The spatiality of recent crises in Brazil: on productive structure and regional resilience in a developing country[1]

Igor S. Tupy[a]

Fernanda Faria Silva[b]

Pedro V. M. Amaral[c]

Anderson T. M. Cavalcante[c]

[a] Departamento de Economia, Universidade Federal de Viçosa (DEE/UFV) – E-mail: igor.tupy@ufv.br; [b] Instituto de Ciências Sociais Aplicadas, Universidade Federal de Ouro Preto (ICSA/UFOP); e [c] Centro de Desenvolvimento e Planejamento Regional, Universidade Federal de Minas Gerais (CEDEPLAR/UFMG).

Abstract: During the last decade, the Brazilian economy was affected by two major recessive shocks. However, their spatiality are still neglected by scholars and policymakers. Thus, we aim to analyze these recessions' spatial structure through Spatial SUR Models, applying theoretical elements of regional resilience literature. Results show great heterogeneity in the crises' territorial extent, key-roles of productive structure in regional resistance and greater impacts of nationwide downturns on less diversified regions, particularly those specialized in extractive activities. This result raises concerns for local economies that are deeply dependent on specialized production in the primary sector, which is typical of developing countries.

Keywords: Crises; Regions; Productive Structure; Resilience; Brazil.

JEL: C31; E32; R13.

Área 6: Crise da Mineração

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1. Introduction

Recent years have been marked by turbulences and disruptions of many kinds in Brazil. After a period of significant growth in the 2000s, the country was since hit by two economic recessions: the first one, derived from the subprime crisis in 2007-8, not only affected the demand for Brazilian main exports, but also brought instability to relative prices and a shortfall of liquidity that severely impaired the national economy.

After an apparent successful strategy of recovery from the effects of the Global Financial Crisis (GFC), a very particular combination of political and economic factors forced the Brazilian economy into a second recession, starting in 2014. The continued slowdown in international growth coupled with a national political turmoil that led to the impeachment of the president forced the country again on a nationwide crisis route. The continued slowdown of the economy raised severe fiscal problems that are now constraining public policies and continuously reducing private actors' confidence to invest.

The occurrence of two major crises in such a short period has raised the attention and concern of academics and policymakers. Moreover, the severity of the recent downturns and the current bad fiscal conditions in many states and municipalities in Brazil have raised important issues regarding the capacity of Brazilian regions to react to these recessive shocks. However, there are still only very few studies that aim to understand the spatiality of such crises.

There is some agreement among scholars and policymakers about the need to understand the place-specific consequences of economic shocks, as well as their spatial patterns at different territorial levels (Di Caro & Fratesi, 2018). As claimed by Martin *et al.* (2016) regions are in a fundamental position, as their ability to contract and recover may significantly alter the outcome of a crises. For this reason, this paper aims to analyze the spatial structure of the crises that reached the Brazilian economy in the last decade, and study its determinants.

The main contribution of this paper is twofold. First, it attempts to shed light on regional resilience patterns from a developing country perspective. As most studies in the literature are focused on developed countries, it is still necessary to discuss the regional particularities of middle- and low-income countries which are often dealing with more vulnerable productive structures, high inequalities and poorly established institutions. The case of Brazil is, therefore, of much importance, given its territorial extension, persistent regional inequality and economic sectoral distribution.

Secondly, this study also contributes in analyzing regional patterns of resilience deriving from two nationwide economic shocks from distinctive natures. The 2008-9 crisis were mainly due to an international shock, while the 2015-2016 recession was more related to internal factors. The analysis of regional patterns between these two recessions, a novelty in the literature, may reinforce the arguments of resilience studies and further support the debates over the fundamental importance of understanding regions as the way to overcome crises and prepare to future ones.

For this purpose, this paper will explore the spatial distribution and the pattern of spatial association of a resistance index based on Martin *et al.* (2016) among 558 Brazilian microregions. A Spatial Lag Seemingly Unrelated Regressions (SUR) Model was estimated for analyzing the role of productive structure on regional resistance. The productive structure of regions was included at the model through a Herfindahl index of economic specialization, Locational Quotient on key-sectors and the Exports-to-GDP ratio. Alternatively, this work also estimated the role of related and unrelated variety on the regional capacity to resist from crises. Applications relating such concepts to regional resilience are still scarce in the regional literature (Cainelli *et al.*, 2018; 2019).

This paper is structured in six sections, including this introduction. The following section presents the discussion of regional resilience after recessive shocks, and in the third section the main theoretical links between economic structure and the resistance dimension of regional resilience are presented. Details on methods and data are explored in Section 4 and the results are discussed in Section 5. The final remarks are presented in the last part.

2. Economic Shocks and the Resilience of Regions

The reappearance of regional issues in economic debates about impacts of the crisis is theoretically reinforced by the emergence of the notion of *regional economic resilience* as a useful tool for understanding the uneven patterns by which local and regional economic systems cope with recessive shocks (Di Caro & Fratesi, 2018; Martin & Sunley, 2015). The idea of resilience has emerged rapidly in policy discourses around regions and localities, focusing attention on the particularly powerful combination of crisis pressures and imperatives for change (Bristow, 2010).

In general terms, resilience is understood as the way a system behaves after being struck by an external shock. This term, commonly used in the exact sciences, such as engineering and physics, in ecology and psychology studies (Pendall *et al.*, 2010, Martin & Sunley, 2015), has been adapted for discussions and studies on regional economies over the past few years. However, many definitions about what it means to be a resilient region can be found in the urban and regional literature.

Within the approach called engineering resilience, which admits the existence of a state of unique equilibrium, as in neoclassical economics, a resilient region retakes a possible pre-shock steady state or path of equilibrium. In the so-called ecological resilience – related to the existence of multiple equilibria – the resilient region is able to reach a new equilibrium trajectory or state, after the shock, where its functions, structures and performance have been improved. Finally, the "evolutionary" resilience considers as a resilient region that with the best ability to constantly adapt and transform its structure, functions and performance due to shocks (Boschma, 2015; Fingleton *et al.*, 2012; Martin, 2012; Martin & Sunley, 2015; Pike *et al.*, 2010).

Economic shocks can take many forms and are likely to have different implications for regions. The shocks originate in the different spatial scales and have as basic characteristics that they are sudden, unexpected and extraordinary events that leads to disruptions in the regional economic dynamic or growth path. Such shocks can be highly destabilizing and are invariably spatially unequal (Boschma, 2015; Martin & Sunley, 2015; Simmie & Martin, 2010).

According to Martin (2012), if an economic shock is too severe, it can change the regional economic structure in such a way that its behavior and expectations do not return to its pre-shock state or path. Therefore, the effect of shocks on regional economies can be permanent (Martin, 2012; Martin *et al.*, 2016). Moreover, regional variation in the depth of shock-induced downturns may create or even exacerbate spatial inequalities through their effects on employment, income and welfare (Martin *et al.*, 2016).

3. Productive Structure and Regional Economic Resilience

The economic structure of regions has been largely pointed to as a major driver of the resilience capacity, in all its dimensions (Angulo *et al.*, 2014; Boschma, 2015; Cainelli *et al.,* 2018, 2019; Martin, 2012; Martin *et al.,* 2016). It is usual to assume that regions with a more diverse economic structure are more resistant to shocks than more specialized structures because a more diverse structure allows regions to "spread risks" of recessions due their industrial "portfolio effects" (Eriksson & Hane-Weijman, 2017; Frenken *et al.*, 2007; Lee, 2014; Martin, 2012; Martin *et al.,* 2016).

