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The Brazilian regional development funds and economic growth

A spatial panel approach

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Abstract: The regional development policy in Brazil materializes mainly in the regional development funds for the north-east (FNE), the north (FNO), and the centre-west (FCO), in which more than EUR 36 billion was invested between 2004 and 2010. This paper examines the economic effect of these regional development funds using for the first time a unique and recent data provided by Brazil's government. The study uses spatial panel models and different spatial scales of municipalities and micro-regions to analyse the effect of development funds on regional GDP per capita growth during 2004-10. The results suggest that development funds have positive impact on GDP per capita growth mainly at municipality level. Furthermore, the results indicate that different modalities of FCO, FNO, and FNE affect regional growth differently.

Keywords: regional policy, economic growth, regional economics, spatial econometrics
JEL classification: O10, R11, C31

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1 Introduction

Large regional disparities hinder regional integration in large economic areas. Market forces alone seem to be ineffective at reducing regional inequality and government-sponsored initiatives are designed in different parts of the globe to promote economic and social convergence.

For instance, in the European Union (EU), the regional policy is an important instrument designed to reduce regional disparities among its Member States[1]. The EU currently uses about one third of its total budget to run Cohesion Policy with the objective of promoting overall harmonious development and in particular to reduce regional disparities across the Union. The Cohesion Policy assistance for the period 2006-13 was around EUR308 billion. Similarly, Brazil is also a large economy but with more severe regional inequality. In this context, regional policy emerges as an important social and economic tool aiming at reducing striking inequality. One of the most significant initiatives is the creation of the regional funds for the north-east (FNE), centre-west (FCO), and the north (FNO) regions. The funds were created by following the directives of the Federal Constitution of 1988.[2] These resources are transferred from the National Treasury to the operating banks via the Ministry for National Integration (MI). The constitutional funds invested more than EUR37 billion between 2004 and 2010.[3]

Given the importance and scale of some regional policy initiatives, many studies analyzing the impact of regional policies have emerged. For the European case, Cappelen et al. (2003), Soukiazis and Antunes (2004) and Rodriguez-Pose and Fratesi (2004) provide earlier discussion on the evidence about the EU structural funds, which is the most significant initiative of regional policy in Europe.[4] Nevertheless, these studies did not explicitly consider spatial dependence in the estimations and were complemented by more recent studies suggesting that regional policy has to be analysed taking into account this dependence in a more explicit manner (e.g., Ramajo et al. 2008; Mohl and Hagen 2010).

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[1] The Lisbon Treaty (2000) confirms the European goals of economic and social cohesion and added territorial cohesion to these initial goals. The consolidated Treaty on the Functioning of the European Union in its article 174 states: 'In order to promote its overall harmonious development, the Union shall develop and pursue its actions leading to the strengthening of its economic, social and territorial cohesion. In particular, the Union shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favored regions. Among the regions concerned, particular attention shall be paid to rural areas, areas affected by industrial transition, and regions which suffer from severe and permanent natural or demographic handicaps such as the northernmost regions with very low population density and island, cross border and mountain regions.'

[2] Article 159 of Brazil's constitution provides the instructions to allocate resources to regional development funds. ART 159 - The Union shall turn over: I- forty-nine percent of the proceeds from the collection of taxes on income and earnings of any nature and on industrialized products, in the following manner:... …..c) three per cent, for application in programmes to finance the productive sector of the north, north-east, and centre-west regions, through their regional financial institutions, in accordance with regional development plans, the semi-arid area of the north-east being ensured of half of the funds intended for that Region, as provided by law.

[3] This is equivalent to BRL82.93 billion in constant 2010 prices (using the exchange rate from 31 December 2010).

[4] Pinho et al. (2013) discusses in more detail the mixed evidence from empirical research on EU structural funds.

The regional constitutional funds, the main regional policy instruments in Brazil, have also been examined. The studies by Almeida et al. (2007) and Silva et al. (2007, 2009) provided the first wave of assessment of constitutional funds in Brazil with data from early 2000's. Other studies followed, and Resende (2014a) analysed the impact of constitutional funds at firm and regional levels considering the aggregation bias and Modified Areal Unit Problem (MAUP). Recently, Resende (2014b) and Resende et al. (2014) provided new evidence about the constitutional funds using better quality data that covers a longer time period. Also, the use of the new data on constitutional funds is very important because the resources allocated to the constitutional funds increased considerably due to the expansion of the Brazilian economy between 2004 and 2013. Nevertheless, the literature that analyses the relationship between regional economic growth and the constitutional funds does not consider explicitly spatial dependence. The recent literature that analyses regional economic growth in Brazil suggests the presence of significant spatial dependence and indicates the use spatial econometrics to deal with this issue (e.g. Silveira-Neto and Azzoni 2006; Resende 2011; Cravo and Resende 2013; Cravo et al. 2015; Resende et al. forhcoming). Statistically, the omission of spatial dependence and spillovers in growth regressions produces biased results, as argued by Rey and Montouri (1999), and requires spatial econometrics to be correctly estimated.

Therefore, the aim of this paper is to address this gap in the literature by providing an analysis of the importance of the constitutional funds for regional economic growth in Brazil from 2004 to 2010 considering the spatial dependence. This research uses a new and unique data made available by the MI and provides for the first time empirical evidence on the importance of spatial dependence for the relationship between constitutional funds and regional economic growth process using spatial panel econometrics estimators suggested by Elhorst (2010a) and firstly estimated for growth regressions in Brazil by Cravo et al. (2015) and Resende et al. (forhcoming).

The remainder of the paper is organized as follows. Section 2 discusses the literature of constitutional funds and economic growth. Section 3 describes the data and the constitutional funds. Section 4 presents the baseline model and its extensions to consider spatial dependencies. Section 5 presents the results, and Section 6 concludes.

