowments. A crude analysis of Brazilian foreign trade statistics shows how much Brazil depends on commodity exports, which are quite intensive in natural resources and labour. An empirical application by Chahad et al. (2003) on regional exports from Brazil confirmed the Heckscher-Ohlin theorem. Two facts led the authors to this conclusion. First, in the North, Northeast and Midwest regions, the export sector employs more people because it is more labour intensive than other sectors and exports are based on natural resources. Second, in the states of the south and southeast, where qualified labour is more abundant, exports use this type of production factor more intensively.

At the same time, since the 1970s, Brazil has invested in new agricultural frontiers, extending production to the northeast, north and especially the Midwest. Areas producing sugar and grains (corn and soybeans) became part of the so-called *productive arc,* concentrated in the midwestern region and spreading further north. New market configurations in the context of population flows from the northeast and south to the centre of Brazil and the expansion of agricultural land have given rise to a need for a re-evaluation of the territorial organization. While the evolution of labour and land is inadequate to explain this new agricultural spatial arrangement, productivity is thriving thanks to modern technologies and management techniques (Empresa Brasileira de Pesquisa Agropecuária, 2018). This fact was confirmed in a microeconomic analysis, demonstrating how Brazilian exports are influenced by decisive aspects such as human capital, technology, innovative capacity and returns to scale (De Negri & Araújo, 2006). The authors concluded that potential exports are very concentrated in highly industrialized municipalities. Moro et al. (2006) investigated the spatial determinants of the export potential of Brazilian municipalities. They showed that agglomerations are explained by the presence of external spatial economies and export potential is not only driven by attributes of exporting companies themselves, but also by activities of neighbouring companies. The authors also stated that firms operating in sectors related to information and/or knowledge-intensive activities are more likely to be spatially concentrated. Finally, Díaz-Lanchas, Llano, Minondo, & Requena (2018) pointed out that the most populated cities in Brazil are those with high export specialization. In turn, exported goods are more complex and skill intensive.

In light of the above, it is important to note that Brazil is a continental country with very large differences across regions, which require separate analyses for public policies to be accurate and effective. The necessity for a regional analysis of export determinants in Brazil is driven by the policy relevance of the topic.

3. Estimation strategy: capturing Brazilian spatial heterogeneity

Lack of uniformity is a common feature of space (Anselin, 1988). This spatial heterogeneity has two aspects that need to be addressed in the estimation: parameter instability (non-stationarity) and non-constant variance (heteroscedasticity) (Billé et al 2018). The idea behind is that economic phenomena, in our case, generation of exports, are caused by specific local interactions, both observed and unobserved. As already commented, Brazil is a large country with huge different economic realities. Given these dissimilarities, any model estimating possible local international trade patterns needs to overcome a non-stationarity process in the parameters, since the estimated relationships probably are not the same across space.

There are a couple of methodologies that consider the variability of parameters during the fit process. Some categorize the sample into groups and individualize the estimates of these clusters which were created exogenously. However, they do not account for unobserved heterogeneity (Billé et al., 2018). The other possibilities are applying a parameter structure as either discrete, Spatial Regimes (SR), or continuous, Geographically Weighted Regression (GWR) (Anselin, 2010 and Anselin and Rey, 2014). The advantage of the SR or GWR is the identification of local parameters that change over space.

Both techniques could be adequate in our case. However, this article tries to identify a spatial pattern of varying coefficients across space and a discrete modelling would assume discontinuities that would happen exactly on the administrative borders of the regimes. GWR works with spatially varying parameters which smoothly change over space thanks to the selection a Spatial Weighting Function. Thus, as may be noted, GWR approach is especially suitable in the identification of continuous spatial patterns of the parameters, allowing a visual representation of the differences in the parameters as a spatial continuous process (see Fotheringham et al., 2002 for more details)

In the work of Fotheringham et al. (2002, chapter 2), they cautiously describe the GWR technique, giving the possibility to estimate a model with varying coefficients through the calibration of a linear model for each territory. For other more detailed information, see Ali et al., 2007 or Brunsdon et al., 1998. Some applications of this technique can be found in Eckey et al. (2007), Gutierrez et al. (2018 & 2020), Mcmillen (1996), Shearmur et al. (2007) and Wheeler (2007), among others.

The specification of this type of model in our case would be:

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{m} \beta_k(u_i, v_i)x_{ik} + \varepsilon_i \qquad [1]$$

Where u_i, v_i represent the coordinates of the ith location in space (a municipality in our case) and x_{ik} represents each k independent variable. Therefore, the dependent variable y_i for each municipality is explained by means of a constant for each municipality, β_{i0}, and a set of independent variables, multiplied by a set of coefficients $\beta_k(u_i, v_i)$ that are different in each location. These coefficients are specific evaluation of the continuous function of coefficients $\beta_k(u, v)$ across space. Finally, ε_i represents the unexplained residual in each location. The final expression of the estimator in GWR takes into account the observations in the neighbourhood, as in equation [2]. So, the parameters of each municipality are calculated as:

$$\hat{\beta}(u_i, v_i) = (X^T W_i X)^{-1} X^T W_i y \qquad [2]$$

where a vector of coefficients in each location $\hat{\beta}(u_i, v_i)$ is estimated with a weight matrix W_i that is different for each location i. One interesting property is that this estimation can be made for any point in space, not only the original points of measure, although the residuals can only be calculated when the dependent variable is available. W_i is a diagonal matrix with a weight assigned to each j neighboring location. These weights are estimated through kernel estimation. In this case, the kernel estimator is given by a Gaussian function[1], as shown in equation [3]:

$$W_i = \begin{bmatrix} w_{i1} & 0 & 0 & \cdots & 0 \\ 0 & w_{i2} & 0 & \cdots & 0 \\ 0 & 0 & w_{ij} & \cdots & 0 \\ \dots & \dots & \dots & \ddots & \dots \\ 0 & 0 & 0 & \cdots & w_{in} \end{bmatrix} \qquad [3]$$

$$w_{ij} = exponential\left(-0.5\left(\frac{d_{ij}}{b}\right)^2\right)$$

where w_{ij} is defined by the distance d_{ij} and the kernel bandwidth b. This relation indicates that the closer a place is to location i, the higher its weight. The bandwidth could be a parameter that increases or diminishes the accuracy of the model. In our case, the bandwidth is chosen in each year minimizing the Cross Validation (CV) score as proposed in Bowman (1984). Using an optimal bandwidth should avoid unnecessary assumptions or restrictions in the model.