A productive diversity provides the local economy with a form of insurance against sector-specific shocks (Lee, 2014) and a variety of opportunities so that even when a productive sector is hit by a shock and grows more lethargic, the region tends to be more resilient to shocks (Holm & Østergaard, 2015).

In contrast, a specialized structure tends to increase the regional vulnerability and reduce its capacity for responses to shocks. If a major recessive shock reaches the main sector of economic activity in a region, there is no scope for other resistant industries to provide some "measure of buffering against the contraction" (Martin *et al*., 2016). Specialized industries depend heavily on the same resources, which results in negative congestion effects (Holm & Østergaard, 2015).

However, a diversified structure does not necessarily guarantee a high level of resistance for the regional economy (Martin, 2012). The reaction of a diversified region to a recession will depend on the degree of relatedness that exists in its structure, for example, when the local industries are skill related, this industrial variety works better as a shock-absorber as long as it enhances regional labor matching (Boschma, 2015). In this case, there is redundancy in the regional economy. This concept is related to situations in which a system is composed of similar components or of components with overlapping, complementary or related functions (Martin & Sunley, 2015). In this case, the failure in one module (let's say a sector) can be compensated for by others. The redundancy "*prevents the destruction of human capital in a region as well as the outflow of high-skilled people to other regions*" (Boschma, 2015, 737).

The notion of related variety implies that the presence of diversified domains that allow the exploitation of complementarities across different industries can be more relevant to resilience than the level of productive diversification, *per se*. Such complementarities might arise, for example, from shared competencies or cognitive proximity among local actors (Cainelli *et al.*, 2018). In this sense, "*diverse regions with many related sectors can also absorb laid-off workers due to the transferability of their human capital resources*" (Eriksson & Hane-Weijman, 2017).

Recent studies provide empirical evidence that related diversification of regions improves their ability to absorb the impacts of shocks (Cainelli *et al.*, 2018; 2019; Sedita *et al.,* 2017). Nevertheless, when the many sectors in the region do not provide complementary resources to each other, they "suffer" from unrelated variety (Boschma, 2015). In this case, it may be important for local sectors to be disconnected in terms of input-output relations to avoid the spread of the crisis through the other sectors (Boschma, 2015).

This situation refers to the concept of modularity. A system presents modularity if its structure has components that are weakly connected such that if one of them is affected by a shock, the effect remains relatively contained. In a regional economy set up, modularity can be a mechanism to contain the shocks and minimize their effects on the whole regional economy (Martin & Sunley, 2015).

Finally, some emphasis has also been given to the importance of the integration of regions into global markets and production networks and their resilience capacity (Eraydin, 2016b), Regions with higher degrees of economic dependence on foreign markets and which have a large export concentration tend to be more exposed to exogenous international shocks (Courvisanos *et al.*, 2016; Eraydin, 2016b): "*especially in periods of recession, regions with higher export and import figures are expected to be more negatively affected by external economic conditions*" (Eraydin, 2016a, 607).

4. Method and Data

The main interest in this paper is to study the spatial dynamics of the recent macroeconomic crisis that reached Brazil. For this propose, the methodological choice followed the national business cycle dating based on empirical works such as Martin (2012) and Fingleton *et al.* (2012). The years of recessionary shocks were identified as being those years in which national GDP growth rate was negative.

The main interest here was to compare the regional patterns on the initial impacts of both major shocks in the Brazilian economy during the last decades namely, the financial crisis of 2008 and the Brazilian economic recession that started in 2015. In order to make methodological procedures more consistent and due to the lack of data available to the recent post-crisis period, our analysis focuses on the resistance dimension, that is, the initial impacts of the shock on the economy of a region (Martin & Sunley, 2015). Meanwhile, it is important to understand that regional economic resilience involves other dimensions, for example recovery, re-orientation and renewal (Martin, 2012).

The analysis of regional resistance to the nationwide recessions will be based on a relative resistance index, the *Resis*, proposed by Martin *et al*. (2016). The index was measured by the real GDP[2], using the latest data available. Given the national behavior of the GDP and the availability of data with a regional set up, we define two periods of recessionary shocks: 2009, the year in which the impacts of the GFC have caused an annual decrease in aggregate production; and 2015/2016, years of the current crisis applied to the 558 microregions.

This indicator is based on a particular "counterfactual" reaction of the regional economic activity. The interest of this exploratory measure is to ask how different regions are affected by a nationwide recession. The expectation is that, *ceteris paribus*, each regional product would contract (during the recession) at the same rate as its national counterpart. We define the expected change in GDP in region *r* during a recession of *k* periods as

$$(\Delta Y_r^{t+k})^e = \sum_i g_{..}^{t+k} Y_{ir}^t \qquad (1)$$

In which $g_{..}^{t+k}$ is the rate of contraction of national GDP between time *t* and *t*+*k* and Y_{ir}^t is the product in industry i in region r in starting time t base year – turning point into recession. One can define the measure of resistance to the region *r* as

$$Resis_r = \frac{(\Delta Y_r^{Contraction}) - (\Delta Y_r^{Contraction})^{expected}}{\left|(\Delta Y_r^{Contraction})^{expected}\right|} \qquad (2)$$

Following Martin *et al.* (2016), the resistance index is centered around zero, with positive values of *Resis* indicating that the region is more resistant (less affected) by the

[2] Source of data and specific treatments can be found at Table A1 (Appendix A).

recession than the national economy. Negative values, then, mean that a region is less resistant (more affected) than the overall national economy.

4.1. Spatial Seemingly Unrelated Regression with Spatial Lag.

The role of the productive structure in the regional capacity to resist the two shocks in the Brazilian economy was estimated through a Spatial SUR with a Spatial Lag, following Anselin (1988a, 1988b, 2006) and Anselin, Le Gallo and Jayet (2008). Our data consist of a cross-section for only two periods, and since the equations pertain to cross-sections, the Spatial SUR specification is an appropriate choice. In this model, the objective was to estimate the cross-sectional dependence relying on the time dimension (see Anselin *et al.*, 2008).

The Spatial SUR Model allows us to test different types of hypothesis without the need for specifying a complete structure for the temporal correlation. Thus, in practice there is a nonparametric, unspecified serial correlation. This correlation between different time periods will come from the correlation between the residuals of the different periods (Anselin, 2006; Anselin *et al.*, 2008).

The model is composed of a cross-sectional regression for each *t*. The Spatial SUR can be described as a generalization of a temporal fixed effects model, but this is an even more general case than the case in which there are only different intercepts at different points in time. In this case, there is a different β for each time period *t.* This generates efficiency gains from exploiting the cross-equation covariance (Anselin, 2006; Anselin *et al.*, 2008).

In the Spatial Lag SUR Model, the autoregressive coefficient is allowed to vary by time period. Therefore, for each period

$$y_t = \rho_t W_N y_t + X_t \beta_t + \varepsilon_t \qquad (3)$$

In the stacked form, this model can be described as

$$y = \rho(I_t \otimes W_N)y + X\beta + \varepsilon \qquad (4)$$

W_n is the spatial weight matrix and ε_t is the error term. $\otimes$ is the operator of the Kronecker product. The serial correlation is constant across cross-sectional units, that is, the effect over time is the same across the regions, $E[\varepsilon_{it}, \varepsilon_{is}] = \sigma_{ts}$. The cross-equation correlation is

$$E[\varepsilon'\varepsilon] = \Sigma_T \otimes I_N \qquad (5)$$

This model was estimated by using a Three Stages Generalized Least Squares, 3SGLS estimator (see Anselin, 1988b, 2006). The Spatial SUR Model also allows us to test many important hypotheses on the coefficients across time. This is a special case of the Chow test, which is reported in Table B4, in the appendix. The focus of this paper consisted of testing whether the Spatial Lag of the *Resis* index was the same over time, that is, if there is a stable spatial structure on the explanation of the crises' regional set up.