2 Literature on regional funds

This section reviews the available evidence on constitutional funds and presents the points in which this paper furthers the knowledge on the regional effect of regional funds. Despite recent efforts to assess the influence of constitutional funds, the literature about the issue is still scant. Also, most of the work used data until the mid-2000's, a period characterized by low disbursement rate of constitutional funds' resources (Almeida et al. 2007).

Earlier studies on the constitutional funds were more descriptive and Jayme Jr and Crocco (2005) point out that the descriptive analysis of the constitutional funds indicates a concentration of credit in more developed regions and stronger preference liquidity in those regions. In addition, Oliveira and Domingues (2005) suggest that the influence of the funds is concentrated in richer municipalities. Macedo and Matos (2008) also provide an analysis based on descriptive statistics and suggest that constitutional funds are allocated to the richer cities of the eligible regions, suggesting that the funds might reinforce regional income inequality.

Researchers also looked at the impact of constitutional funds at firm level. Silva et al. (2009) indicate that firms financed by constitutional funds experienced positive employment growth in the north-east. Resende (2014a) complements this work and provides evidence of the impact of the constitutional funds at firm and regional level in order to take into account the problems related to aggregation bias and the MAUP that emerge from observing different results at different aggregation levels. The results indicate that the positive effect of constitutional funds at firm level do not spillover at regional level.

The work of Galeano and Feijó (2012) complements the existing evidence of the influence of constitutional funds by providing insights on the effect of the combination of these funds with credit lines provided by the Brazilian Development Bank (BNDES). Their paper uses aggregated data at state level and results suggest that the combination of these lines of credit affect GDP per capita and productivity in the centre-west region of Brazil.

More recent and better quality information about the constitutional funds opened up possibilities for the assessment of the impact of the funds over a broader period that includes a decade of continuous economic progress in Brazil. Also, the new data considers different types of credit lines by sector. Resende (2014b) estimate panel regressions with region fixed effects to assess the impact of the constitutional fund of north-east (FNE) at various regional scales to consider the MAUP. The results show a positive and statistically significant impact of the FNE on the GDP per capita growth at the municipal and micro-regional level, with no effect of FNE funds at the larger geographic scale of meso-regions. Also, the results suggest that the positive effects of FNE are largely influenced by the performance of the FNE loans to the agricultural sector.

Similarly, Resende et al. (2014) present new evidence for the constitutional fund of centre-west (FCO). The results of the fixed effects estimations show that FCO influences GDP per capita growth positively only at municipal level and results suggest that this positive effect is mainly influenced by the specific FCO line of credit aiming at the service sector. The results for micro- and meso-regions suggest that FCO does not stimulate economic growth in more aggregated regions.

Although these studies provide a considerable amount of evidence on the influence of the constitutional funds on regional performance, the literature on the issue is still limited in some aspects. For instance, most of the studies quoted above do not take into account the issue of spatial dependence that is a well-known factor that influences regional growth in Brazil (e.g. Cravo et al. 2015, Cravo and Resende 2013, Resende et al. forhcoming). This analysis is very important to assess the extent to which any positive effect of constitutional funds might spillover in neighbouring regions, especially if the analysis considers data that encompasses the period in which there were more resources allocated to the funds due to a decade of continuous economic growth. Thus, the aim of this paper is to address this gap in the literature by providing for the first time a thorough analysis of the constitutional funds by considering the importance of spatial dependence for the relation between constitutional funds and regional economic growth process in Brazil using the spatial panel econometrics estimators suggested by Elhorst (2010a).

3 Constitutional funds and data

The constitutional funds are allocated to productive activities in the north, north-east, and centre-west regions of Brazil. The funds were created to spur regional and social development in the three least developed regions of the country through subsidized credit lines.[5] As mentioned before, the constitutional funds were created by following the directives of the Federal Constitution of 1988, and were constitutionalized in the article 159. The funds were then regulated by the law 7.827 of 27 September 1989. The resources designated to the constitutional funds are managed by MI and loan operations are carried out by authorized banks.

The resources allocated to FNO, FNE, and FCO come from the collection of income tax (IR) and earnings of any nature and from taxes on industrialized products (IPI). Three per cent of the revenue of IPI and IR is allocated to the fund as follows: 60 per cent assigned to FNE, 20 per cent to FNO, and 20 per cent to FCO. In addition, resources from repayments of the loans are reinvested in the funds.

The directives and implementation strategies change slightly according to the constitutional fund.[6] Further, different operators lend the resources from the constitutional funds according to the region. The institution responsible for the operation of the FNO is the Bank of the Amazon (BASA), a state owned regional development bank. The priority of FNO is to finance small entrepreneurs, mainly familiar agriculture, businesses that use local raw materials and workers, and that produce food for the local economy (BASA 2010, p. 15). Similarly, the Bank of the north-east (BNB) is the development bank that manages the FNE. The guidelines give priority for the loans that: i) support 'Cluster Development Projects (APLs)'; ii) are located in priority areas as defined by National Plan of Regional Development (PNDR);[7] iii) support smallholder farmers that are eligible by the National Family Farming Programme; and iv) support urban self-employed and micro and small businesses (BNB 2013). Finally, the FCO loans are managed by the state owned Bank of Brazil. The FCO's guidelines give priority for the loans that:[8] i) support familiar agriculture and smallholder farmers; ii) have high potential for employment and income generation and/or are related to solidarity economy that contribute to the dynamic of local labour market and the reduction of inequality; iii) are for projects aiming at environmental conservation; iv) use innovative technology to generate and disseminate technology in business and agriculture sectors; v) modernize and expand tourism infrastructure in the 2014 FIFA World Cup host cities; and vi) contribute to the reduction in inequality in priority areas as defined by the PNDR.

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[5] For instance, interest rates for the investment loans in the credit line 'FNO Sustainable Amazon' for rural micro entrepreneurs was 3,53 per cent per year (BASA 2012), less than a half of the Brazilian Central Bank reference interest ratethat was 7.25 per cent in December 2012.

