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PNDR Instruments and Economic Growth in the Northeast: A Spatial Analysis of the FNE, FDNE, and Tax Incentives

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ABSTRACT

This study investigates the impacts of the main instruments of the National Policy for Regional Development (PNDR) — the FNE, FDNE, and Sudene's tax incentives — on the economic growth of municipalities in the Brazilian Northeast between 2003 and 2019. To this end, spatial econometrics applied to panel data is employed to analyze the direct, indirect, and total effects of these policies on the growth rate of per capita GDP, Sectoral Gross Value Added, and municipal tax revenue. The results indicate positive impacts for all instruments, with FDNE and tax incentives standing out due to their significant effects on industrial GVA and tax collection. The spatial analysis reveals patterns of spatial dependence among municipalities, indicating the occurrence of regional spillovers. This underscores the relevance of regional policies in fostering development and suggests the need for strategic coordination in the use of these instruments and the allocation of resources.

Keywords: Regional growth, PNDR, FNE, FDNE, spatial econometrics.
JEL Classification: R58; H25; C23.

SUMMARY

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1. INTRODUCTION

Regional inequality remains one of the main challenges to Brazil's economic development. In particular, the Northeast faces structural disparities in relation to other regions of the country, resulting from a historical process of economic concentration and adverse socioeconomic factors (Furtado, 1959; Cano, 1977; Baer, 2003). These inequalities are reflected in indicators such as GDP per capita, education, and infrastructure, limiting the region's growth potential. In this context, public policies aimed at promoting regional development have been implemented over the decades, seeking to mitigate these disparities and foster more balanced economic growth.

Data from the Brazilian Institute of Geography and Statistics (IBGE) indicate that, between 2002 and 2020, the Northeast recorded an average annual growth in gross domestic product (GDP) of 2.2%, exceeding the national average of 2.0% and the rates observed in the South and Southeast regions (1.7%) (Brazil, 2023). This performance increased the Northeast's share of the national GDP from 12.8% in 2003 to 14.5% in 2017. However, the region still has the lowest levels of GDP per capita and the highest rates of poverty and inequality in the country. The northeastern states are among the ten with the lowest GDP per capita in the country, and the region accounts for 43.79% of the population vulnerable to poverty, in addition to exhibiting a Gini Index of 0.536 (Brazil, 2023).

To address these disparities, the federal government instituted the National Regional Development Policy (PNDR) through Decree No. 6,047 of 2007, aiming to articulate and coordinate public actions aimed at reducing regional inequalities. The PNDR relies on instruments such as the Constitutional Financing Funds for the Northeast (FNE), the Midwest (FCO), and the Amazon (FNO), the Development Funds for the Northeast (FDNE), the Midwest (FDCO), and the Amazon (FDA), in addition to tax incentives granted by the Superintendences for the Development of the Northeast (Sudene), the Midwest (Sudeco), and the Amazon (Sudam). These mechanisms aim to stimulate productive investments, strengthen local economic chains, and boost job and income generation in the region.

In the Northeast region of Brazil, the FNE disbursed more than R$ 270 billion between 2002 and 2019, supporting sectors such as agriculture, industry, and infrastructure (Banco do Nordeste, 2020). The FDNE, in turn, financed strategic projects in the Sudene area, especially in the energy and transportation segments, with investments exceeding R$ 40 billion during the period. Tax incentives provided an important stimulus to the productive sector in the Northeast, attracting new companies to the region and strengthening the local economy (Sudene, 2023).

Empirical studies point to the positive impacts of funds and tax incentives on per capita GDP growth, job creation, and tax collection (Resende, 2012; Linhares et al., 2014; Oliveira and Silveira Neto, 2016; Carneiro et al., 2024). However, there is still a gap in the joint analysis of these instruments and their spatial interactions, especially with regard to direct and indirect effects on neighboring municipalities (Ferreira, Irffi, and Carneiro, 2024).