Regarding the X Matrix, two specifications were tested to verify the role of productive structure. In the first model, the X matrix contains: Natural logarithm of GDP *per capita*, Populational Density, Exports-to-GDP ratio, Herfindahl index, sectorial specialization dummies and dummies to the Brazil Macro-regions. In the alternative specification, the Herfindahl index is changed by the indicators of related variety and unrelated variety.

The Herfindahl index was used in order to measure the specialization of local economic activity. The higher the index, the more specialized is the region in a particular set of industries (Brown & Greenbaum, 2017; Doran & Fingleton, 2018).

$$herf_{rt} = \sum_i \left(\frac{E_{ir}^t}{E_{\cdot r}^t}\right)^2 \qquad (6)$$

Where E_{ir}^t is the formal employment in industry *i* in region *r* during the period *t* and $E_{\cdot r}^t$ is the total employment in region *i* at the same period *t*. The model also includes sectoral dummy variables for which the purpose is to capture the regional specialization in specific sectors: agriculture, extractive activities, manufacturing, construction, commerce, services and public administration.

In order to provide sectoral dummies, the Locational Quotient (LQ) was computed as the regional share of workers in a specific sector divided by the national share of workers in the same sector. Regions with LQ larger than one to a specific sector were considered more specialized than average in this sector (Angulo *et al.*, 2014). To these regions, the sectoral dummies assume the value of one, otherwise they are zero.

Following Frenken *et al.* (2007), the proxies for regional related and unrelated variety are based on entropy measures. This methodology has as its advantage the possibility to be decomposed at each sectoral level of employment, entering a regression analysis without necessarily causing collinearity (Frenken *et al.*, 2007). In this work, the entropy measures are computed using formal employment data, available at the RAIS[3] at different levels according the CNAE 2.0 (National Classification of Economic Activities).

According to Frenken *et al.'s* (2007) notation, consider the participation of each *i* class of economic activity. P_i is the participation of each class on total employment. One can aggregate this into a higher level of economic activity, S_g, where $g = 1, \dots, G$. Thus, the participation of each class of activity, P_g, can be derived from the sum of lower-level activities:

$$P_g = \sum_{i \in S_g} P_i \qquad (7)$$

The measure of *unrelated variety* is the entropy at the higher level (section).

$$UV = \sum_{g=1}^{G} P_g log_2 \left({}^{1}/_{P_g} \right) \qquad (8)$$

The *related variety* is based on a weighted sum of the entropy measure at the lower level of activity, CNAE class, within each higher level of activity. The entropy at the classes within the section of activities, H_g, can be expressed by

$$H_g = \sum_{i \in S_g} \frac{P_i}{P_g} log_2 \left(\frac{1}{P_i / P_g} \right) \qquad (9)$$

The *related variety*, then, is this entropy measure weighted by P_g.

$$RV = \sum_{g=1}^{G} P_g H_g \qquad (10)$$

The natural logarithm of GDP *per capita* was included to control to the pre-crisis level of economic activity on each region. Considering similar constraints in data at

[3] See Table A1.

regional level as in this study, Giannakis and Bruggeman (2017) used this measure to compare the economic well-being of regional citizens. Population density was used as proxy for urbanization economies, and it was measured by the number of inhabitants per km².

The export-orientation of the regional economies was measured by the Exports-to-GDP ratio as an indicator of the openness of a regional economy to global economic volatilities and external threats (Eraydin, 2016b). The high participation of the primary sector in Brazilian exports implies that many regions have become too exposed to cycles in commodity prices. Moreover, the reduction of the international demand to Brazilian products, mainly commodities, during the GFC, was an important transmission channel of its impacts on the national economy (Freitas, 2009).

Even though our model contains the Spatial Lag of the dependent variable, we included also Macro-regional dummies (North, Northeast, Center-West and South), with the Southeast Region as the basis. As used by Sedita *et al. (2017)*, the Macro-geographical area dummies can be considered proxies to institutional structure which, despite being an important variable, is often neglected in the resilience literature.

The analysis will be based on a distance weight matrix W, where each w_{ij} is the inverse of squared Euclidian distance between the centroid of region *i* and region *j*, with $i \neq j$. In order to test the robustness of results, the same analysis and estimations were made using an alternatives weights matrix (contiguity matrix Queen of order 1, and a 4-nearest neighbors). The main results of the exploratory analysis and the model estimation do not change significantly, which indicates the robustness of the results.[4]

5. Results and Discussion

During the last decade, the Brazilian economy was reached by two major recessive shocks in terms of production. When the effects of the global financial crisis hit Brazil, its economy was passing through a period of robust growth due to the combination of a favorable external scenario in respect to the exports of commodities and the impacts of the redistributive policies that were implemented from 2003. The subprime crisis and the economic downturn that followed were the main factors for the fall on the international price of commodities, the decrease on the demand for Brazilian exports, and a liquidity reduction in international markets (Freitas, 2009). Even though the global crisis impacted production starting in the last quarter of 2008, it was not until in 2009 that Brazil registered a real decrease on GDP in annual terms. As shown in Figure 1, the GFC caused a downturn of -0.13% on aggregate real GDP.

[4] See Supplementary Data.

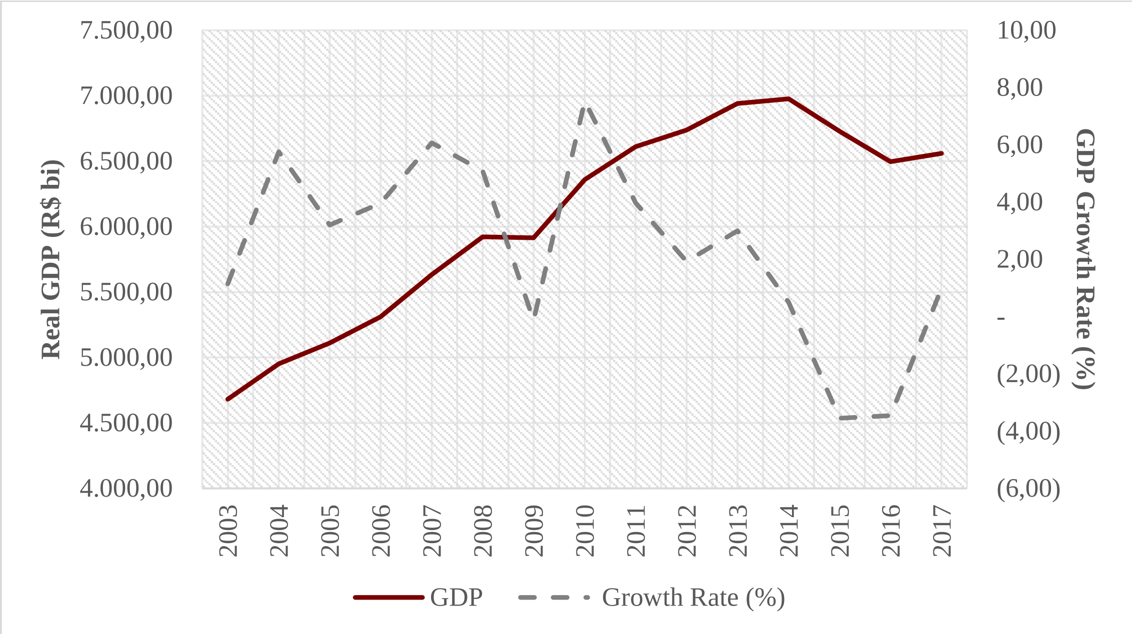

Figure 1. Growth Path of Brazil's Real GDP, 2003 - 2017.
Source: Own elaboration based

After a brief period of recovery from the global crisis, the Brazilian economy began a new downward phase of the cycle in 2013, having reached a recessive stage in 2015 which continued throughout all of 2016. The Brazilian crisis lead to decreases of -3.55% and -3.46% of real GDP during 2015 and 2016, respectively. Given the characteristics of the current crisis in terms of depth and duration, the downturn extended itself during eight sequential quarters.