[6] In general, constitutional funds are available for self-employed, micro and small entrepreneurs, rural producers, and associations and co-operatives.

[7] Projects localized in semi-arid regions, priority regions defined by the MI, in the regions defined as *Regiões Integradas de Desenvolvimento* and in regions defined as priorities by the PNDR (low income, stagnated, and dynamic). In addition, as defined by law, 50 per cent of FNE loans must be allocated to semi-arid areas of the north-east region.

[8] Source: http://www.sudeco.gov.br/fco .

The data used in this study is provided by MI under an agreement with the Institute of Applied Economic Research (IPEA), which is the institution responsible for carrying out the study. From the raw information on the lending portfolio of constitutional funds provided by MI, this paper constructs the share of the lending amount of constitutional funds over regional GDP. This share is constructed for different sub-periods and for the different types of lending shown in Table 1.

Table 1 shows the lending portfolio with resources from the constitutional funds by year between 2004 and 2010. The total lending amount over the period reached BRL82.9 billion and FNE, the biggest constitutional fund, accounted for BRL50.3 billion (61 per cent of the total). This amount is equivalent to 13.5 per cent of the north-east region GDP in 2004. The FCO is the second largest constitutional fund and the loans approved over the period amounted to BRL19.4 billion, 23 per cent of the amount allocated to constitutional funds overall. Finally, the FNO is the smallest fund of this sort and the loans approved between 2004 and 2010 amounted to BRL13.2 billion, representing 16 per cent of the constitutional fund lending amount over the period. Interestingly, the numbers show that the yearly lending amount for FNE doubled from 2004 to 2010. This is influenced by a decade of continuous growth that increased the tax revenue in the country. As the resources allocated to constitutional funds are defined in the constitution as a fixed share of tax revenue, this prosperous economic period led to substantial increase in the resources available for the funds.

The amount allocated to different categories of each constitutional fund is also shown in Table 1. About 42 per cent of FNE loans were provided to entrepreneurs in the agriculture sector (FNE agriculture), while 25 per cent went to the manufacturing sector (FNE manufacturing), 20 per cent to commerce and services modality, and only 13 per cent to infrastructure projects.[9] Similarly, 51 per cent of the FNO loans benefited the agriculture category, followed by manufacturing (18 per cent), commerce and service (18 per cent), infrastructure (10 per cent), and export (2 per cent). The FCO loans have fewer categories but they are also concentrated in agriculture sector, despite the fact that the share of FCO business loans constantly increased over time.

[9] The evaluations of FNE-infrastructure, FNO-infrastructure, and FNO-exports are not carried out in this paper.

Table 1: Constitutional funds lending (2004-10), by FNO, FNE, as well as FCO and modality of loan

	2004	2005	2006	2007	2008	2009	2010	Total	Total%
FNO *(BRL in million, constant price in 2010)*									
FNO rural	1.227	913	714	853	1.116	951	959	6.731	
Share (%)	68	70	56	64	49	35	37	51	
FNO manufacturing	218	217	271	251	517	678	320	2.473	
Share (%)	12	17	21	19	23	25	12	19	
FNO service/commerce	81	114	153	177	624	509	775	2.432	
Share (%)	4	9	12	13	28	19	30	18	
FNO infrastructure	70	3	140	48	1	574	515	1.350	
Share (%)	4	0	11	4	0	21	20	10	
FNO export	203	64	0	0	6	0	0	273	
Share (%)	11	5	0	0	0	0	0	2	
FNO total	1.798	1.310	1.277	1.328	2.264	2.712	2.568	13.258	15.99%
Share (%)	100	100	100	100	100	100	100	100	
FNE *(BRL in million, constant price in 2010)*									
FNE agriculture	1.837	2.956	3.165	2.616	3.336	3.586	3.866	21.362	
Share (%)	42	53	53	52	40	35	36	42	
FNE manufacturing	1.595	1.807	1.338	863	1.929	1.99	2.868	12.39	
Share (%)	37	33	23	17	23	20	27	25	
FNE service/commerce	931	776	889	1.071	1.739	2.439	1.988	9.833	
Share (%)	21	14	15	21	21	24	19	20	
FNE infrastructure	0	0	550	523	1.433	2.137	2.02	6.663	
Share (%)	0	0	9	10	17	21	19	13	
FNE total	4.364	5.539	5.942	5.074	8.437	10.151	10.742	50.248	60.59%
Share (%)	100	100	100	100	100	100	100	100	
FCO *(BRL in million, constant price in 2010)*									
FCO rural	1.025	1.395	1.234	1.396	2.307	2.108	1.983	11.448	
Share (%)	64	71	66	59	60	60	47	59	
FCO business	570	575	636	966	1.518	1.434	2.271	7.971	
Share (%)	36	29	34	41	40	40	53	41	
FCO total	1.595	1.970	1.871	2.362	3.825	3.543	4.253	19.419	23.42%
Share (%)	100%	100%	100%	100%	100%	100%	100%	100%	
Total Constitutional Fund	7.757	8.819	9.09	8.764	14.526	16.406	17.563	82.925	100

Note: The paper kept the original nomenclature of the regional constitutional funds. For instance, FNO rural and FNE agriculture have similar objectives and target the agriculture sector, however, they have a different name according to the region. The last column indicates the percentage amount of total funds allocated to each constitutional fund between 2004 and 2010.

Source: Ministry for National Integration (MI). Authors' elaboration.

Table 2 shows the global Moran's I, the statistic used to test for spatial dependence, which is calculated for the constitutional fund variable and GDP per capita at municipality and micro-regional geographic scales. The data show very strong spatial correlation; the null hypothesis of no spatial correlation is rejected at the significance level of 1 per cent for all variables. These numbers show that the resources are not allocated in a homogenous manner across regions, suggesting that existence of spatial dependence. The values of the share of constitutional funds over GDP are correlated across space. This is an initial suggestion that methods that take into account spatial dependence might be more appropriate to assess the relationship between the constitutional funds and regional growth.