Given this scenario, this study seeks to assess the simultaneous impacts, identify patterns of spatial dependence, and verify the existence of regional spillovers from the FNE, FDNE, and Sudene tax incentives on GDP per capita growth rates and sectoral Gross Value Added (GVA) in northeastern municipalities between 2003 and 2019. To this end, spatial econometrics is used in panel data, through the specification and estimation of the Generalized Spatial Dependency Model (GNR).

The results indicate that the three instruments analyzed have positive effects on the region's economic growth, although with different impacts across sectors. The FNE showed positive effects in agriculture and the service sector, while the FDNE had a greater impact on industry, especially in municipalities that received infrastructure investments. Tax incentives, in turn, had a significant influence on municipal tax collection and the creation of formal jobs. The spatial analysis revealed patterns of spatial dependence, showing that the effects of the policies extend beyond the municipalities that directly benefited, generating positive spillovers for neighboring localities and highlighting the importance of regional coordination in the allocation of resources.

The article is structured in four sections, in addition to this introduction. In the second section, a literature review, the theoretical foundations of regional policies and a survey of empirical studies will be addressed in subsections. The third section presents the econometric strategy used in the analysis. In the fourth section, the results are presented and discussed. Finally, the fifth section presents the final considerations, highlighting the main conclusions and implications of the study.

2. LITERATURE REVIEW

2.1 Theoretical Framework

Regional inequality in Brazil has historical roots dating back to the colonial period, when the economy of the Northeast was based on sugar production for export. With the decline of this activity and the rise of the coffee economy in the Southeast, the concentration of investments and infrastructure favored the industrialization of the latter region, widening economic disparities in the country (Furtado, 1959; Cano, 1977). This process resulted in the persistence of a fragile productive structure in the Northeast, characterized by low economic diversification, high levels of informality, and less access to credit and infrastructure (Baer, 2003).

Economic literature presents several theories to explain regional inequalities. The theory of economies of location, based on the work of Marshall (1890), suggests that geographical proximity between companies generates positive externalities, such as the sharing of skilled labor, the dissemination of knowledge, and the development of infrastructure. This phenomenon favors the concentration of economic activity in certain regions, creating competitive advantages that perpetuate spatial disparities.

Myrdal (1957) and Hirschman (1958) emphasize cumulative causation and chain effects, whereby richer regions attract investment and human resources, thereby deepening regional inequalities. While Myrdal (1957) highlights the feedback effects that favor developed areas, Hirschman (1958) suggests that investments can generate positive and indirect impacts in less developed regions, provided they are accompanied by appropriate public policies.

Krugman (1991), expanding on this theory with New Economic Geography, argues that increasing returns to scale and transportation costs encourage industrial concentration in a few regional hubs. This process results in the polarization of development, with central regions attracting investment and skilled labor, while peripheral regions remain marginalized.

Another determining factor of regional disparities is the failure of the credit market, highlighted by Stiglitz and Weiss (1981). In peripheral economies such as the Northeast, the scarcity of collateral and the high perception of risk limit access to financing, hindering productive investment and the modernization of the local economy. In response, public policies that offer subsidized credit and tax incentives become essential instruments for correcting these failures and stimulating regional development (Crocco et al., 2006; Além and Madeira, 2015).

The financing funds and tax incentives analyzed in this study are directly related to these theories. The FNE and FDNE seek to correct credit market failures by ensuring long-term financing for strategic sectors. Tax incentives, on the other hand, act to reduce the cost of capital and attract investment to less developed areas. Thus, these instruments not only promote economic growth but also have a significant social impact by generating jobs, reducing poverty, and strengthening regional productive capacity (Garsous et al., 2017; Carneiro et al., 2023).

2.2 PNDR Instruments

The PNDR was created with the aim of reducing socioeconomic disparities between regions in Brazil, promoting more equitable development. The Northeast, historically marked by adverse conditions, is one of the main target regions of this policy. Among the main instruments of the PNDR are the FNE, the FDNE, and the tax incentives granted by Sudene. These mechanisms aim to stimulate productive investments, strengthen local economic chains, and boost job and income generation in the region (Brazil, 2007).