Although many works have been published since then trying to explain the causes of such severe recession and also to show the differences between both crises in terms of nature, impacts and reactions[5], however, most of these studies have neglected the territorial features of both crises. As claimed by Fratesi and Perucca (2018), the macroeconomic country-level impacts of the crises are very important, but the impact on various regions within countries has been far from uniform. This paper is aiming to remedy the omission of this spatial dimension of the crisis in the debate.

The maps in Figure 2 illustrate the geographical distribution of these downturns, where two quite distinct spatial settings can be observed. On the one hand, we can clearly delimit the spatial frame of the national recession during the GFC to a small number of specific locations. On the other hand, the unprecedented nature of the more recent crisis also expresses itself by its wide diffusion across space.

[5] See for example Nassif (2017) and Prates et al. (2017).

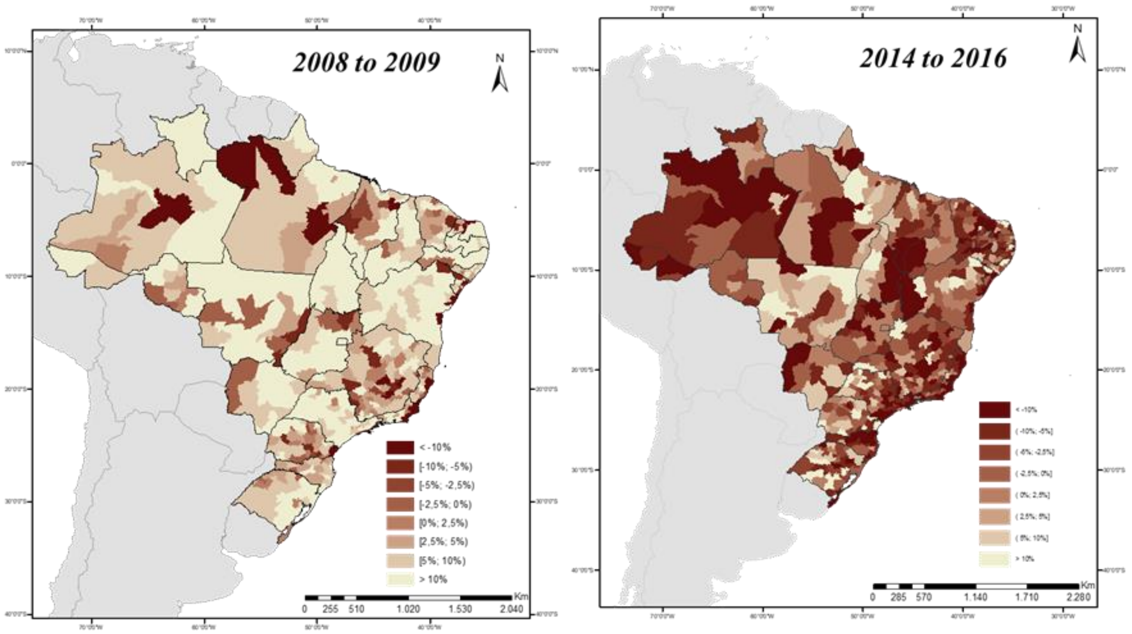

Figure 2. The Geography of Brazilian Downturns: Real GDP decline/growth rate.
Source: Own elaboration based on IBGE dataset "GDP of Brazilian Municipalities". Aggregated to the microregional level. GDP deflationated by the IGP-DI.

The darker the colors in the maps of Figure 2, the deeper was the recession in each microregion. The results of the maps present an important distinction between these two recessive shocks in terms of territorial extent. Although shocks are a recurrent feature of economic systems, their incidence and geography tends to be highly uneven. In this sense, we can classify the most recent Brazilian recession as a "system-wide shock." Different from the subprime shock, which was mostly concentrated in the richest regions of Brazil, i.e. the Southeastern region, the latter crisis has a generalized spatial feature that has been deeply ignored by academics and policymakers in Brazil. The conjunctural Brazilian crisis has definitely spread and materialized across all geographical space, reaching the production level of the major part of regions in the country.

Nevertheless, it is necessary to investigate these patterns to look also into similarities that are not evident at first glance. To this, the resistance relative index, detailed in Section 3, will be used. As stated before, the *Resis* compares the regional performance during the crisis with the national performance. Regions with *Resis* larger than zero will be classified as "Resistant Regions" and as "Non-Resistant Regions" otherwise[6]. During the 2009 recession, 46 out of 558 Brazilian regions were classified as non-resilient regions. This number increased to 181 regions during the 2015/2016 recession.

To compare these results between both periods, we adopted a classification of four groups to Brazilian regions according to their capacity to resist crises[7]. Groups II and IV are composed of regions resistant to only one crisis. Regions in Group II improved their capacity to resist shocks during the period, while the resistance of regions in Group IV has gotten worse. Regions within Group I are the resistant regions, the best case. Then, in Group III are the non-resistant regions, the worst case. 342 regions can be classified as

[6] Figure A1 (at the Appendix A) illustrates this classification across the territory to both periods.

[7] Adapted from a taxonomy suggested by Martin *et al.* (2016) and Faggian *et al.* (2017). See Figure A2, at the Appendix A.

resistant to both crises in Brazil. At the same time, 34 microregions are classified as non-resistant regions for being in Group III. Figure 3 offers a representation of this taxonomy.