Table 2: Test for spatial autocorrelation (Moran's I) of Constitutional Funds and GDP per capita (2004-10)

	Municipality	Micro-region
FCO	0.392 ***	0.510***
FNO	0.376***	0.284***
FNE	0.117***	0.200***
GDPpc Growth	0.102***	0.127***

Note: *p*-value <0.10; ** *p*-value <0.05; *** *p*-value <0.01. Moran's I calculated using the squared inverse distance between the centroid of the regions.

Source: Authors.

Thus, the construction of the rich data used in this paper is a significant effort to provide a panel data that identifies different categories of constitutional funds during a period of a significant increase in the financial resources available to these funds. This new data is very important to assess one of the main tools of regional policy in Brazil and this paper is the first study that will use this data to analyse the impact of the funds on Brazilian regional development taking into account spatial dependence in a panel data setting.

4 Regional growth regressions with constitutional funds

In this paper, we seek to examine the effect of the constitutional funds on regional economic growth using the same data aggregated at municipality and micro-regional level by systematically repeating a method used to examine this phenomenon across multiple scales. This allows us to investigate the measurement issue that might cause variability in the impact of the constitutional funds on regional economic growth estimates due to the use of different spatial scales, likely due to the Modifiable Areal Unit Problem (MAUP).

The baseline model stems from the neoclassical growth model based on Solow (1956) and Mankiw et al. (1992). The specification used in this study is the common ad hoc regression that is considered a generalization of the neoclassical growth model that encompasses other factors that influence growth (e.g. Barro 1991; Temple 1999; Sala-i-Martin 2002). Many evaluations of regional policy follow this strategy (e.g. Cappelen et al. 2003; Soukiazis and Antunes 2004; Rodriguez-Pose and Fratesi 2004; Resende 2014b) and the baseline model takes the following form:

$$gr_{it} = -\beta ln_{y_{i,t-1}} + \psi lnX_{it} + \phi lnCF_{it} + \alpha_i + \mu_t + \upsilon_{it} \qquad (1)$$

where *gr* denotes the annual GDP per capita growth, ln y_{t-1} is the initial GDP per capita, β the convergence coefficient, *CF* is the share of constitutional funds over GDP in each region and ϕ the coefficient that captures de impact of CF on growth. Furthermore, *i* denotes each individual region, *t* represents each period of time considered and υ_{it} is the error term $\sim N(0, \sigma^2)$. The vector *X* represents a set of control variables that encompasses growth determinants suggested by the Solow

model as well as growth determinants that come from outside this model. The variables included in this vector are the average year of schooling of workers and population density.

The data for the panel estimations are organized in intervals over the period 2004-10 to minimize business cycle influence (Casseli et al. 1996). Three sub-periods are considered and the panel is constructed based on the average of the dependent variable and *CF* over the following periods: 2004-06, 2006-08, and 2008-10. The remaining conditioning variables are considered at the initial year of each interval.

As mentioned earlier in this section, we include the regional policy treatment as an additional growth determinant. Thus, the additional feature of the specification is the inclusion of the value amount of the constitutional fund (*CF*) in Equation (1). However, the equation ignores the existence of spatial dependence in the regional growth process and instead assumes that regional observations are independent, which results in major model misspecification (Rey and Montouri 1999).

4.1 The model specification with spatial dependencies

There are many ways to consider the spatial dependence in Equation (1). The most common specifications in spatial econometrics according to Lesage and Pace (2009) are the spatial error model (SEM), the spatial autoregressive model (SAR), and the spatial Durbin model (SDM). The first considers the spatial dependence in the terms and Equation (1) becomes:

$$gr_{it} = -\beta \ln(y_{i,t-1}) + \psi \ln X_{it} + \alpha_i + \mu_t + \varepsilon_{it} \qquad (2)$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^{N} w_{ij} \varepsilon_{jt} + \upsilon_{it}$$

where the variables are defined as in Equation (1), but hereafter to simplify the notation, *CF* is also included in the vector *X*. The term ε is the error term, where w_{ij} contains information about the spatial structure and connectivity between regions *i* and *j*, λ is a scalar spatial error coefficient, and $\upsilon \sim N(0, \sigma^2 I_n)$. A random shock in a specific region also affects growth rates of other regions through the transformation in the error term (Rey and Montouri 1999; Ertur et al. 2006).

An alternative way of considering the spatial dependence is through the spatial lagged values of the dependent variable in the SAR specification:

$$gr_{it} = \rho \sum_{j=1}^{N} w_{ij} gr_{jt} - \beta \ln(y_{i,t-1}) + \psi \ln X_{it} + \alpha_i + \mu_t + \upsilon_{it} \qquad (3)$$

where ρ is the spatial autoregressive parameter and all other terms are defined as in Equation 2. Lesage and Pace (2009) argue that this distinctive spatial econometrics specification and can be extended into the SDM specification that has the advantage of allowing for spatial effects working through the dependent variable, the initial income variable, and a set of conditioning variables:

$$gr_{it} = \rho\sum_{j=1}^{N} w_{ij} gr_{jt} - \beta_1 \ln(y_{i,t-1}) + \beta_2 \sum_{j=1}^{N} w_{ij} \ln(y_{j,t-1}) + \psi_1 \ln X_{it} + \psi_2 \sum_{j=1}^{N} w_{ij} \ln X_{jt} + \alpha_i + \upsilon_{it} \quad (4)$$

where everything is defined as in Equation (3), with the inclusion of the vectors $WlnX_{jt}$ and $Wln(y_{t-1})$ used to account for the spatially lagged values of all conditioning variables.