Sudene's tax incentives aim to attract and expand productive investments in the Northeast, reducing regional inequalities. The main mechanism is a 75% reduction in Corporate Income Tax (IRPJ) for companies that implement, modernize, or expand activities in the region. This benefit is granted to companies under the real profit regime that operate in priority sectors defined by Sudene. To access the incentive, the company must present an investment project that proves its contribution to regional development, ensuring, among other factors, job creation and the efficient use of natural resources (Sudene, 2023).

Empirical evidence indicates that Sudene's tax incentives have a positive impact on economic growth and the labor market in the Northeast. Garsous et al. (2017) assessed the impact of Sudene's tax incentives on the tourism sector and identified significant employment growth, ranging from 30% to 39%, reinforcing the potential of these benefits to boost strategic sectors.

Carneiro et al. (2023) analyzed the efficiency of companies benefiting from the 75% reduction in corporate income tax, finding that, although the policy has achieved its goal of attracting investment, many companies operate below the efficiency frontier. Braz and Irffi (2023) found evidence that the tax incentive resulted in a 3.2% increase in formal jobs and a 1.2% increase in municipal average income, with more pronounced effects in more developed municipalities. Ferreira, Irffi, and Carneiro (2024) demonstrated that tax incentives contributed to a reduction in infant mortality and an increase in GDP per capita, with positive spillovers for neighboring municipalities. However, there are challenges in the spatial distribution of benefits, as incentives tend to concentrate in more structured areas, reinforcing intraregional inequalities.

The FDNE is a fund aimed at financing large structural projects in the region, such as infrastructure projects and basic industries. Financing can cover up to 80% of the total investment, with payment terms of up to 20 years, depending on the sector and location of the project. Priority is given to sectors such as energy, transportation, and sanitation, seeking t te investments with high regional impact. Studies indicate that the FDNE has positive effects on GDP growth and the creation of formal jobs (Carneiro et al. 2024, Ferreira, Irffi, and Carneiro, 2024, Irffi et al., 2025).

The FNE, managed by the BNB, is the main long-term financing mechanism for productive activities in the Northeast. Although it also finances large projects, its priority is to support small producers and micro and small businesses. The FNE operates with subsidized interest rates, long terms, and flexible conditions, allowing companies and rural producers to access capital for the expansion and modernization of their activities (Banco do Nordeste, 2020).

Several studies have assessed the impacts of the FNE on the economy of the Northeast. In general, there is consensus that the fund contributes to job creation and economic growth, with the most evident effects in the agricultural and service sectors (Linhares et al., 2014). Resende (2012, 2014) identified positive impacts on job creation and income, although with limited effects on per capita GDP growth. Cravo, Resende, and Carvalho (2014) used spatial models and pointed out that the effects of the FNE may depend on specific regional characteristics, such as infrastructure and available human capital.

Carneiro (2018) analyzed the efficiency of municipalities in the use of FNE resources and found that those with higher levels of human capital have greater economic returns. Do Monte et al. (2024) found that the allocation of FNE resources to companies resulted in significant increases in the wage bill and GDP per capita, especially when financing represented a substantial portion of total investment. However, some studies indicate that the effects of the FNE may be heterogeneous and more limited in municipalities with less economic dynamism (Resende, Silva, and Silva Filho, 2017).

Ferreira, Irffi, and Carneiro (2024) and Carneiro et al. (2024) conduct a joint analysis of PNDR instruments. Ferreira, Irffi, and Carneiro (2024) assess the effects of tax incentives and the FDNE, managed by Sudene, on the economic development of municipalities in the Northeast. The methodology combines the construction of a Municipal Development Index (IDM) with spatial econometric analyses to capture both local economic development and the impacts of these instruments on neighboring municipalities. The results indicate that tax incentives contributed significantly to economic development, reducing infant mortality and increasing GDP per capita, with spillovers to neighboring municipalities, while the FDNE had an impact limited only to the income subindex.