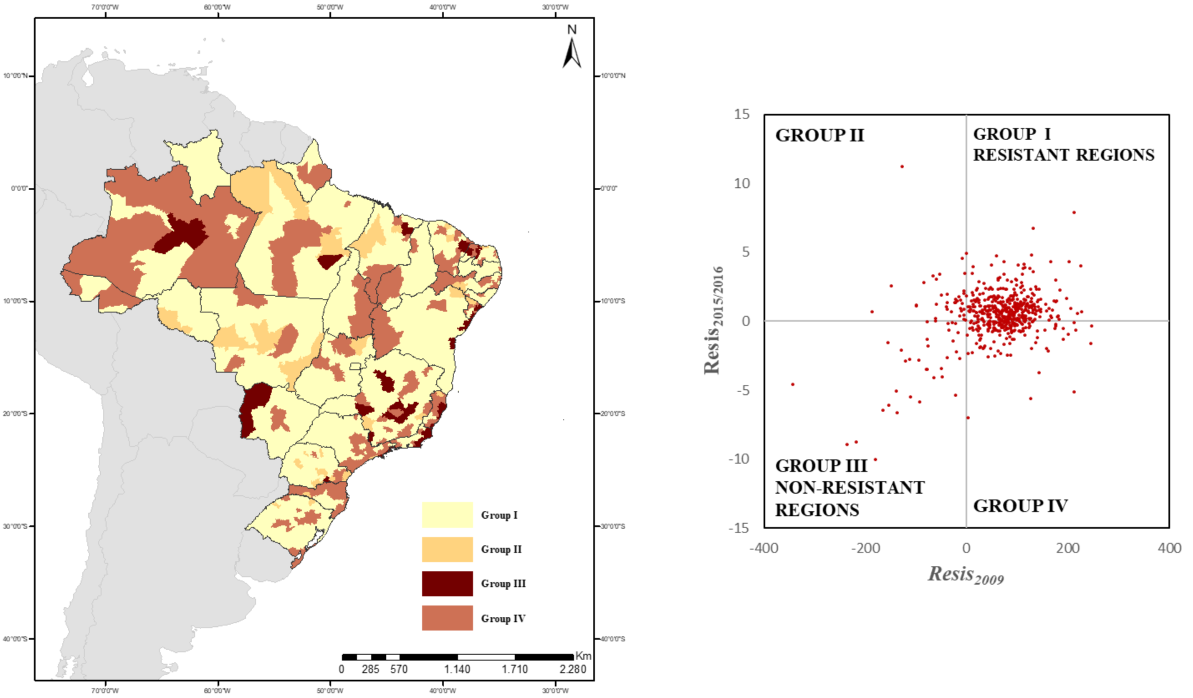

Figure 3. Resistance Taxonomy between crises: 2009 and 2015/2016
Source: Own elaboration based on IBGE dataset.

During the 2009 downturn, regions dependent on the external markets were between the most affected ones, such as the regions of Santos and Paranaguá, where two of the most important Brazilian ports are located. Minas Gerais concentrated a large number of regions in recession already during 2009 downturn and many of them stayed non-resistant to the current crisis. The weakness of the Metropolitan area, mainly regarding mining microregions (Ouro Preto, Itabira and Conselheiro Lafaiete) can be evidenced. A similar frame was perceived in the microregion of Ipatinga, located in the “Vale do Aço” – Steel Valley – specialized in metallurgy and heavily dependent on the activity of a single firm.

Iron and Steel are the main items at Minas Gerais export agenda (Campolina & Cavalcante, 2016). The non-resistant regions of Itabira and Ouro Preto, specifically, are the most dependent regions on the mining-metallurgical international chain (Reis & Silva, 2015). Similar cases were observed, particularly during the global crisis, in the state of Pará. The most sensitive regions were those specialized in mining activities. In the Southeast of the State are the microregions of Parauapebas and Marabá and, in the North, Santarém.

In the State of Rio de Janeiro, we observed high contractions on production during the crises mainly in the microregions of Macaé, Campos dos Goytacazes, Bacia de São João and Lagos, in the north coast. These regions are highly concentrated and dependent on the petroleum production, given the proximity between them and the Campos Basin. Economic activity on these regions are also heavily dependent on the dynamics of external markets (Hasenclever *et al.*, 2017).

The share of the extractive activities, mainly of oil and gas, had increased in the economy of the whole State in the last years. Hasenclever *et al.* (2017) state that the structural changes in the economic activity of the state were directed to a high productive specialization focusing on the extractive industry. This movement is due to new discoveries of marine oil fields located on the north of the state (Hasenclever, Cavalieri, et al., 2017; Hasenclever, Filho, et al., 2017).

According Hasenclever *et al.* (2017), these activities have an internationalized nature that can be problematic to the regional development (and, thus, to resilience), since they are subordinated to the volatility in the prices of commodities and Exchange rate movements. The dependence the extraction of oil and gas is also relevant to explain the low resistance of the microregion of Coari, located at Amazon region.

This analysis allows for the identification of some patterns on the impacts of both crises, in terms of the resistant and non-resistant regions and, at the same time, points to regions that changed their relative responses in the period. In addition, this paper applies an Exploratory Spatial Data Analysis (ESDA) to access the spatial association of the regional resistance.

The Moran's I index indicates a positive spatial association to the *Resis* index. The index for 2009 was 0.118 and for 2016/15 it was 0.113, both significant at 1%. This means that resistant regions tend to be close to other resistant regions. The next figure illustrates the local patterns of univariate association to the resistance index. The formation of clusters High-High, Low-Low, High-Low and Low-High was based on the Local Indicator of Spatial Association (LISA).

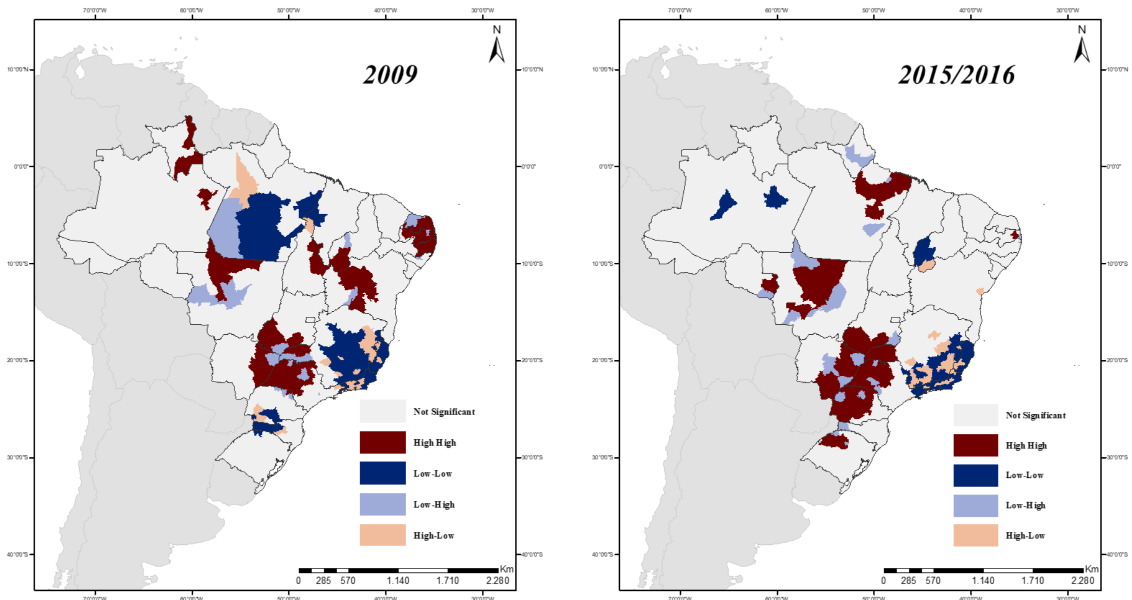

Figure 4. Cluster Maps – Local Indicator of Spatial Autocorrelation to Microregional Resistance

Source: Own elaboration based on IBGE dataset. Software: GEODA. Spatial Weights Matrix: Inverse of Squared Distance (centroids). Distance Metric: Euclidian Distance.

Again, the focus of this study is on exploring the concentration of less resistant regions. One can see that for both crises, there is a formation of a very large cluster of Low-Low that is mainly located in Southeastern Brazil. Although one may perceive an important difference in the spatial intensity and spread of both crises, there is a pattern between the two crises regarding the most affected regions and their spatial association. It is evident the role of the mining microregions (Minas Gerais) and the petroleum and gas extractive regions (Rio de Janeiro) on the formation of this Low-Low cluster. In both cases, beyond the role of the specialization in extractive activities itself, there is also a high influence on the volatile prices of commodities and of their link and dependence on external sectors (Hasenclever *et al.,* 2017; Reis & Silva, 2015).

After identifying these patterns on the geography of the Brazilian crises, this paper next step is to further investigate the role of the elements of productive structures on the regional resistance to crises. In order to do this, Spatial Lag SUR Models were used, which allowed to make correlations between the error terms in both equations[8]. The estimation results for the distance matrix are showed in Table 1, below.