This is an attractive specification because if $\psi_2 = 0$ and $\beta_2 = 0$ it becomes the SAR model, and if $-\rho\psi_1 = \psi_2$ and $-\rho\beta_1 = \beta_2$ the model is reduced to the SEM model. Lesage and Fisher (2008), Lesage and Pace (2009), and Elhorst (2010b) provide a detailed discussion about the motivations and advantages of the SDM specification for growth models from a statistical point of view. They show that the use of an SDM specification rests on the plausibility of two circumstances that are likely to arise in applied regional spatial growth regressions: the spatial dependence in the disturbances of an Ordinary Least Square (OLS) regression, and endogeneity in the form of an omitted explanatory variable (that follows a spatial autoregressive process) that exhibits non-zero covariance with the variables in the model. These plausible circumstances observed in applied spatial growth regressions make the SDM model the econometric choice over competing alternatives.

The inferences of the models above are based on the maximum likelihood estimator proposed in Anselin (1988) and extended for panel data by Elhorst (2010a). Panel data models, as the one used in this paper, have advantages over cross-section ones as they have more degrees of freedom, can control for individual and time fixed effects, and contain less collinearity among the variables in the model. In this paper, the spatial panel estimations use the developments made by Elhorst (2010a). He shows that maximum likelihood estimations of spatial panel models with fixed effects can be carried out after demeaning the variables in the model in order to control for the space-specific and time-fixed effects.[10]

Unlike the data of the constitutional funds described in detail in the previous section, the auxiliary data required to estimate the models presented in this section is public. The GDP per capita is retrieved from the National Statistics Office (IBGE), the average years of schooling of workers is calculated from RAIS (Brazilian Annual Report of Social Information of the Ministry of Labour)

[10] The log-likelihood functions for spatial panel data and the demeaning process to remove time and space (individual) fixed effects are detailed in Elhorst (2010a). Importantly, the spatial econometrics literature has shown that OLS estimation is inappropriate for models incorporating spatial effects. In the SEM specification, parameters' estimation will be unbiased, but inefficient due to the non-spherical structure of the disturbance variance matrix. The OLS estimator will be biased and inconsistent for the parameters of the SAR model due to the simultaneity in the nature of the spatial autocorrelation process caused by the introduction of the spatial lag.

following Cravo (2012) and Cravo et al. (2015) and population density was taken from IPEADATA.[11]

5 Empirical results

This section presents the results for the panel estimations at municipality and micro-regional level. The existing literature provides evidence on the effect of constitutional funds on regional growth. Nevertheless, there is no evidence about the effect of constitutional funds on growth considering spatial spillovers in a panel data setting for different geographical scales to account for the MAUP. Thus, the evidence considering this dimension in the context of a developing country might add to the understanding of how regional policy might influence economic growth.

Table 3 shows the Pooled OLS and Least Square Dummy Variables (LSDV) estimations at municipality and micro-regional level. The first four columns show the results for municipalities and the Pooled OLS regression provides a first indication that FNE and FCO affects growth positively. FNO does not have any positive relationship with regional growth. The consideration of non-observable municipality fixed-effect in the LSDV estimation indicate a positive effect of FNE and FCO in the estimation presented in column 3; this estimation does not control for time fixed effects. The inclusion of time fixed effect in column 4 makes the effect of FNE on growth insignificant, a result also found in Resende (2014b). The difference in results that emerges after the inclusion of time dummies can be related to the fact that that FNE might be associated to year-specific shocks.[12] Interestingly, the magnitude of FCO reduced after controlling for time-specific effects but the positive effect remained significant, suggesting that the effect of FCO on growth is less associated to shocks over time. The estimates also suggest an inverse relationship between FNO and economic growth.

The OLS estimation results for micro-regions (columns 9-16) show a positive correlation between FNE and regional growth (columns 9-10). Nevertheless, this effect fades away with the inclusion of region and time dummies (columns 11-12), suggesting that the effect captured by FNE in the OLS regressions might be related to the spatial structure, specific characteristics of micro-regions, and with time shocks as in the case of municipalities. In addition, panel data estimations at micro-regional level suggest that FNO and FCO have no positive impact at this broader regional scale.

Nevertheless, the literature shows that regional growth in Brazil is intrinsically dependent on space and the Moran's I in Section 3 showed that the relative importance of constitutional funds present a positive association between the original variable and its spatially lagged version. We therefore verified if the error term of the non-spatial regressions is spatially autocorrelated. The Moran's I for the residuals of the estimations are reported at the bottom of Table 3. The results show the presence of a significant spatial dependence in the error term at both spatial scales. Interestingly, the inclusion

[11] http://www.ipeadata.gov.br

[12] For instance, shocks that affect GDP in specific years increase resources available for FNE. In a regression without time dummies, this effect is captured by the FNE variable. However, the inclusion of time dummies might also capture these effects if FNE is correlated to year-specific shocks.

of an area specific dummy in the LSDV estimations reduces the spatial dependence, a sign that the region specific dummies are related to the spatial structure of the regions.

The regressions considering the different types of constitutional fund are presented in columns 5 and 8 for municipalities and 13 and 16 for micro-regions. The Moran's I for the residuals also indicate spatial dependence. As in the case that does not consider the different types of loans, the inclusion of an area specific dummy reduces the spatial dependence. The results for municipalities show that LSDV regressions with the inclusion of time fixed effect in column 8 make the coefficients of all modalities of FNE on growth insignificant.