Carneiro et al. (2024) analyzed the impact of the three main PNDR instruments on the economy of municipalities in the Northeast: FNE (Industry and Infrastructure), FDNE, and Tax Incentives. The study uses the two-stage difference-in-differences method (Gardner, 2021) and the estimator by Callaway and Sant'Anna (2021). The results indicated that a 10% increase in the contracted value of FNE Industry and Infrastructure raises municipal GDP per capita by approximately 7%, while the same increase in FDNE would generate a 23% increase in this indicator. As for tax incentives, the results were inconclusive, with some models indicating positive effects and others not.

In this sense, this study represents an extension of the latter two, as it jointly analyzes the effects of PNDR instruments on the growth rates of municipalities in the Sudene area, but takes spatial effects into account, unlike Carneiro et al. (2024), and by using panel data, it advances on the approach of Ferreira, Irffi, and Carneiro (2024).

3. METHODOLOGY

To assess the impact on the local economy of having enterprises supported by at least one of the regional policy instruments, we started from the *Two-Way Fixed Effects* (TWFE) model, taking as the treatment group the municipalities with companies benefiting from Tax Incentives, FNE, and/or FDNE. The control group considers the other municipalities in the Sudene area, similar to Carneiro et al. (2024), but which do not have companies covered by PNDR instruments. However, unlike these authors, we sought to adapt the model to consider the presence of spatial effects.

This is relevant because, as Ferreira, Irffi, and Carneiro (2024) showed, the distribution of beneficiaries of development policy is not homogeneous across space, but concentrated in regions with a higher degree of development. Furthermore, interaction between neighboring regions can cause the effects of the policy to spill over into neighboring municipalities. Such interaction may result from the movement of goods, people, or information through space (Odland, 1988). Therefore, disregarding this phenomenon can lead to misguided conclusions about the effects of the policy.

3.1 Econometric Strategy

Like Carneiro et al. (2024), we used the fixed effects model with time *dummies*, known as TWFE, as a starting point to estimate the causal effect of regional policy instruments on economic growth. Under certain conditions, this method provides an extension of the standard difference-in-differences model considering several periods, allowing us to obtain the average treatment effect on the treated (ATT), expressed by:

$$y_{it} = \beta_0 + \tau D_{it} + \beta^{'X_{it}} + \delta_t + c_i + \varepsilon_{it} \quad [1]$$

Where D_{it} takes on a value of one from the moment unit i begins to receive the treatment; the term δ_t represents temporal shocks common to all units, represented by *dummies* for each year. While the term c_i represents individual heterogeneity, potentially correlated with D_{it}, that is, the unobserved individual characteristics, fixed in time, that may affect the receipt of treatment. And X_{it} is a set of observed characteristics of the units (time-varying variables).

Equation 1 can be estimated using the Ordinary Least Squares (OLS) method after subtracting each variable by its respective time average, a process that eliminates c_i (Wooldridge, 2010). In this case, the parameter captures the ATT if: (i) the treatment is homogeneous between the treated units and over time; and (ii) the parallel trajectories hypothesis is respected (Ruttenauer and Aksoy, 2024). However, in the presence of spatial effects, the Gauss-Markov hypotheses and OLS assumptions are violated, making the estimators biased and inefficient (Almeida, 2012).

To verify the existence of such effects, the presence of spatial autocorrelation was investigated using Moran's I diagram and coefficient of the dependent variable (Anselin, 1996). To this end, a spatial weight matrix (W) is used, which measures the degree of connection between regions based on some criterion of contiguity or proximity, defined by neighborhood, geographical and/or socioeconomic distance, or a combination of both (Almeida, 2012)[1].

1 In the present study, a second-order “tower” matrix was used, i.e., the possibility of interaction between immediate neighbors and neighbors of neighbors was considered, ignoring the vertices of the map. The choice of this matrix followed the procedure of Baumont (2004), which consisted of testing the presence of spatial autocorrelation of the residuals of an auxiliary OLS regression for different matrices and choosing the one with the highest Moran's value. First- and second-order “tower” and “queen” matrices were tested, as can be seen in Appendix A.