[8] A robust LM test indicates the use of a Spatial Lag rather than a Spatial Error Term. For the diagnostics for spatial dependence on the errors, Moran's I, Lagrange Multiplier (LM) Tests, and the Anselin-Kalejian test for different specifications, please refer to Table B1 and B2 in the Appendix B.

	Model 1		Model 2	
	2009	2015/2016	2009	2015/2016
Constant	**246.0786*** **	**5.9631*** **	**163.7127*** **	**4.2990*** **
	(22.7840)	**(0.8761)**	**(22.5791)**	**(0.6534)**
W_Resis	**0.5226*** **	**0.7685** **	**0.4589*** **	**0.8165*** **
	(0.1373)	**(0.1470)**	**(0.1375)**	**(0.1446)**
ln (GDP per capita)	**-63.0631*** **	**-1.9405*** **	**-64.2882*** **	**-1.9167*** **
	(6.4188)	**(0.1989)**	**(6.4485)**	**(0.1987)**
Population Density	**0.0177** **	**0.0005** **	**0.0134* **	**0.0005* **
	(0.0076)	**(0.0002)**	**(0.0077)**	**(0.0002)**
Export/GDP ratio	**-1.3885*** **	0.0133	**-1.2190*** **	0.0109
	(0.4165)	(0.0133)	**(0.4214)**	(0.0136)
Herfindhal Index	**-97.4963*** **	**-1.6271*** **	-	-
	(19.9408)	**(0.5948)**		
Unrelated Variety	-	-	5.9473	**0.4931** **
			(8.5086)	**(0.2456)**
Related Variety	-	-	**20.3042*** **	-0.0147
			(6.1740)	(0.1713)
Agriculture	-9.4821	**0.4682*** **	-2.1037	**0.4447*** **
	(6.0435)	**(0.1636)**	(6.2716)	**(0.1683)**
Extractive Activities	**-22.7381*** **	**-0.2435* **	**-20.4099*** **	**-0.2530* **
	(5.6060)	**(0.1510)**	**(5.7363)**	**(0.1535)**
Manufacturing	**10.7224* **	0.2297	**10.7778* **	**0.2910* **
	(6.4005)	(0.1636)	**(6.3972)**	**(0.1651)**
Construction	**-17.3184*** **	-0.0675	**-16.4883** **	-0.1171
	(6.6474)	(0.1821)	**(6.8022)**	(0.1881)
Public Administration	**-21.5361*** **	**-0.3984* **	-13.0585	**-0.3914* **
	(7.6455)	**(0.2063)**	(8.0456)	**(0.2189)**
Services	-0.4150	0.3491	1.4398	0.2786
	(10.2462)	(0.2794)	(10.4463)	(0.2855)
North	8.4952	-0.0960	14.0333	-0.0831
	(10.4772)	(0.2780)	(10.6390)	(0.2813)
Northeast	**-16.8204* **	**-0.5788** **	-10.9374	**-0.5512** **
	(9.6296)	**(0.2325)**	(9.7936)	**(0.2366)**
South	-5.0316	**0.5060** **	-4.7654	**0.5187** **
	(7.6383)	**(0.2285)**	(7.6817)	**(0.2294)**
Center-West	**31.1087*** **	**0.5942** **	**38.7947*** **	**0.5939** **
	(10.7322)	**(0.2934)**	**(10.8556)**	**(0.2954)**

Table 1. Spatial Lag SUR Models[1]. Dependent Variables: Resis Index
Notes: [1]Standard Errors at parentheses. Spatial Weight Matrix: Inverse of Squared Distance (centroids). Distance Metric: Euclidian Distance. *** p < 0,01; ** p < 0,05, * p < 0,1.

In this part of analysis, the first objective is to investigate the spatial structure that determines the resistance to the crisis. The Spatial Lag coefficient was positive and significant to both crises. Thus, there is a positive relation between the resistance of a region after an aggregate shock and the resistance pattern in its neighbor regions. Furthermore, the spatial autoregressive component of the regional resistance remained statistically the same to the analyzed periods. This spatial stability is confirmed by the Chow test in the appendix (Table B4). Therefore, due to such spatial dependence, the economic performance of a region during the national crises tends to be similar to the performance of the closest regions. This implies the existence of some spillover effect that would spread the effects of the exogenous shock – for example, flows of capital, labor, trade or commuters (Angulo *et al*., 2018).

It also became evident that there were some macro-regional patterns on the sensitivity to the effects of both crises. The most significative of them is that the regions located in the Center-Western area of Brazil have systematically resisted better than others. Both models showed also that regions in the South were more resistant than those in the Southeast (and, respectively in North and Northeast). For its turn, after controlling for the pre-crisis economic level of income, urbanization and industrial structure, Northeastern regions were less able to resist during the crises. This result did not maintain its significance to GFC when the Herfindahl index was replaced by the related and unrelated variety.

The second focus of this analysis was on explaining how the regional economic structure shapes its capacity to resist to a nationwide recessive shock. The first implication that emerged from the results was that productive specialization reduces the regional capacity to resist to crises in Brazil. The Herfindahl index, which measures the regional specialization level in terms of employment in the first model, was highly significant and negatively related to *Resis* in both periods.

In tandem with the theoretical framework discussed (section 3), the nature of sectoral specialization was also relevant for understanding the geography of crises in Brazil. In particular, we can indicate that the role of sectoral-specific specialization depends on the nature of each shock, except in the case of extractive activities. As expected, in the exploratory analysis of the second model, it was verified that the regions that specialized in these kinds of activities were less resistant in both crises. Specialization in manufacturing can be associated with higher resistance during the GFC, and regions specialized in agriculture and services performed better during the current crisis. Results also show that during the GFC, the specialization in the construction sector and public administration increased the sensitiveness of the microregions to negative shocks.

But if the results lead to conclude that specialization tends to reduce the resistance, they also make clear that diversity *per se* does not guarantee a better performance during both sorts of shocks in Brazil. In the alternative specification, the Herfindahl index was substituted by the measures of related and unrelated variety. Results showed that related variety was significant to increase the resistance to the GFC, while the unrelated variety was relevant to explaining higher resistance to the current crisis. On the one hand, related variety improves regional resistance because related sectors can re-absorb shocks more quickly than others, through redundancy. On the other hand, unrelated variety allows the regional economy to isolate the effect of idiosyncratic sector-specific shocks through modularity (Diodato & Weterings, 2015).

As shown in Table 1, the local weight of exports on regional economies was significant only to the 2009 downturn. For this period, the Exports-to-GDP ratio was highly significant and negatively related with the regional resistance. This was due to the role of the decrease on international trades and the transmission of its effect to Brazil (Freitas, 2009). In this sense, Eriksson and Hane-Weijman (2017) stress that this crisis primarily affected export-oriented sectors. This result does not allow to assert that more exported-oriented regions were necessarily more affected by the crisis. However, this causal effect depends on the nature of the shock, being highly relevant during international disruptions. Fratesi and Rodríguez-Pose (2016) argue that those European regional economies that were more dependent on exports were more adversely affected during the initial stages of this downturn. This was particularly significant for regions specialized in *"products for which price is an important determinant of international competitiveness*" (Fratesi & Rodríguez-Pose, 2016, p. 36). This feature is particularly appropriate for explaining the case of Brazilian regions specialized in mining and oil extraction.

The results provided by this study suggest that regions with higher pre-crisis GDP *per capita* were more affected by the nationwide recessions, that is, they were less resistant. Thus, the success of a regional economy is not enough to ensure a good capacity to deal with the first impacts of the aggregate crises. Indeed, resilience is not necessarily conditioned by a higher level of previous economic success. As stated by Christopherson *et al.* (2010), *"…what looks like and is portrayed as regional success in one era does not necessarily look the same when conditions change*" (p. 6).