Table 3: Impact of constitutional funds on GDP per capita growth at municipality and micro-region level (Pooled OLS and LSDV)

	Municipalities								Micro-regions							
	(1) Pooled OLS	(2) Pooled OLS	(3) LSDV	(4) LSDV	(5) Pooled OLS	(6) Pooled OLS	(7) LSDV	(8) LSDV	(9) Pooled OLS	(10) Pooled OLS	(11) LSDV	(12) LSDV	(13) Pooled OLS	(14) Pooled OLS	(15) LSDV	(16) LSDV
FNE	0.0471***	0.0352**	0.0608***	0.0183					0.0494***	0.0530***	0.0141	0.00951				
	(2.71)	(2.02)	(3.08)	(1.45)					(8.13)	(9.09)	(1.60)	(1.32)				
FNO	0.0154	0.0424	-0.469***	-0.408***					0.0315	0.0999	-0.887*	-0.871**				
	(0.23)	(0.65)	(-4.16)	(-4.09)					(0.13)	(0.44)	(-1.67)	(-2.17)				
FCO	0.252***	0.253***	0.248**	0.0776*					0.174	0.206	0.392	-0.194				
	(2.89)	(3.09)	(2.46)	(1.69)					(0.81)	(1.05)	(1.41)	(-0.69)				
$Ln(GDPpc)_{t-1}$	-0.0400***	-0.0412***	-0.398***	-0.558***	-0.0409***	-0.0422***	-0.399***	-0.558***	-0.0276***	-0.0275***	-0.460***	-0.553***	-0.0275***	-0.0279***	-0.462***	-0.554***
	(-17.20)	(-17.85)	(-31.80)	(-25.53)	(-17.31)	(-17.99)	(-31.23)	(-26.21)	(-5.26)	(-5.50)	(-15.87)	(-16.76)	(-5.14)	(-5.42)	(-15.83)	(-16.84)
Ln(School)	0.0116**	0.000312	0.172***	-0.00296	0.0124***	0.00121	0.169***	-0.00253	0.0417***	0.0267*	0.486***	-0.0650	0.0448***	0.0273*	0.463***	-0.0681
	(2.46)	(0.06)	(10.66)	(-0.30)	(2.65)	(0.24)	(10.60)	(-0.26)	(2.83)	(1.71)	(9.08)	(-1.38)	(3.01)	(1.75)	(8.47)	(-1.41)
Ln(Dens)	0.000429	0.000491	0.0587***	-0.145***	0.000719	0.000689	0.0564***	-0.146***	0.00160	0.00192	0.142*	-0.102	0.00178	0.00191	0.157**	-0.0909
	(0.56)	(0.65)	(3.96)	(-6.80)	(0.92)	(0.89)	(3.72)	(-6.98)	(0.93)	(1.17)	(1.87)	(-1.11)	(1.00)	(1.12)	(2.12)	(-1.01)
FNE-Agr					0.0925*	0.0344	0.151**	0.0440					-0.0275***	0.00276	0.154	-0.0758
					(1.69)	(0.64)	(2.29)	(1.10)					(-5.14)	(0.01)	(1.09)	(-0.62)
FNE-Manuf.					0.0143	0.0257**	0.00706	0.0252					0.0448***	0.0682*	0.00545	0.0181
					(1.05)	(2.02)	(0.32)	(1.16)					(3.01)	(1.73)	(0.12)	(0.48)
FNE-Serv.					0.421*	0.337	1.908***	0.424					0.00178	-0.332	0.604	-0.168
					(1.79)	(1.39)	(3.43)	(1.43)					(1.00)	(-0.86)	(0.58)	(-0.38)
FNO-Agr					0.0211	0.0479	-0.560***	-0.453***					-0.0275***	-0.129	-1.858***	-1.584***
					(0.33)	(0.78)	(-5.39)	(-4.59)					(-5.14)	(-0.52)	(-3.26)	(-4.43)
FNO-Manuf.					0.800***	0.738***	0.834***	0.527***					0.0448***	1.506***	0.874	0.578
					(8.34)	(7.03)	(7.14)	(4.46)					(3.01)	(3.48)	(1.33)	(0.77)
FNO-Serv.					-0.987***	-1.052***	-0.681***	-0.817***					0.00178	-0.591	1.402	0.501
					(-5.55)	(-5.84)	(-2.75)	(-8.27)					(1.00)	(-0.38)	(0.65)	(0.42)
FCO-Rural					0.506***	0.478***	0.613***	-0.0330					-0.0275***	0.0909	0.723*	-0.233
					(4.87)	(4.78)	(2.74)	(-0.20)					(-5.14)	(0.36)	(1.68)	(-0.62)
FCO-Bus					0.0794**	0.0954**	0.125**	0.115***					0.0448***	0.374	0.0933	-0.140
					(1.96)	(2.45)	(2.13)	(4.27)					(3.01)	(0.74)	(0.24)	(-0.32)
dummy2006		0.0403***		0.0672***		0.0400***		0.0668***		0.0436***		0.0742***		0.0437***		0.0734***
		(15.99)		(30.88)		(15.53)		(31.02)		(8.12)		(13.39)		(7.60)		(12.90)
dummy2008		0.0167***		0.115***		0.0162***		0.115***		0.00749		0.116***		0.00866		0.116***
		(7.29)		(24.22)		(7.03)		(25.85)		(1.46)		(10.43)		(1.60)		(10.32)
Obs.	8511	8511	8511	8511	8511	8511	8511	8511	972	972	972	972	972	972	972	972
Adj. R^2	0.078	0.110	0.419	0.568	0.082	0.113	0.424	0.569	0.078	0.155	0.533	0.651	0.074	0.148	0.54	0.654
I (2004)		0.121***		0.058***		0.123***		0.058***		0.138***		0.056***		0.132***		0.048***
I (2006)		0.125***		0.098***		0.123***		0.096***		0.146***		0.068***		0.146***		0.059***
I (2008)		0.123***		0.078***		0.120***		0.079***		0.041***		0.055***		0.038**		0.062***

Note: * *p*-value <0.10; ** *p*-value <0.05; *** *p*-value <0.01. Numbers in brackets for the coefficients are the *t*-statistics.
Source: Authors.

The segmentation of FNO in different types shows a significant positive impact of FNO manufacturing on growth at municipality level after controlling for time and area fixed effect. The segmentation of FCO indicates that the positive total effect of this fund on growth at municipality level is likely to be driven by the modality FCO business (columns 5-8). These findings for the constitutional fund of the centre-west are in line with Resende et al. (2014). Also, the LSDV estimations for the segmented regional funds at micro-regional level indicate that there is no positive relationship between any constitutional fund modalities and regional growth.