3.2 Specification of the Spatial Model

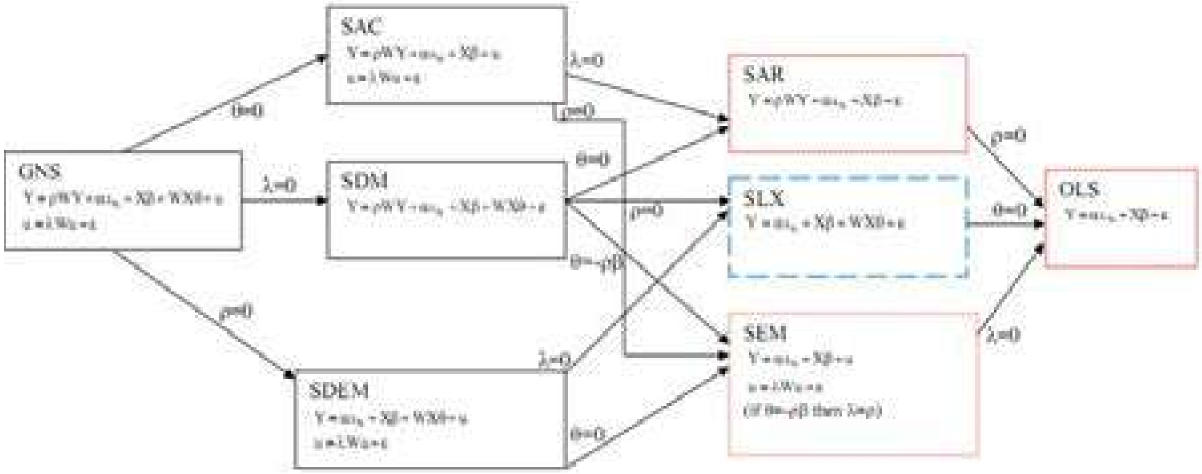
Once spatial effects have been identified, they must be adequately considered in the estimation of the econometric model. This can be done by including spatial lags of the dependent variable (Wy), the explanatory variables (WX), and/or the error terms ($W\varepsilon$) (Almeida, 2012). The different combinations of these lags will give rise to different spatial models. The most flexible approach to spatial models, and the starting point for other specifications, is the GNR Model, proposed by Manski (1993).

The GNR incorporates the three types of spatial lag of the dependent variable through the spatial autoregressive factor (ρWy), the explanatory variables (θWX) and the error term (λWu), as described in Equation 2.

$$y = \rho Wy + \beta X + \theta WX + u$$
$$u = \lambda Wu + \varepsilon \qquad [2]$$

Starting from the GNR and eliminating each of the three spatial lag parameters in all possible permutations, different spatial econometric models are created, as described in Figure 1.

Figure 1 – Different situations in Spatial Econometrics.



Source: Seifi, Ebrahim, and Ahmadi (2020). Note: SDM: Spatial Durbin Model; SDEM: Spatial Durbin Error Model; SAR: Spatial Autoregressive Model; SEM: Spatial Error Model; OLS: Ordinary Least Squares Model; SLX: Spatial Lag of X Model; SAC: Spatial Autoregressive Combined; GNS: General Nesting Spatial Model.

To choose which lags to include in the model, the following strategy was employed: all specifications were estimated and a series of focused tests were performed to verify the significance of the spatial parameters, ρ, θ e λ. Specifically, the Wald and Likelihood Ratio (LR) tests were used for the spatial terms. The Wald test has as its null hypothesis the absence of spatial effects, which would indicate that OLS is the most appropriate for each model. The lower the value of this statistic, the less likely it is that the null hypothesis is true. The LR test tests the significance of spatial terms based on the most complete models and compares them with the most restrictive specifications, with the null hypothesis that the restrictions are true[2].