Lastly, OLS is not recommended given that there is an abundance of municipalities with no exports, as seen in Figure 1. Thus, an extension of the usual linear model is needed. As stated by Tsekeris (2016), any disaggregated model of exports has to deal with many zero values in the database. Therefore, the common assumption of a normal distribution of the dependent variable and errors could introduce bias in the estimation process and conclusions. Then, Poisson specification is more suitable since it can consider municipalities with no exports – (see Wooldridge; 2018, chapter 17 for more details). In this model (see equation [4]), it is assumed that the dependent variable follows an estimated Poisson distribution.

$$\widehat{log(y_i)} = \hat{\beta}_0 + \sum_{k=1}^{m} \hat{\beta}_k x_{ik} \qquad [4]$$

This distribution allows to consider the asymmetrical distribution of exports. Although the formulation is a bit different than an OLS model, the logarithm of the expected value is a linear function. Therefore, a coefficient represents the percentage change in the expected value given an increment in an independent

[1] Bi-square weight function was also testes, but it has produced significantly lower results in the CV (see Table A1 in the Appendix)

variable. If this variable is expressed in logarithms, the coefficient would represent an elasticity, as explained in Wooldridge (2018, chapter 17). Some examples with a loglinear formulation of exports can be found in Santos Silva and Tenreyro (2006) or Moura et al. (2019).

It is also possible to introduce advanced spatial techniques in a Poisson distribution (see chapter 8 in Fotheringham et al., 2002 and Nakaya, et al., 2015)[2]. GWR applied in this analysis is enhanced to allow the inclusion of count data (with a Poisson distribution) by means of GWGLM. The estimated model becomes:

$$\widehat{log(y_i)} = \hat{\beta}_0(u_i, v_i) + \sum_{k=1}^{m} \hat{\beta}(u_i, v_i)x_{ik} \qquad [5]$$

The coefficients of the model vary over space for each specific municipality, taking into account the values in the neighbourhood and giving greater weight to closer municipalities based on the distances between them, as in equation [3]. For a deeper understanding and greater transparency, replication of all the estimates and maps can be performed through R-code based on the R package 'spgwr'[3] (Bivand & Yu, 2020).[4] The same estimations, as well as additional tests (AIC and non-stationarity tests), can be obtained by means of the GWR4 software (Nakaya et al. 2016).

4. Empirical setting: dataset sources, variables, and spatial disaggregation

Our objective is to identify spatial patterns of exports in Brazil at a very local, disaggregated level through the GWGLM estimation specified in equation [5] of the previous section. The dependent variable of that equation is presented, and later, data sources and definitions in the independent variables are discussed.

The database includes all the municipalities with available information in both, the dependent and independent variables. In total, 5,242 in 2007 and 5,381 in

[2] As explained in Fotheringham et al. (2002), the distribution of y_i does not need to have all the properties of a Gaussian distribution.

[3] Other R packages, including 'ggplot2', 'pals', 'plm' and 'spdep', were also used in a secondary way.

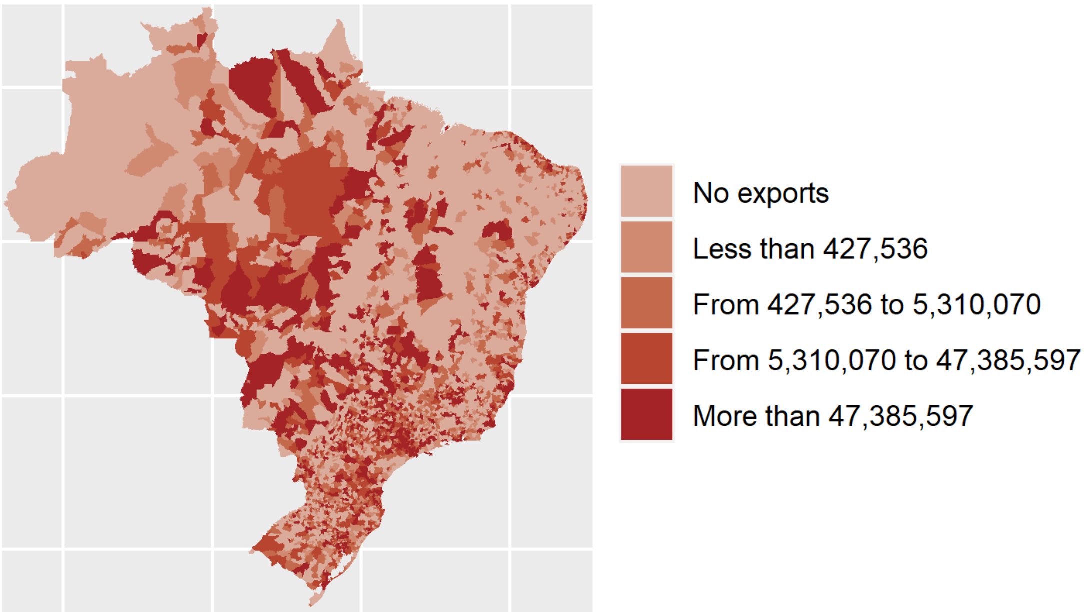
[4] Data and code that support the findings of this study are openly available in DOI: 10.6084/m9.figshare.13667597 under license CC BY 4.0.

2017 municipalities. However, given the GWR methodology, it is still possible to evaluate and map the continuous function of parameters for the whole country.

Dependent variable: exports of Brazilian municipalities

Data on *local exports* - the dependent variable - are available as part of the database of international trade offered by the Ministry of Economy (2020b), Comexstat. This dataset is assembled from customs declarations at firm level, offering information about the FOB value in US dollars of total exports for the 5,570 Brazilian municipalities[5]. Data of this specific variable are available for all years of the last decade until 2020, but the others until 2017. We chose to analyse the specific years of 2007 and 2017 to obtain a picture of the situation prior to the Great Recession in 2007 and of the current situation, captured by the data for 2017.

Figure 1 – Municipal exports in FOB terms (US dollars), 2017



The representation of this export data by municipality for 2017 is presented in Figure 1. It shows the distribution (in quantiles) of exports over the Brazilian territory in 2017 based on the FOB (free on board) value in US dollars. If we compare the export data by municipality for the two years (2007 and 2017), it appears that just 10 municipalities represent approximately 26% of all Brazilian

[5] Brazil is divided into 5 regions (similar to the NUTS1 level in the European Union), 27 states (similar to NUTS2) and 5,570 municipalities (similar to LAU1).

exports for 2007 and 24% for 2017—an almost negligible reduction in concentration. Seven municipalities are part of this list for both years: São Paulo (4.5%, 2007; 3.7%, 2017), Angra dos Reis (3.7%; 3%), Rio de Janeiro (1.6%; 3%), Paranaguá (1.9%; 2%), São José dos Campos (3.9%; 2%), São Bernardo do Campo (2.7%; 1.8%), Santos (2%; 1.8%), Itajaí (1.6%; 1.7%) and Vitória (2.2%; 1.4%). By 2017, the city of Barcarena, which appeared in the top 10 in 2007, was no longer among the top 10 municipalities in which export activities were concentrated. On the other hand, Parauapebas entered the list in 2017. Among the 10 top exporter cities in 2017, two are considered metropolises (São Paulo and Rio de Janeiro), 3 are regional capitals (São José dos Campos, Santos and Vitória), three are subregional centers (Paranaguá, Angra dos Reis and Itajaí) and just one is a zone center (Parauapebas). Only São Bernardo do Campo is not classified as an independent city, as it is considered part of the São Paulo metropolitan area[6]. These figures reflect what Imori, Guilhoto, & Hewings (2016) also concluded: the Brazilian states that are most integrated in the global value chain are Amazonas, Paraná and São Paulo, as they are the places that send the highest shares of their production abroad.