Nevertheless, regression results obtained from estimating the non-spatial models indicate that the model suffers from spatial dependence, since the Moran's I tests are statistically significant. This confirms the presence of spatial dependence in the error term, indicating that OLS regressions will be biased and suggesting that spatial econometrics models are likely to be more appropriate to assess the effect of constitutional funds on regional economic growth.[13]

Table 4 shows the results of the three spatial models described in Section 4. All spatial models suggest significant spatial correlation evidenced by the estimated parameters ϱ (SAR and SDM models) and λ (SEM model). Nevertheless, the SDM model provides a more complete assessment of the spatial effects as it is the only specification that sheds light on how spatial effects work through dependent and independent variables. Also, as argued by Lesage and Fisher (2008), Lesage and Pace (2009) and Elhorst (2010b), the SDM model is preferred from a statistical point of view as the model accommodates better the plausibility of spatial dependence in the disturbances of an OLS regression, and endogeneity in the form of an omitted explanatory variable (that follows a spatial autoregressive process) that exhibits non-zero covariance with the variables in the model.

The results from the SDM estimation at municipality level are in line with fixed-effect estimations (column 4) and show that only FCO affects regional growth positively. Nevertheless, the FCO in neighbouring regions are negatively related to growth. This might be related to the fact that neighbouring municipalities, which have more access to the resources of the constitutional fund, attract more investment and human capital from the vicinity, leading to a perverse effect on their GDP per capita. Also, constitutional funds appear to have an inverse relation with economic growth in the north of Brazil, evidenced by the coefficient of FNO in the three spatial specifications. Finally, the SAR model suggests a positive effect of FNE on growth; however, this result is not confirmed by the preferred SDM estimation.

[13] The spatial weights used in all spatial regressions are the row-standardized inverse squared distance.

Table 4: Impact of constitutional funds on GDP per capita growth at municipality and micro-region level (spatial regressions)

	Municipalities			Micro-regions		
	(1)	(2)	(3)	(1)	(2)	(3)
Main	SAR	SEM	SDM	SAR	SEM	SDM
FNE	0.0217*	0.0158	0.0186	0.0142**	0.0101	0.0104
	(1.78)	(1.37)	(1.57)	(2.02)	(1.43)	(1.52)
FNO	-0.321***	-0.334***	-0.313***	-0.801**	-0.836**	-0.783*
	(-3.20)	(-3.08)	(-2.85)	(-2.07)	(-2.02)	(-1.96)
FCO	0.0554	0.0928*	0.0871*	-0.296	-0.151	-0.134
	(1.08)	(1.90)	(1.75)	(-1.05)	(-0.49)	(-0.39)
$Ln(GDPpc)_{t-1}$	-0.518***	-0.539***	-0.532***	-0.527***	-0.541***	-0.533***
	(-25.20)	(-22.52)	(-21.71)	(-16.79)	(-16.07)	(-16.27)
Lnesc	-0.00122	-0.00204	-0.00234	-0.0556	-0.0605	-0.0614
	(-0.13)	(-0.22)	(-0.24)	(-1.21)	(-1.31)	(-1.28)
lndenspop	-0.120***	-0.132***	-0.126***	-0.0937	-0.0798	-0.0684
	(-6.08)	(-5.84)	(-5.46)	(-1.02)	(-0.85)	(-0.73)
ρ or λ	0.449***	0.690***	0.660***	0.294***	0.419***	0.375***
	(14.60)	(20.35)	(16.35)	(4.92)	(4.86)	(3.83)
Wx (spatially lagged variables)						
FNE			0.127			0.0775
			(1.22)			(0.14)
FNO			-0.0682			-0.0736
			(-0.20)			(-0.05)
FCO			-0.314*			-0.700
			(-1.71)			(-0.82)
$Ln(GDPpc)_{t-1}$			0.239***			0.0664
			(4.18)			(0.69)
lnesc			-0.0165			-0.0372
			(-0.47)			(-0.21)
lndenspop			0.0166			-0.369*
			(0.31)			(-1.74)
N	8511	8511	8511	972	972	972

Note: The Wald test suggests the use of the SDM model. * *p*-value <0.10; ** *p*-value <0.05; *** *p*-value <0.01. Numbers in brackets for the coefficients are the t-statistics. Time dummies were included in all regressions.

Source: Authors.

The results for micro-regional level also present significant spatial correlation but of lesser intensity when compared with results at municipality level. For the SDM estimations, for instance, the estimated parameter ρ at municipality level suggests that per capita GDP growth changes by 0.66 percentage points in association with an additional one percentage point increase in the per capita GDP growth of neighbouring municipalities. In comparison, micro-regional growth changes by 0.37 percentage points due to one percentage point increase in the per capita GDP growth of neighbouring regions. The SDM results at micro-regional level also support the result from the LSDV (column 12). The regression coefficients suggest that constitutional funds are not positively correlated to regional growth in the north-east and centre-west regions and that FNO has an inverse relationship with regional growth.

Finally, the estimates presented in Table 5 allow us to further investigate whether different types of constitutional funds have different impacts on regional growth when controlling for spatial dependence. The SDM results confirm that spatial correlation is stronger at municipality level. The segmentation of the FNO data uncovers some interesting results. FNO affects municipal growth only through its manufacturing modality. On the contrary, FNO resources allocated to

agriculture or commerce and services, present an inverse relation between FNO and regional growth. At micro-regional level, FNO does not positively correlate with economic growth. The positive overall impact of FCO on municipal growth observed in Table 4 is probably driven by a specific modality of the fund, as only the coefficient of FCO business is positive and significant. At micro-regional level, FCO does not correlate with economic growth.