Finally, it should be noted that the interpretation of coefficients in the presence of spatial autocorrelation differs from traditional models. The effects are decomposed into direct effects, which measure the impact of an explanatory variable on the dependent variable in the same spatial unit, and indirect effects, which capture the impact of that variable on neighboring units, known as spatial *spillovers* (Elhorst, 2014; LeSage and Pace, 2009). In the case of panel data with spatial effects, LeSage et al. (2009) propose impact measures such as average effects over time, whose expression will depend on the chosen spatial specification. Instead of using only the neighborhood matrix W_N, the panel structure requires the introduction of the block-diagonal matrix $W_T = I_T \otimes W_N$, considering spatial dependence over time. Thus, considering a general spatial model, the impact matrix in the panel context is adjusted to obtain direct and indirect effects in the same way as in *cross-section* models.

3.3 Empirical Model

To assess the effect of regional policy instruments on economic growth, a strategy similar to Linhares et al. (2014) was used, based on the growth models of Sala-i-Martin (1996). According to this specification, the growth rate of output between two periods is a function of the values in the initial period, in order to avoid simultaneity in the results derived from possible reverse causality. Thus, when considering the *TWFE* equation and inserting all spatial lags as in the GNR, the general spatial model of unobserved effects would have the following configuration:

$$y_{it} = \gamma y_{t-1} + \rho W y_{it} + \tau D_{it-1} + \beta X_{it-1} + \theta W(X_{it-1} + D_{it-1}) + \delta_t + u_{it}$$
$$u_{it} = \lambda W u_{it} + c_i + \varepsilon_{it}$$

2 The results, available in Appendices C and D, indicated that the GNR model was the most appropriate.

Where y_{it} is the growth rate of *per capita* output of municipality i between periods t-1 and t; the variables y_{t-1}, D_{it-1} e X_{it-1} represent *per capita* output, treatment status, and observable characteristics at the beginning of each period (t-1); and Wy_{it}, $W(X_{it-1} + D_{it-1})$ and Wu_{it} are the weighted averages of these variables in neighboring municipalities. The parameters were estimated using the Quasi-Maximum Likelihood (QML) method proposed by Lee and Yu (2010) for spatial fixed-effects panels.

Specifically, in the case at hand, three treatment variables were considered: two post-treatment *dummies* for the first receipt of tax incentives and FDNE; and for the FNE, the total value of financing divided by GDP was considered. This last variable was due to the fact that the FNE has great capillarity, so that every year there are operations in all municipalities in the Sudene region, therefore, it would not be possible to establish a starting point for the treatment. Thus, while the coefficients for Tax Incentives and FDNE report the effect of having at least one company benefiting from these instruments, the FNE will report the effect of a proportional increase in GDP from fund disbursements on the growth rate.

3.4 Data

To estimate the econometric model, a panel of the 2,074 municipalities in the Sudene area of operation was constructed[3], which includes, in addition to the states of the Northeast, municipalities in the north of the states of Minas Gerais and Espírito Santo. The time frame considered the period from 2003 to 2019, although the joint analysis of the three instruments was based on data from 2008 onwards, due to the availability of public data on tax incentives and because this was the year of the FDNE's first operation.

The municipal GDP *per capita* growth rate was used as a result indicator. Control variables were also used to cover characteristics of the municipalities that could explain both their level of output and the possibility of having a business that benefited from regional policy instruments, following Carneiro et al. (2024). Thus, the variables chosen were the average level of education of workers, the degree of formalization, the number of companies, and population density.

In addition to GDP *per capita*, a sectoral analysis of GVA in agriculture, industry, services, and public administration was performed to measure the impact of the instruments on

3 Thirty municipalities (~1.4%) were removed from the sample because they had missing information in some of the years analyzed.

municipal production levels. Table 1 details the variables used in the study.

Table 1 - Variables explained in the analysis and their respective data sources.