Independent variables: local factors explaining the propensity to export

The dependent variable is regressed over a set of k independent variables (x_{ik}) for each municipality i, which allows us to describe the main economic and demographic characteristics of each municipality according to equation [5] in the previous section. Nine variables are considered covering thematic groups of: (i) *economic development*, (ii) *economic specialization*, (iii) *potential productivity,* (iv) *internal scale economies*, (v) *diversity of products* and (vi) *agglomeration economies*. All variables are lagged since it is expected that the current level of exports of a municipality is heavily influenced by past characteristics. Put another way, the independent and dependent variables are not concomitantly determined. It is standard in the literature to measure the level of *economic development* of a location using gross domestic product (GDP) per capita (see Brodzicki et al., 2018,

[6] Brazilian cities are classified is based on their size, number of networks and area of influence; the classification is provided by Brazilian Institute of Geography and Statistics (2007) and reflects information about the Brazilian urban hierarchy. The institute uses 5 levels of urbanization: metropolis, regional capital, subregional center, zone center and local center.

or Chahad et al., 2003, as examples). Normally, it is difficult to obtain this information at the local level. But in the case of Brazil, the Brazilian Institute of Geography and Statistics (2020) offers this information at the highly disaggregated level of municipalities.

The general picture given by GDP_{pc} can be complemented with information on *economic specialization* measured by the location quotient (LQ) for industry ($LQ_{ind_{t-1}}$), services ($LQ_{ser_{t-1}}$) and public administration ($LQ_{adm_{t-1}}$). The standard specification of the LQ is used[7]:

$$LQ_{sj} = \frac{GVA_{sj}/GVA_j}{GVA_s/GVA} \quad [6]$$

where GVA_{sj} is the gross value added of sector s in municipality j, GVA_j is the GVA of all sectors for municipality j, GVA_s is the total of the specific sectors for all municipalities and GVA is the national GVA for all sectors. Hence, these ratios compare the concentration in the sector for each municipality vis-à-vis the average national concentration (Tsekeris, 2016). The GVA data are also provided at the municipal level by the Brazilian Institute of Geography and Statistics (2020).

Information from formal sector employer-employee records comes from the RAIS (in English, the Annual Registry of Social Information) of the Ministry of Economy (2020a). The three following variables are provided by it.

Human capital (h_{t-1}), defined as the percentage of the population in the municipality with a higher education degree, can be used as a proxy of *potential productivity* since higher education helps develop skills among workers, as described in the seminal work of Mankiw et al. (1992). This variable has been widely applied in the empirical literature: for example, in Brodzicki et al. (2018), De Negri (2006) and Moro et al. (2006), among others.

The percentage of workers living on less than the minimum wage (pov_{t-1}) is a proxy of the *economic development* of the municipality and complements the information given by GDP_{pc}, since both can measure the local livelihood level of a city. This indicator was applied by De Negri (2006), for example, to identify technological clusters over space.

[7] An analysis of the distribution of the introduced LQs has been carried out, observing that there are no very relevant extreme values or very unequal distributions that could affect the estimates.

Internal scale economies, which offer advantages in firms' production process, are considered based on the percentage of employees working in firms with 100 employees or more ($Bfirms_{t-1}$). According to the ideas proposed in Parr et al. (2002), it is possible that large firms have advantages in terms of productivity and access to international markets, which might boost the exports of the municipality. De Negri (2006) also used this measure to verify whether firms that export are more efficient in scale than those that do not export.

The possible effect of a *diversity of products* on the exports of the municipality, which may involve either *scale economies* or a lack of specialization (see Balavac (2012) or Harrigan and Zakrajsek (2000)), is incorporated through a Theil index ($Theil_{t-1}$) of the distribution of municipalities' exports across the Harmonized System (HS4) codes for international trade, the data for which come from the Ministry of Economy (2020b). This index has a range between 0 (minimum diversity) and 1 (maximum diversity), with higher values indicating that the exports are distributed across more products categories. Sectoral intensity is already considered through the location quotients described above, so this index indicates the effect of diversity within sectors.

Finally, the influence of *agglomeration economies*, that is, *urbanization*, is considered based on the population density of local areas ($Density_{t-1}$) and follows a common criterion used by several authors, including Brodzicki et al. (2018) and Tsekeris (2016). This indicator is provided by the Brazilian Institute of Geography and Statistics (2020) at the municipal level. Table 1 presents the descriptive statistics of the abovementioned variables.

Table 1. Variables proposed (all at municipal level) and descriptive statistics, 2007 and 2017

Variable		Description	2007		2017	
			Mean	Std. Dev.	Mean	Std. Dev.
Local exportations	Y	Value of FOB exports in US dollars	30,610,732	233,960,626	40,462,328	280,986,200
Economic specialization	LQindt-1	Location Quotient of industry sector	0.515	0.551	0.623	0.632
	LQsert-1	Location Quotient of service sector	0.612	0.247	0.603	0.236
	LQadmt-1	Location Quotient of administrative sector	2.018	1.032	1.875	0.97
Economic development	Povt-1	% employees earning less than the minimum wage	0.156	0.175	0.091	0.085
	GDPpct-1	Gross Domestic Product per capita	8,163	9,773	21,205	19,964
Internal scale economies	Bfirmst-1	% employees in firms with more than 100 jobs	0.584	0.221	0.525	0.21
Diversity of products	Theilt-1	Theil index SH4 classification of products	0.254	0.569	0.274	0.593
Potential productivity	ht-1	% employees with high education	0.092	0.061	0.178	0.097
Agglomeration economies	Densityt-1	Population in each squared kilometre	20.721	155.874	25.711	181.535

* Independent variables are expressed in terms of the previous year.