A resilient region is not only economically successful but manages to keep its status over time when facing the inevitable adaptations that are required by shock-induced changes in the system (Christopherson *et al.*, 2010). Thus, resilience involves maintaining that success in the future, particularly when the region is faced with an economic recession or other challenges. The likelihood that success will hold up over time will depend crucially on their ability to adapt to changing circumstances and adjust to external shocks when they occur. Finally, it is possible to observe a positive association between population density and regional resistance to both crises in Brazil. Therefore, regions with higher degrees of urbanization were more able to cope with the initial effects of both crises in Brazil.

6. Conclusions

This study aimed to investigate similarities and differences between the spatial patterns of recent Brazilian economic crises. Recent discussions of the economic resilience of regions were considered in order to explore the determinants of its resistance dimension. The analysis allows the observation of distinct spatial features among these two recessive shocks. While the national recession related to the GFC hit the Brazilian territory in some very specific locations, the recessive crisis starting in 2015 is indeed a territorially generalized crisis.

However, by analyzing the similarities in both crises, one can see that the most affected regions, such as Minas Gerais and Rio de Janeiro, have the highest concentration of non-resistant regions. Based on the LISA, using a distance matrix, a significant part of Southeastern Brazil can be classified in a single Low-Low spatial cluster, in which low-resistant regions are surrounded by other low-resistant regions.

The focus on Southeastern Brazil is relevant not only because of the position it has in the national economy but also because two out of the four states in the region (namely Minas Gerais and Rio de Janeiro) are now facing their own deep fiscal crises. It seems evident that such a low capacity of resistance, which certainly reflects a lack of resilience as a whole, on the local dynamic centers of economic activity, combined with sequential recessive shocks, have contributed to local governmental fiscal problems. In these states, the tax revenues from mining, oil, and gas activities correspond to a high percentage of the total budget of the state governments.

The Spatial SUR Lag Model results confirm that the productive structure is a key determinant of the resistance to crises in Brazil. On the one hand, more specialized regions were more affected during the nationwide shocks, that is, specialization *per se* harms the regional resistance. It was also observed that specialization in distinct sectors played distinct roles in resilience according to the nature of each economic shock. Furthermore, in all cases, regions specialized in extractive activities which are heavily dependent on external markets tend to be more affected when a shock reaches the national economy than during international crises, and those regions that are more export-oriented tend to suffer to a higher extent.

Results regarding the Brazilian regional setting bring some relevant insights to explain why Brazilian regions were so affected by both recent national crises. As such, these results can orient policy and decision making towards a regional planning that ensures the local productive structures are rearranged so they can better cope with recessive shocks. This is particularly urgent for less resistant regions that are specialized in mining activities, not only because of their discussed vulnerabilities, but also in the context of the socioeconomic costs derived from the complete halt of production following the recent dam break disasters in Brazil. Plans for reconversion of activities in these less resistant territories must include planning tailored activities that ensure smart diversification, local sustainability, funding availability, and improvement in local labor capabilities in order to foster a more equitable development.

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APPENDIX A – COMPLEMENTARY ILLUSTRATIONS

Data	Source	Treatments	Variables
Population	IBGE (Brazilian Institute of Geography and Statistic)	-	Population Density
Regional Area	IBGE (Brazilian Institute of Geography and Statistic)	-	Population Density
Real GDP (Gross Domestic Product)	IBGE database: "GDP of Brazilian Municipalities"	- Aggregated to the microregional level - Deflated by the IGP-DI index (measured by the Getulio Vargas Foundation / FGV).	*Resis* Index Export-GDP Ratio
Real GDP (Gross Domestic Product) *per capita*	IBGE database: "GDP of Brazilian Municipalities"	- Aggregated to the microregional level - Deflated by the IGP-DI index (measured by the Getulio Vargas Foundation / FGV). - Value in Natural logarithm	ln(GDP *per capita)*
1st Level Sectorial Employment	Ministry of Work and Employment database RAIS/MTE. IBGE Classification	Formal Employment at agriculture, extractive activities, manufacturing, construction, commerce, services and public administration	Locational Quotients and sector-specific dummies.
2-Digit Sectorial Employment	RAIS/MTE. CNAE 2.0 (National Classification of Economic Activities): Sections	Formal Employment	- Herfindahl Index - Unrelated Variety - Related Variety
5-Digit Sectorial Employment	RAIS/MTE. CNAE 2.0 (National Classification of Economic Activities): Classes	Formal Employment	- Related Variety
Exports	Database of Foreign Trade Secretariat (Secex) of the Ministry of Development, Industry and Foreign Trade (MDIC).	Aggregated to the microregional level.	External Dependence: Export/GDP ratio.

Table A1. Data Sources and Treatments

Source: Own Elaboration.

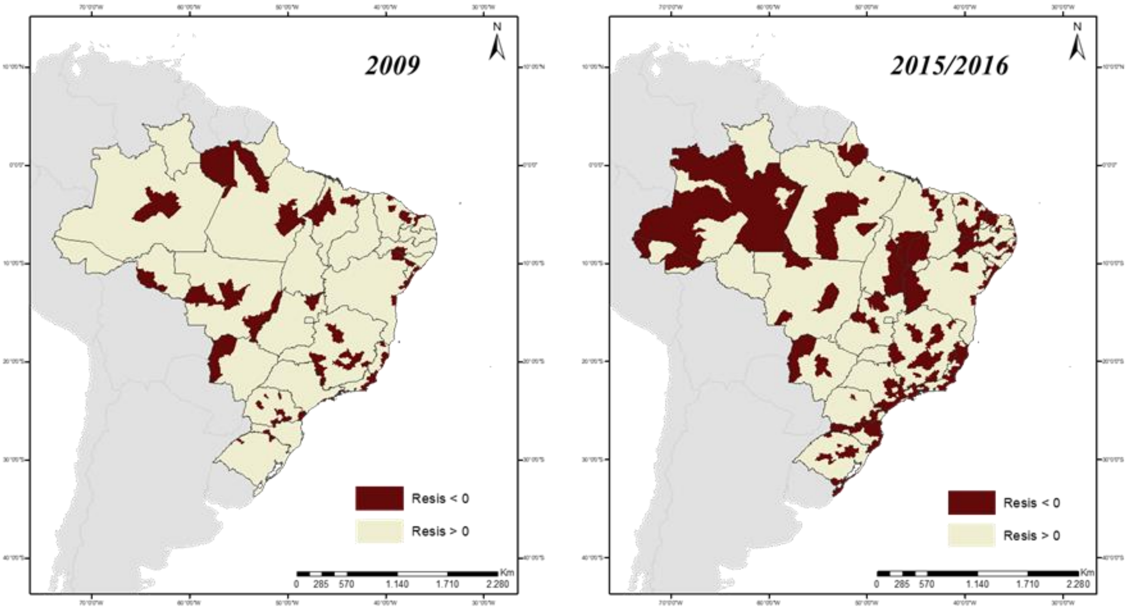

Figure A1. Resistance Index to Brazilian Nationwide Downturns: 2009 and 2015/2016
Source: Own elaboration based on IBGE dataset "GDP of Brazilian Municipalities". Aggregated to the microregional level. GDP deflationated by the IGP-DI.