Variable	Description	Source
Municipal GDP per capita growth	Municipal GDP per capita growth rate, at constant 2019 prices	IBGE
Agricultural GVA per capita	Growth rate of Gross Value Added in the agriculture sector, per capita, at constant 2019 prices	IBGE
Per capita industrial GVA	Growth rate of Gross Value Added in the industry sector, per capita, at constant 2019 prices.	IBGE
GVA Services per capita	Growth rate of Gross Value Added in the services sector, per capita, at constant 2019 prices.	IBGE
GVA Public Administration per capita	Growth rate of Gross Value Added in the public administration sector, per capita, at constant 2019 prices	IBGE
Taxes per capita	Growth rate of total taxes collected, per capita, at constant 2019 prices.	IBGE
FNE/PIB	Value of disbursements as a proportion of municipal GDP	BNB
FDNE	Dummy variable that assumes a value of one after the first contract with the FDNE	Sudene
IF	Dummy that assumes a value of one after receiving the first tax incentive	Sudene
Education	Average education level of formal workers (median for the class)	RAIS
Employment contracts	Number of formal employment relationships / population	RAIS
Number of companies	Number of companies	RAIS
Population density	Population density	IBGE

Sources: Prepared by the authors

4. ANALYSIS OF RESULTS

4.1 Descriptive Analysis and AEDE

First, it is necessary to conduct a preliminary descriptive analysis of the economic indicators of the municipalities and the resources allocated to projects in the region covered by SUDENE between 2003 and 2019. According to Table 1, the analysis of the data reveals a growth trajectory in investments by the Constitutional Fund for Financing the Northeast (FNE) over the years, with a notable sharp increase in 2018. The Northeast Development Fund (FDNE), in turn, shows irregular values, being non-existent in some years and with greater contributions in 2009 and 2013. The number of companies receiving incentives began to be recorded in 2008 and grew significantly until 2018, indicating greater adherence to tax incentives. The real GDP of the municipalities in the Sudene area shows continuous growth until 2014, with a decline from 2015 onwards, both for GDP and GDP per capita, possibly reflecting the impacts of the national economic recession that occurred during the period.

Table 1 – Output and quantities of FNE, FDNE, and Tax Incentives in the Sudene area

Year	FNE Amount (R$ million)	FDNE Value (R$ million)	Incentivized Companies	Real GDP (R$ million)	GDP *per capita*
2003	4,530.9	0	-	948.43	17,540.33
2004	11,766.4	0.0	-	997.29	18,235.34
2005	15,848.3	0.0	-	1,040.04	18,805.85
2006	16,946.6	0.0	-	1,093.19	19,549.78
2007	14,458.5	0.0	-	1,140.45	20,424.63
2008	23,597.8	576.6	1	1,192.73	20,732.14
2009	28,589.7	3,786.2	2	1,221.09	21,034.56
2010	29,844.2	0	24	1,293.47	22,502.87
2011	29,197.5	61.7	201	1,328.03	22,926.14
2012	29,043.9	0	179	1,370.81	23,492.17
2013	29,173.2	3,076.2	223	1,400.55	23,176.79
2014	29,713.5	558.7	177	1,431.54	23,526.84
2015	22,701.8	42.5	219	1,394.10	22,764.19
2016	20,598.3	192.8	256	1,354.05	21,973.88
2017	28,735.4	4.0	237	1,381.55	22,288.75
2018	54,567.2	0	552	1,392.01	22,657.34
2019	46,132.4	170.5	253	1,390.49	22,510.06

Source: Prepared by the authors based on data from IBGE/Sudene/BNB. Note: FNE and FDNE deflated by the IGP-M for average values for 2019.