5. Main results and discussion

Estimation outcomes

As proposed in section 3, the Poisson global estimation is complemented with the GWGLM approach. The Poisson and GWGLM results are compared based on the Akaike information criterion (AIC) and Bayesian information criterion (BIC). The GWGLM estimates seem to show significant evidence of spatial non-stationarity in the estimations for both periods, revealing that overall parameters do not represent specific local effects. In contrast with the 10 parameters provided by the Poisson (one for each variable and the constant), GWGLM procedure provides a set of parameters for each municipality. As GWGLM provides information about the sign and importance of each effect in each location, it allows us to identify changes in the effect of each variable depending on the location.

For practically purposes, it is necessary to summarize this information to isolate the empirical conclusions. The results of both models are presented in Table 2 (2007) and Table 3 (2017). In these tables, the first column of results presents the estimated Poisson coefficients, while the rest of the columns show the GWGLM coefficient intervals (1^{st} quartile, median, 3^{rd} quartile and maximum).

Table 2. Poisson and GWGLM results in 2007

		Poisson	GWGLM					
			Min	1st quartile	Median	3rd quartile	Max	Non-stationary test
	Constant	17.74 *** (0.0001)	6.837	17.331	18.574	20.38	37.735	***
Economic specialization	$Ln(LQ_{ind})_{t-1}$	1.751 *** (0.00001)	0.788	1.325	1.886	2.117	2.568	***
	$Ln(LQ_{ser})_{t-1}$	2.677 *** (0.00001)	1.316	2.261	2.995	3.311	4.268	***
	$Ln(LQ_{adm})_{t-1}$	-0.572 *** (0.00001)	-3.386	-2.236	-0.593	-0.17	0.456	***
Economic development	$Ln(Pov)_{t-1}$	-0.007 *** (0.000004)	-0.648	-0.204	0.019	0.26	1.055	***
	$Ln(GDP_{pc})_{t-1}$	0.293 *** (0.00001)	-2.002	-0.176	0.341	0.509	1.283	***
Internal scale economies	$Ln(Bfirms)_{t-1}$	0.934 *** (0.00001)	-0.367	0.685	0.941	1.163	3.194	***
Diversity of products	$Theil_{t-1}$	0.181 *** (0.000004)	-0.181	0.074	0.218	0.357	0.612	***
Potential productivity	$Ln(h)_{t-1}$	0.779 *** (0.00001)	-0.963	0.451	0.923	1.254	1.466	***
Agglomeration economies	$Ln(density)_{t-1}$	0.11 *** (0.000002)	-0.273	0.032	0.108	0.188	0.307	***
	AIC	311084892440	239986960142					
	BIC	311084892506	239986960515					

Note: Numbers in parentheses are standard errors. *, **, and *** represent estimates significantly different of zero at 10 percent, 5 percent, and 1 percent, respectively. Stationary test has been made following the procedure in Nakaya (2015).

Table 3. Poisson and GWGLM results in 2017

		Poisson	GWGLM					
			Min	1st quartile	Median	3rd quartile	Max	Non-stationary test
	Constant	7.301 *** (0.00008)	2.817	7.78	8.312	8.818	13.48	***
Economic specialization	$Ln(LQ_{ind})_{t-1}$	1.461 *** (0.00001)	1.167	1.482	1.545	1.589	1.694	***
	$Ln(LQ_{ser})_{t-1}$	2.541 *** (0.00001)	1.968	2.347	2.488	2.667	3.176	***
	$Ln(LQ_{adm})_{t-1}$	0.479 *** (0.00001)	-0.789	0.07	0.549	0.635	0.772	***
Economic development	$Ln(Pov)_{t-1}$	0.356 *** (0.000004)	0.042	0.256	0.389	0.433	0.468	***
	$Ln(GDP_{pc})_{t-1}$	1.336 *** (0.00001)	0.546	1.155	1.247	1.312	1.753	***
Internal scale economies	$Ln(Bfirms)_{t-1}$	0.323 *** (0.00001)	-0.044	0.045	0.172	0.326	0.725	***
Diversity of products	$Theil_{t-1}$	0.014 *** (0.000003)	-0.092	-0.053	-0.021	0.003	0.25	***
Potential productivity	$Ln(h)_{t-1}$	0.753 *** (0.00001)	0.21	0.456	0.843	0.976	1.102	***
Agglomeration economies	$Ln(density)_{t-1}$	0.143 *** (0.000002)	-0.149	0.102	0.204	0.239	0.28	***
	AIC	545988881301	480022271617					
	BIC	545988881367	480022271729					

Note: Numbers in parentheses are standard errors. *, **, and *** represent estimates significantly different of zero at 10 percent, 5 percent, and 1 percent, respectively. Stationary test has been made following the procedure in Nakaya (2015).

Economic specialization: location quotient for industry, services and public administration

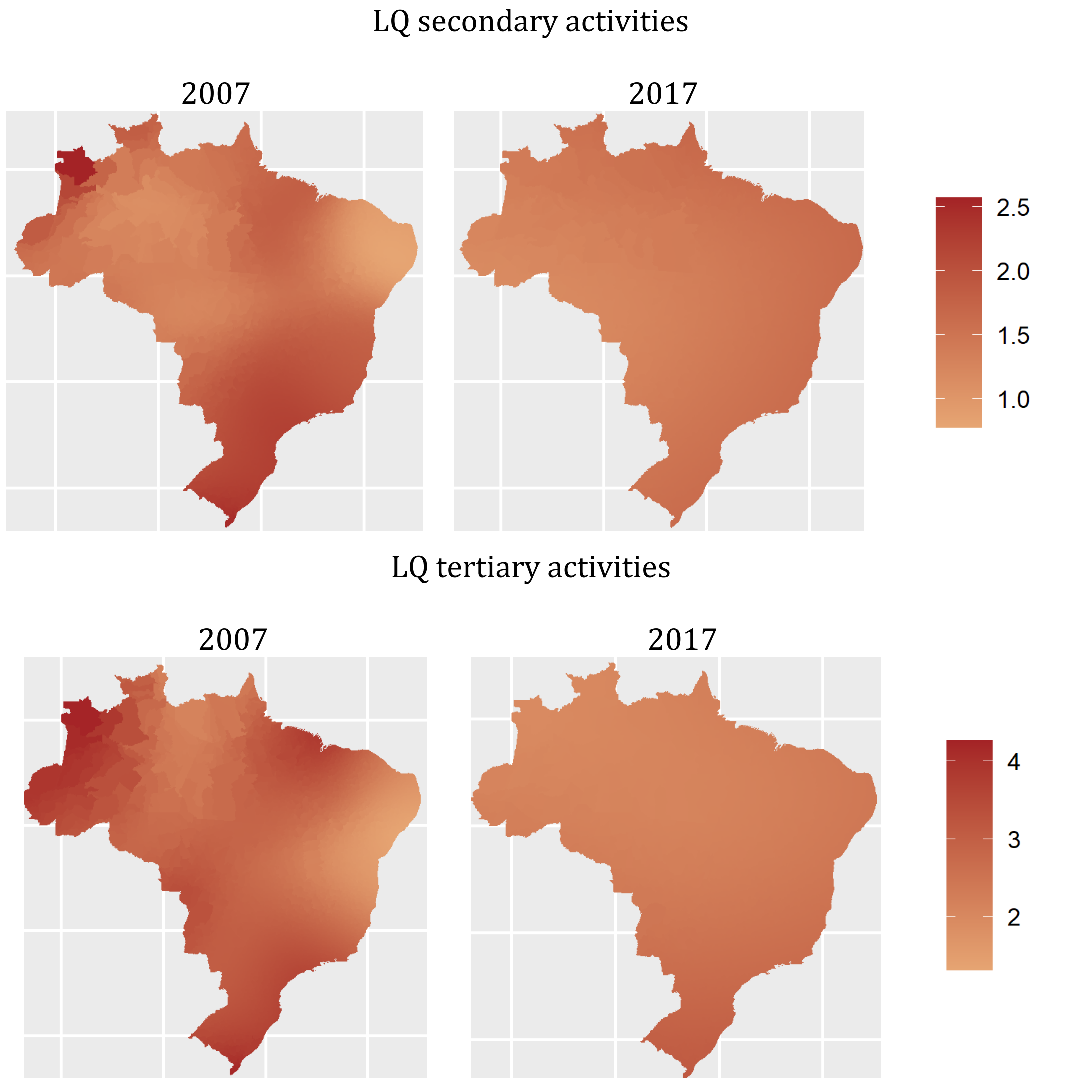
Previous literature has pointed out the relevance of *economic specialization* for a place's export generation (for a summary, see Tsekeris, 2016). According to Brodzicki et al. (2018), deindustrialization could even diminish regional exports, but this aspect can be compensated by an increase in service offerings. According to Chahad et al. (2003), most of the workforce in the Brazilian export sector is in the tertiary sector, followed by agriculture and industry.