There is no spillover effect stemming from any modality of constitutional fund, the estimated coefficients of the spatially lagged variables of constitutional funds suggest that economic growth is not influenced by any different modality of constitutional funds in neighbouring municipalities and micro-regions alike. In other words, none of the modalities of constitutional funds appear to influence the economic growth in neighbouring municipalities or micro-regions.

Therefore, the use of the new data on the constitutional funds allowed us to analyse different modalities of these funds and uncover relationships that would not be observed with the aggregated data.

Table 5: Impact of different types of constitutional funds on GDP per capita growth at municipality and micro-region level (spatial regressions)

	Municipalities			Micro-regions		
	(1) SAR	(2) SEM	(3) SDM	(1) SAR	(2) SEM	(3) SDM
Main						
FNE-agr.	0.0592	0.0396	0.0459	0.0278	-0.0457	0.00397
	(1.43)	(1.03)	(1.14)	(0.24)	(-0.37)	(0.03)
FNE-manuf.	0.0216	0.0215	0.0220	0.0151	0.0197	0.0161
	(1.00)	(1.14)	(1.11)	(0.45)	(0.58)	(0.48)
FNE-Serv&Com	0.488*	0.344	0.400	-0.117	-0.187	-0.204
	(1.70)	(1.28)	(1.48)	(-0.26)	(-0.46)	(-0.48)
FNO-agr	-0.342***	-0.363***	-0.338***	-1.423***	-1.543***	-1.471***
	(-3.31)	(-3.25)	(-2.93)	(-3.80)	(-3.82)	(-3.46)
FNO-manuf	0.466***	0.437***	0.441***	0.467	0.526	0.497
	(3.60)	(3.65)	(3.46)	(0.60)	(0.71)	(0.65)
FNO-serv&com	-0.817***	-0.844***	-0.823***	0.360	0.0769	-0.106
	(-9.62)	(-12.55)	(-11.87)	(0.28)	(0.07)	(-0.10)
FCO-rural	-0.143	-0.0671	-0.0711	-0.422	-0.179	-0.104
	(-0.91)	(-0.33)	(-0.32)	(-1.16)	(-0.45)	(-0.22)
FCO-Business	0.122***	0.136***	0.129***	-0.139	-0.111	-0.0178
	(4.57)	(3.79)	(3.98)	(-0.31)	(-0.25)	(-0.04)
$Ln(GDPpc)_{t-1}$	-0.518***	-0.539***	-0.532***	-0.530***	-0.544***	-0.537***
	(-25.90)	(-23.10)	(-22.26)	(-16.99)	(-16.29)	(-16.58)
lnesc	-0.000835	-0.00161	-0.00172	-0.0601	-0.0658	-0.0640
	(-0.09)	(-0.17)	(-0.18)	(-1.29)	(-1.40)	(-1.36)
lndenspop	-0.122***	-0.133***	-0.127***	-0.0836	-0.0708	-0.0685
	(-6.29)	(-6.01)	(-5.60)	(-0.93)	(-0.77)	(-0.76)
ρ or λ	0.451***	0.689***	0.660***	0.277***	0.407***	0.377***
	(14.43)	(20.76)	(16.39)	(4.59)	(4.93)	(4.26)
Wx (spatially lagged variables)						
FNE-agr.			0.171			-0.215
			(1.13)			(-0.22)
FNE-manuf.			0.0224			-0.0870
			(0.14)			(-0.13)
FNE-Serv&Com			3.197			0.526
			(1.62)			(0.33)
FNO-agr			-0.0201			1.441
			(-0.06)			(0.65)
FNO-manuf			0.367			-0.538
			(0.28)			(-0.29)
FNO-serv&com			2.504			7.449
			(0.58)			(1.09)
FCO-rural			-0.0374			-1.235
			(-0.07)			(-0.80)
FCO-Business			-0.329			0.172
			(-1.20)			(0.09)
$Ln(GDPpc)_{t-1}$			0.235***			0.0719
			(4.35)			(0.75)
lnesc			-0.0124			0.0348
			(-0.35)			(0.18)
lndenspop			0.0121			-0.393*
			(0.23)			(-1.81)
N	8511	8511	8511	972	972	972

Note: The Wald test suggests the use of the SDM model. * *p*-value <0.10; ** *p*-value <0.05; *** *p*-value <0.01. Numbers in brackets for the coefficients are the t-statistics.

Source: Authors.

6 Conclusion

This paper analyses the importance of constitutional funds for regional economic growth in Brazilian municipalities and micro-regions using spatial panel econometrics. The results show that non-spatial panel data estimations suffer from spatial dependence and more efficient estimations of the effect of constitutional funds on growth require the use of spatial panel econometrics.

The results show significant spatial correlation in the data and confirms previous results found in the literature that the micro-regional growth process presents spatial correlation of lesser intensity when compared with results at municipality level. The SDM estimations using the total amount of all modalities of constitutional funds shows that only FCO presents some positive correlation with regional growth at municipality level. The estimation also suggests that FCO in neighbouring regions are negatively related to growth, suggesting that the positive effect of FCO is local and does not spillover across neighbouring municipalities. Conversely, FNO and FNE do not present any positive relation with economic growth. The SDM results at micro-regional level shows that constitutional funds do not promote regional growth in any of the regions eligible to benefit from these funds, an indication that the effect of the funds are more likely to be localized at a smaller geographic area.

The new data used in the paper opens up the possibility to investigate the effect of different types of constitutional funds on economic growth. For instance, the segmentation of constitutional funds shows that the positive overall impact of FCO on municipal growth is probably driven by the FCO business modality. Interestingly, the results suggest that the FNO manufacturing modality affects growth positively despite the overall inverse relation between FNO and growth.

The use of the new panel data on the constitutional funds reveals relationships that would not have been observed with cross-sectional aggregated data. Further exploration of this data will produce important results that can influence the design of better guidelines to make more effective use of the constitutional funds.

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