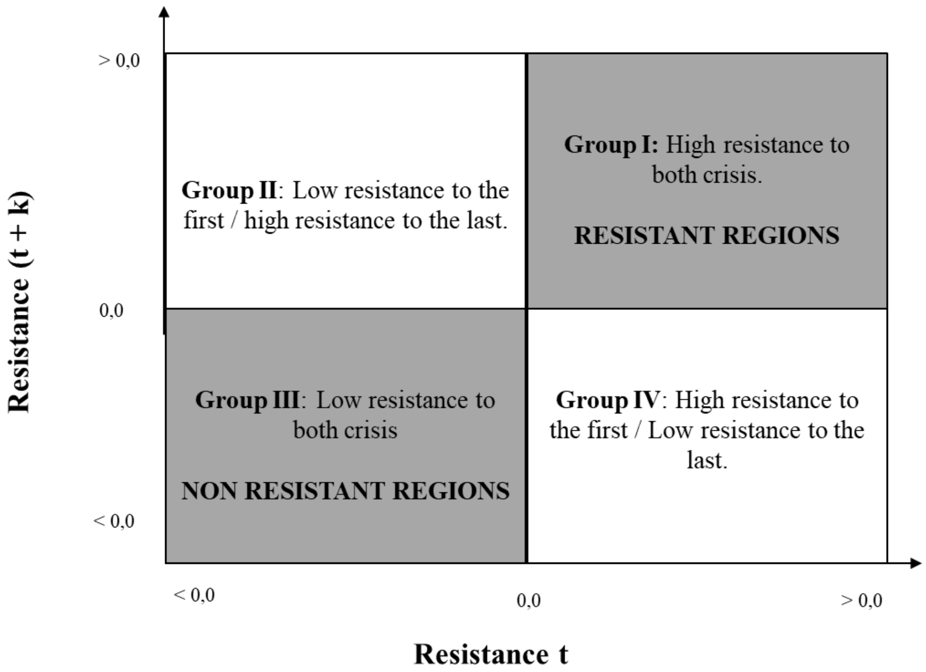

Figure A2. Proposed Taxonomy to Resistance Possibilities
Sources: Own Elaboration. Adapted from Martin *et al.* (2016) and Faggian *et al.* (2017)

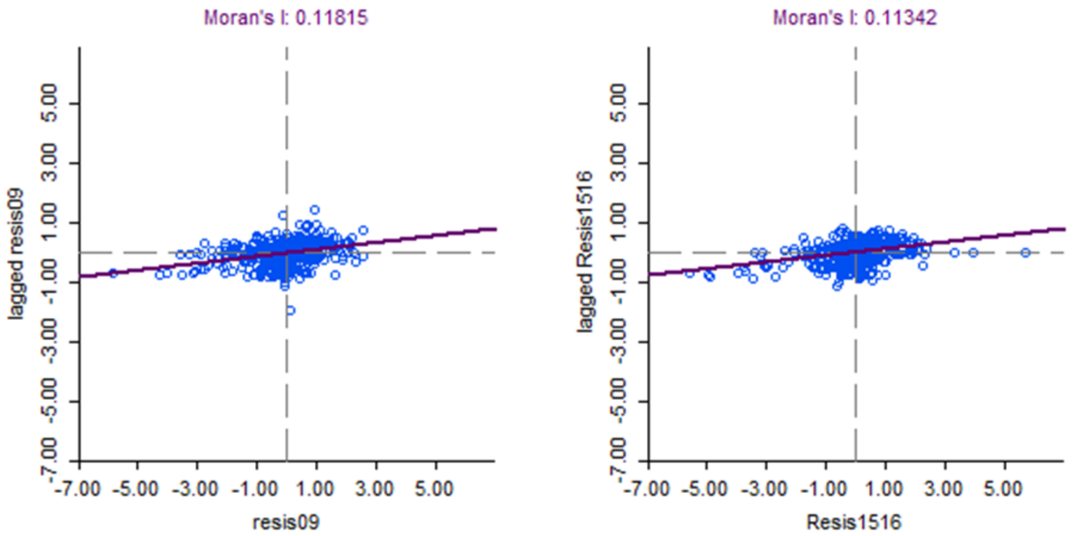

Figure A3 Spatial Association – Moran's *I* to Resistance Indexes: 2009 and 2015/2016

Source: Own elaboration based on IBGE dataset "GDP of Brazilian Municipalities". Aggregated to the microregional level. GDP deflationated by the IGP-DI. Software: GEODA. All values are significant at 1%

APPENDIX B – DIAGNOSTICS AND POSTESTIMATION TESTS

		Moran's *I*	LM - Lag	LM - Error	Robust LM - Lag	Robust LM - Error
W = Inverse of Squared Distance	2009 Model 1	8.830	68.919	8.526	61.530	1.136
		(0.0000)	(0.0000)	(0.0035)	(0.0000)	(0.2865)
	2009 Model 2	8.810	66.916	60.813	7.735	1.632
		(0.0000)	(0.0000)	(0.0000)	(0.0054)	(0.2014)
	2015 Model 1	3.826	12.306	3.074	9.485	0.253
		(0.0001)	(0.0005)	(0.0795)	(0.0021)	(0.6149)
	2015 Model 1	3.860	12.370	9.590	3.002	0.222
		(0.0001)	(0.0004)	(0.0020)	(0.0832)	(0.6373)

Table B1. Diagnostics for Spatial Dependence (Independent Regressions)

Source: Own Elaboration. p-values at parentheses.

	GFC - 2009		Current Brazilian Crisis - 2015	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Queen 1	0.091	0.156	4.518	4.132
	(0.7625)	(0.6928)	(0.0335)	(0.0421)
4 nearest neighbors	1.171	0.458	1.373	1.550
	(0.2793)	(0.4986)	(0.2413)	(0.2132)
Inverse of Squared Distance	0.470	0.162	1.592	1.706
	(0.4932)	(0.6875)	(0.2070)	(0.1915)

Table B2. Anselin-Kelejian Test for Spatial Dependence (Independent Regressions)

Source: Own Elaboration. p-values at parentheses.

	Model 1	**Model 2**
LM test on Σ	28.577	30.054
	(0.0000)	(0.0000)
LR test on Σ	29.335	30.893
	(0.0000)	(0.0000)
Cross-Equation Correlation	0.184108	0.187657

Table B3. Regression Diagnostics on the Variance-Covariance Matrix, Σ.

Source: Own Elaboration. Note: p-values at parentheses.

	Model 1	**Model 2**
Constant	111.928	59.060
	(0.0000)	(0.0000)
W_Resis	*1.682*	2.764
	(0.1946)	(0.0964)
ln (GDP *per capita)*	91.333	89.318
	(0.0000)	(0.0000)
Population Density	5.188	3.214
	(0.0227)	(0.0730)
Export/GDP ratio	11.418	7.968
	(0.0007)	(0.0048)
Herfindhal Index	23.306	-
	(0.0000)	
Unrelated Variety	-	0.133
		(0.7150)
Related Variety	-	10.829
		(0.0010)
Agriculture	2.729	0.016
	(0.0985)	(0.8982)
Extractive Activities	16.197	13.593
	(0.0001)	(0.0002)
Manufacturing	2.704	2.606
	(0.1001)	(0.1065)
Construction	6.750	6.649
	(0.0094)	(0.0099)
Public Administration	7.692	4.565
	(0.0055)	(0.1620)
Services	0.006	0.071
	(0.9404)	(0.7894)
North	0.678	3.013
	(0. 4103)	(0.0826)
Northeast	2.866	0.123
	(0.0905)	(0.7260)
South	0.531	0.397
	0.4663	(0.4051)
Center-West	8.149	17.572
	(0.0043)	(0.0000)

Table B4. Other Diagnostics - Chow Test: Chi-Squared Values.

Source: Own Elaboration. Note: p-values at parentheses.