The coefficients of these variables are presented in terms of elasticities, assuming a linear relationship in terms of percentual increases. So, their coefficients represent the percentage change in exports when the Location Quotient has a percentage change of one. This interpretation takes into account the initial position of the municipality. So, it has to be noted that an increase in the Location Quotient from 0.5 to 0.6 implies a 20% increase from the initial value.

Our results confirm this conclusion of the previous literature. *LQs* in the global estimation by the Poisson show that one of the most important determinants of location of exports is the specialization in the secondary sector (2007: 1.75; 2017: 1.46) and, to an even greater degree, in tertiary activities (2007: 2.68; 2017: 2.54). This is more clearly observable with GWGLM analysis. High levels of specialization in services and manufacturing are essential determinants of the location of exports across the entire geography of Brazil. Even the minimum estimated coefficients represent a positive influence (2007: services 1.32 and secondary activities 0.79; 2017: services 1.97 and secondary activities 1.17).

In general terms, all the coefficients of *LQ* show a more homogeneous pattern for 2017, which may indicate a more even distribution of economic specialization over space, as seen in Tables 2 and 3 and the spatial representation of the continuous function of its parameters in Figure 2. However, in the case of the influence of secondary and tertiary activities, there is still a greater concentration of high parameters on the Brazilian coast. *LQs* for public administration follow a different logic. In this case, it is imperative to visualize the distribution of the coefficients across the Brazilian territory, and the maps help with this issue. For 2007, the most negative values appear along the horizontal belt of the north and northeast, the least developed regions of Brazil (see Figure 2). These regions hardly participate in international trade and depend heavily on the public sector to generate wealth. This whole zone pulled the overall parameter down to a negative level, with a minimum value of -3.39 for this year. For 2017, this negative tendency decreased, which is reflected in a positive overall parameter. For this year, there is a high concentration of positive values in the mid-western, southern and south-eastern regions of Brazil, its richest areas.

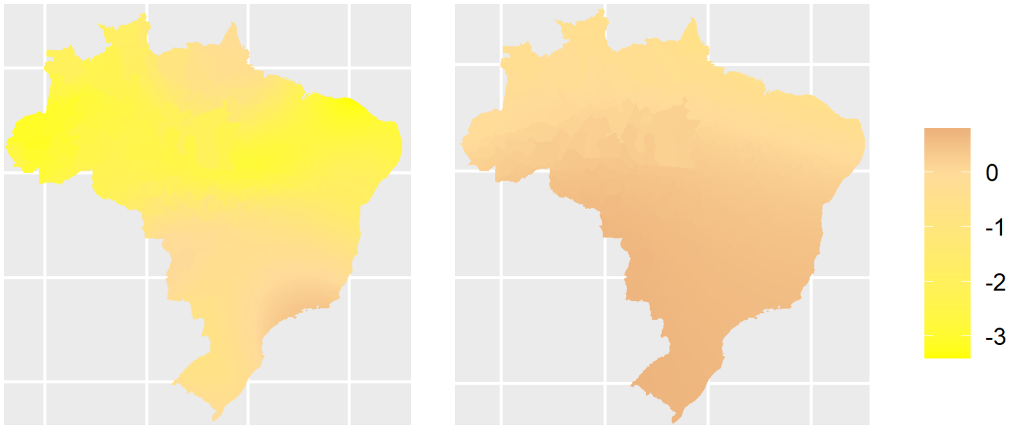
Figure 2. GWGLM results for economic specialization (LQs), 2007 and 2017



LQ public sector activities

2007

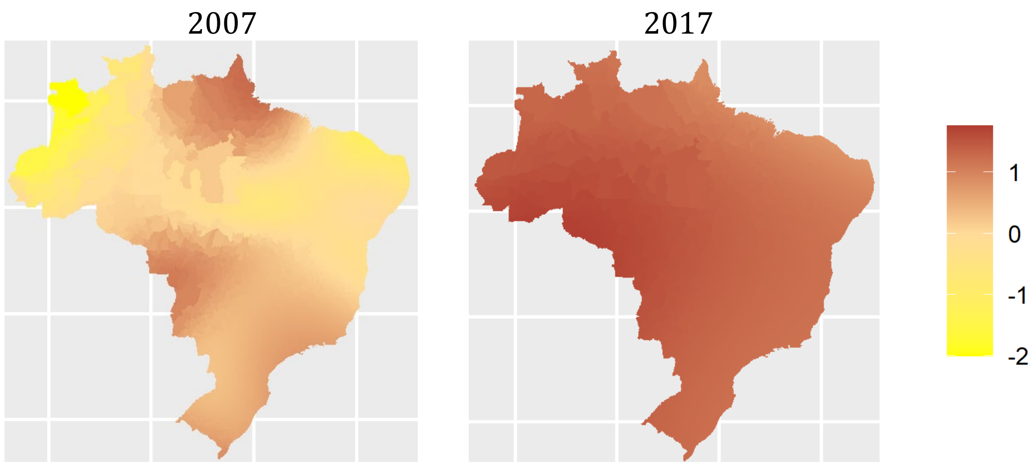
2017



Economic development: GDP per capita and percentage of workers living on less than the minimum wage

We attempt to capture the relevance of local *economic development* with GDP per capita ($GDP_{pc_{t-1}}$). This variable has also been used by Moro et al. (2006), Artuc et al. (2014) and Tsekeris (2016), among others. The parameter of this variable grows dramatically for the analysed years (2007: 0.29; 2017: 1.34). In addition, in the GWGLM estimates, it can be seen that for 2007, there are areas where the sign is negative or very close to zero, while in 2017, the effect of local development on the propensity to export is consistent across the entire geography of Brazil, as shown in Figure 3.

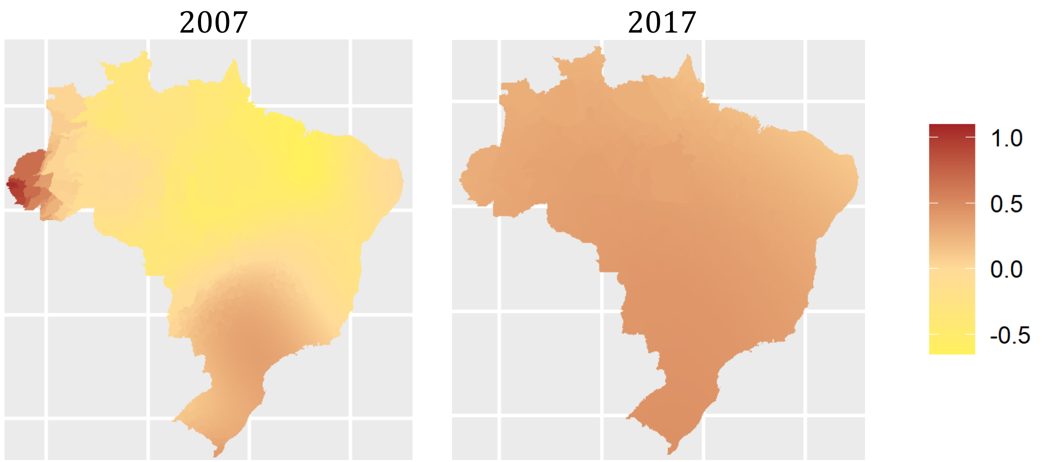
Figure 3. GWGLM results for economic development (GDP_{pc}), 2007 and 2017



GDP_{pc}, as a proxy of economic development, is complemented with the percentage of workers living on less than the minimum wage (pov_{t-1}). As the NEG postulates, markets that are enlarged through the agglomeration process, *ceteris paribus*, have higher real wages (Krugman, 1980). According to De Negri (2006), the average wage of the population of a region in Brazil is what drives its insertion into the international market.

The estimates show an undeniable growth in the effect of this variable, from -0.01 (2007) to 0.36 (2017), as a determinant of Brazilian exports. This increase in the parameter is easily understood when GWGLM outcomes are analysed (see Figure 4). It is found that in some areas within Brazil, there is a null or even a negative relation between wages and exports for 2007 (minimum of -0.65), while the coast has positive values (maximum of 1.05). This trend had changed by 2017, with the overall parameter becoming positive and this positive correlation between wages and exports holding for all Brazilian municipalities. This evidence indicates that an important share of the population has not been able to improve its quality of life, which could easily lead to permanent problems of inequality, with part of the population excluded from productive jobs. This problem was restricted to a few areas in 2007. However, it has quickly spread, becoming a problem across all territories in Brazil.

Figure 4. GWGLM results for economic development (percentage of workers living on less than the minimum wage), 2007 and 2017



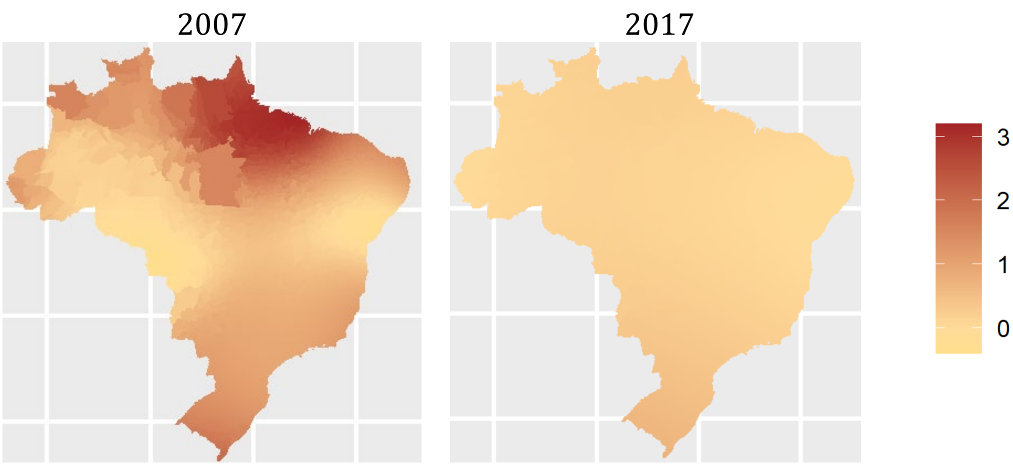
Internal scale economies: firms with 100 employees or more

The importance of firm size has been discussed in the microeconomic literature (see Araújo, 2006). Large firms are more able to incur in fixed costs and take risks. Therefore, in general terms, it is postulated that the larger the firm is, the greater the probability of being in foreign markets. According to this author, in 2003, the existence of large firms, proxied by firms with 100 employees or more, was crucial to generate exports. De Negri (2006) observed similar outcomes for Brazil, concluding that firms that export are, on average, 6.84 times more efficient in scale than those that do not export.

Our results confirm the relevance of this variable, but its influence (although significant) decreases by 65% between the two years (2007: 0.93; 2017: 0.32), indicating that firms of other sizes are also trying to compete in international markets.

GWGLM estimates confirm the relevance of large firms throughout the territory. The parameter for this variable is positive for almost all municipalities and clearly significant throughout the entire territory. However, in comparison with other variables studied, firm size is not one of the main determinants of the export level, especially in 2017. Our results comparing the coefficients over both space and time (see Figure 5) point to the idea that firm size can be very important at the beginning of export development but less crucial once the culture of international trade is clearly established.

Figure 5. GWGLM results for internal scale economies (% of firms with more than 100 employees), 2007 and 2017



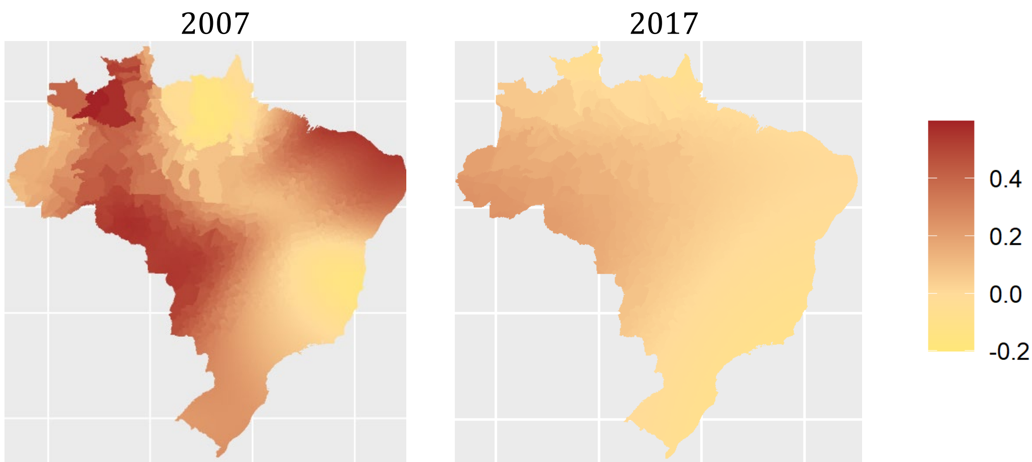
Diversity of products: Theil index

The outcomes for the Theil index, included in the estimation to evaluate the relevance of product diversification across localities. The results show that the impact of product diversification on exports is declining over the analysed years (2007: 0.18; 2017: 0.01).

Matthee and Naudé (2008), studying export generation in South Africa, concluded that local demand in a region positively influences exports by increasing returns to scale. This home market effect is the result of a circular process of a local increasing demand due to increases in export revenues. In conclusion, it can be inferred that product diversity is an important determinant of the export performance of a municipality in Brazil. A result that is expected under the new economic geography framework (Krugman, 1980).

As seen in Figure 6, territories on the coast are developing virtuous circles of specialization or reductions in variety. It is also true that empirical work demonstrates that resource abundance leads to export concentration and therefore that specialization occurs where human capital is an abundant endowment factor (Harrigan and Zakrajsek, 2000). The estimated coefficients for diversity indicate that cities on the coast obtain a diminished advantage from greater variety in their production. Therefore, diversifying production is a reasonable strategy for territories outside this core, where it is not possible (or more difficult) to specialize in only a few products and/or services. This differential effect is coherent with the dynamics of the coefficients and previous research. For Croatia, Artuc et al. (2014) inferred that the varying export performance within the country can be explained by export product diversity. The conclusions of Díaz-Lanchas et al. (2018) applied to Brazil go in the same direction: they found that large cities tend to concentrate on more intense and diversified skills through their workforce, which leads to more specialized exports.

Figure 6. GWGLM results for diversity of products (Theil index HS4 product classification), 2007 and 2017

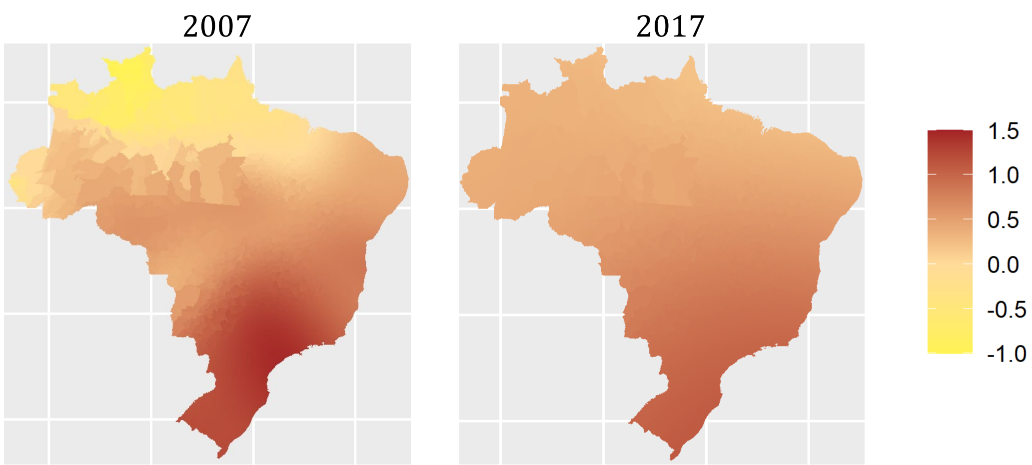


Potential productivity: human capital

The coefficient of *human capital*, that is, the percentage of the population with higher education, also seems to indicate a positive relation between the educational background of employees and the level of exports for both years (2007: 0.78; 2017: 0.75). This goes in line with results from previous literature. For example, Araújo (2006) used this same variable to check if it relates to Brazilian exports and came to the conclusion that workers in exporting firms in Brazil have studied longer than those who work for firms that produce for the domestic market. In the context of Croatia and Poland, Artuc et al. (2014) and Brodzicki et al. (2018) also concluded that the export performance of a region is dependent on the skill ratio of the population.

As with previous variables, the difference between the patterns found on the coast versus those in the interior reappears when the coefficient of human capital is considered (see Figure 7). The influence of this variable can be interpreted in two ways: it captures the positive impact of education on export activity, but it also represents the capacity of a territory to accommodate highly specialized workers in suitable jobs. Therefore, this is a key variable to understand whether a territory is creating a suitable environment for specialization in high-value sectors in the long run. Moreover, if there exists a process of agglomeration, a factor analysed in the following paragraph, it is natural to think that human capital could be easier to employ in the urban areas of the coast. As a result, specialized workers tend to work in areas where they know their *potential productivity* can be realized.

Figure 7. GWGLM results for potential productivity (human capital: percentage of workers with a higher education degree), 2007 and 2017



Agglomeration economies (population density) and location effect

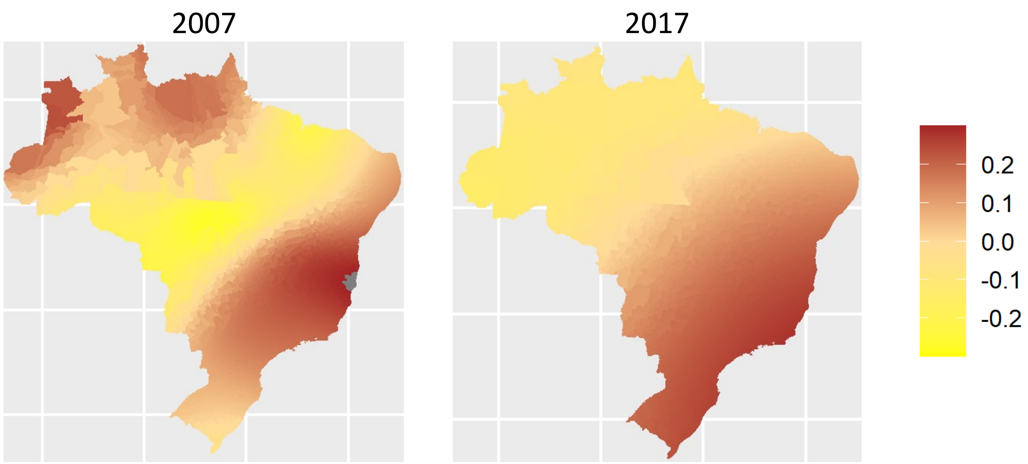
One of the main objectives of this work is to evaluate the importance of territory and location in determining which places are most likely to export. This has been addressed using the GWGLM methodology, which allows us to observe the variation in the coefficients throughout the territory. This type of variation is relevant across all variables. In addition, a centre/periphery pattern is observed in most of them. In the case of Brazil, this pattern corresponds to the coast/interior. However, a specific analysis of the role of agglomeration needs to be addressed.

The coefficient of *population density* shows some growth over the period (2007: 0.11; 2017: 0.14). This result indicates that concentration of population, or economic agglomeration, has maintained its importance for Brazilian exports.

These results are in line with those of other papers, such as Artuc et al. (2014), Brodzicki et al. (2018), Matthee and Naudé (2008) or Tsekeris (2016). Krugman (1980) explained the relationship between these two variables (economic size and exports) through the concept of the home market effect, whereby production tends to become concentrated in larger regions as firms seek economies of scale and low transport costs. He further pointed out that these dynamics are part of the agglomeration process and that trade is an extension of internally developed economic activities. Ciccone (2002) contributed by postulating that this variable reflects whether a municipality is urban or rural. From this perspective, the current results demonstrate that Brazilian exports are more concentrated in urban areas than in rural areas. Other studies have demonstrated similar outcomes for Brazil. Moro et al. (2006) found that firms with a higher probability of exporting concentrate in larger cities. Finally, Bottasso et al. (2018), analysing Brazil's international trade flows, inferred that population size is an important variable for augmenting these flows.

The GWGLM results for population density are even more interesting. The first is that the coefficient of the relationship seems to vary dramatically across Brazil. Figure 8 represents the distribution of these coefficients over space. There are municipalities where this factor even has a negative influence on the openness of the territory or almost no effect at all. Mapping these results reveals a different pattern of agglomeration on the coast than in the upcountry of Brazil. While cities near the coast easily tap into the positive effects of agglomeration (higher population density), leading to higher levels of international integration, inner parts of the country seem to experience growth of diseconomies, where a higher population leads to lower levels of international integration or no effect at all. Indeed, most urban areas are close to the Brazilian coast (of the country's 12 metropolises, 8 have connections to the sea). Urbanized areas are concentrated in the south and southeast regions in Brazil. Even with only 18% of the total territory, these regions are home to 42% of Brazil's metropolises, 63% of its regional capitals, 58% of its subregional centers, 57% of its zone centers and 54% of its local centers (Brazilian Institute of Geography and Statistics, 2007).

Figure 8. GWGLS results for *agglomeration economies* (*population density*), 2007 and 2017



It is also very interesting to associate the conclusions obtained for the agglomeration variable with those related to other variables in our study. For example, if we connect the conclusions on both *population density* and *human capital*, it can be inferred that even considering all export flows in Brazil, without separating types of flows, the turn towards the international market has been conditioned by territorial dynamics. This interpretation is in line with that of other studies on Brazil (see De Negri, 2006; De Negri and Araújo, 2006 and Moro et al., 2006, among others). However, this process does not seem to be easy to start, and there is an important barrier that must be surpassed in some places—or at least, the effects are not the same in every place. Therefore, a strategy focused on a transformation focusing on higher education of the population without taking care to provide the necessary jobs and environment to make workers productive could lead to a weak effect of *human capital*. These results provide a warning to policy makers trying to boost activity in their territories through investments in higher education. On their own, the effects of higher education outside the core of the country might not be enough to generate positive dynamics. In the same way, the process of agglomeration of economic activity, captured through the variables *population density* and *human capital* as well as *economic development* (GDP_{pc}), leads to *economies of scale*, which increase the potential for diversification of these areas, as was pointed out by Balavac (2012).

6. Conclusions and policy recommendations

The analysis of exports in empirical research is usually conducted by modelling national-level macroeconomic variables. However, this type of analysis does not provide much information about the geographical distribution of any detected effects. This paper tries to clarify whether local determinants can modify the quantity of exports of a territory, creating differences within a country. Furthermore, this research tries to determine the mean effect of these variables on the integration of a territory into international markets through exports. To truly capture the different realities of a territory, we estimate local relationships across the country through geographically weighted regressions in the context of a generalized model.

Our results indicate that there are significant advantages associated with variables capturing regional processes of accumulation. That is, agglomerated areas (cities) with higher levels of *population density* and more trained workers tend to be more integrated into international markets. This result indicates that export firms tend not to locate homogeneously in the country and highlights the importance of cities as networks of key nodes in the context of international trade. Given that exporting firms are more dynamic than average firms, higher development of the areas with more suitable environments for these firms is expected. This mechanism was described in the work of Randall, Hewings, Rey, & Gracia (2019) as a backlash effect. When production and employment increase in the most prosperous regions, more wealth is generated there, which leads to income divergence among regions unless specific public policies are applied to reduce it.

In the case of Brazil, given the differences calculated through GWGLM, the same policy formula cannot be applied to every location. As stated by Ribeiro, Domingues, Perobelli, & Hewings (2017), a great share of Brazilian regional inequalities are caused by the industrialization process. For the authors, the high cost of domestic transportation in Brazil has made products from the southeast, the country's most industrialized region, more price competitive, which has led to low industrial participation in the northeast region, for example. On the other hand, regional disparities have decreased slightly over the years, according to Silveira-Neto & Azzoni (2011), and the authors attributed these outcomes to public authorities' actions to minimize them.

The need for local rather than uniform solutions raise the issues of not forcing extreme specialization in a few sectors or expecting the same returns to *human capital* without additional policies. This conclusion is in line with the local perspective proposed in the 'smart specialization strategy' of the European Union (see Foray and Hall (2009) and Barca et al. (2012) among others). From this perspective, a customized economic policy project should be proposed for each location with consideration of local determinants in the analysis.

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Appendix

Table A1. Optimal Cross-Validation Scores

	Gaussian	Bi-square
2007	2.363e+20	2.371e+20
2017	4.202e+20	4.209e+20