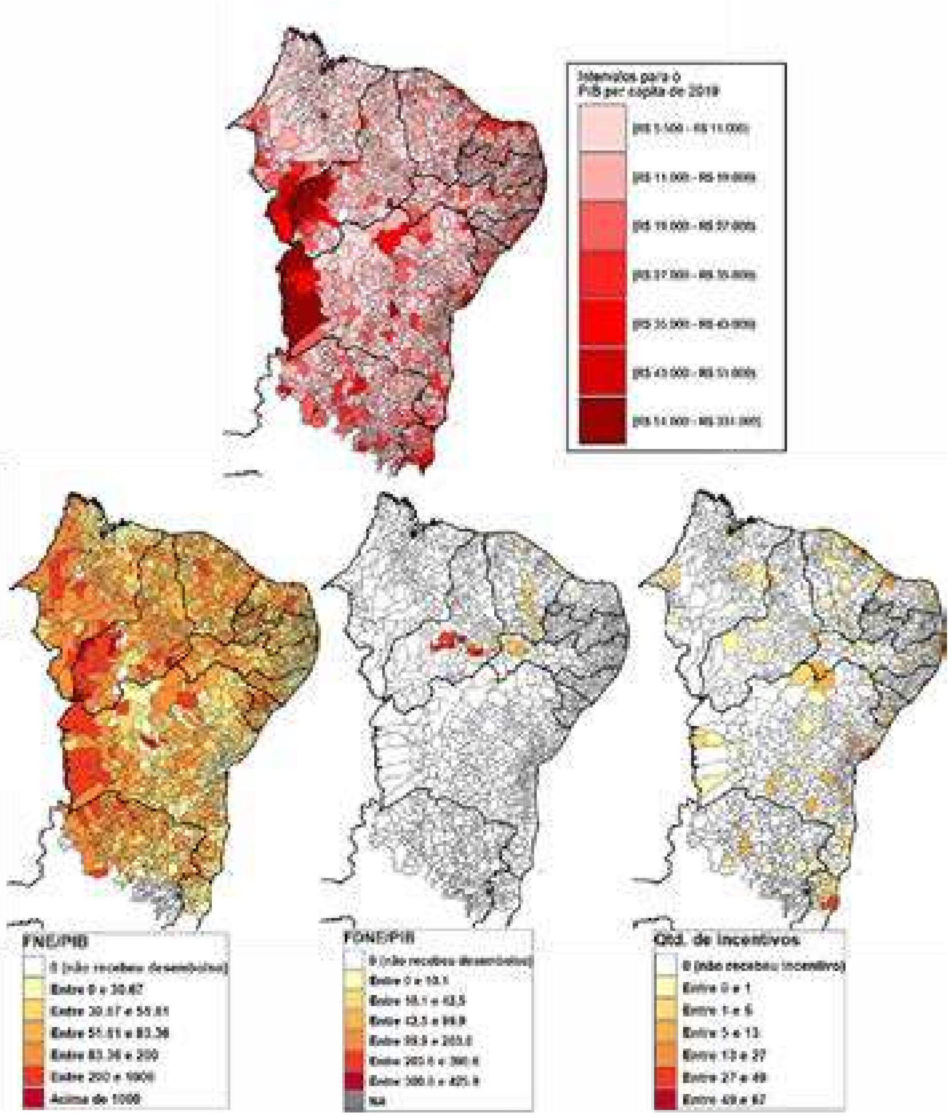
The municipal distribution of GDP per capita for 2019 can be seen in Figure 2, which highlights some development patterns. In addition to the traditional metropolitan regions of the capitals of the northeastern states, it is possible to find municipalities with extremely high levels of GDP per capita throughout western Bahia, southwestern Piauí, and southern Maranhão, a region known as Matopiba (Maranhão, Tocantins, Piauí, and Bahia), which stands out as an expanding agricultural frontier. Not as large as these, but still relevant, there are municipalities with values between R$ 27,000.00 and R$ 43,000.00 in the Submédio do São Francisco region, along the northeastern coast, in northern Espírito Santo, and in Minas Gerais, such as the Jequitinhonha and Vale do Mucuri regions. One interesting thing to note is that, despite the apparent dispersion of municipalities with high GDP per capita values, most of them have few neighbors in their surroundings that show the same trend.

In addition, the same figure shows the distribution of the annual average disbursements from the FNE and FDNE as proportions of municipal GDP, and the total number of projects supported per municipality. It can be seen that the FNE is present in practically the entire territory, demonstrating its high capillarity, although some municipalities have large credit absorbers and others less so. This situation is reversed with the FDNE, whose resources are present in very few municipalities, notably in southeastern and southwestern Piauí; the Pernambuco hinterland; and south-central, hinterland, and coastal Ceará. This is due to the size of the projects, especially in the industry and infrastructure sectors, which, because they require large investments, are less distributed in space. Tax incentives, although more widely distributed than FDNE resources, are still less dispersed than those of the FNE. Their presence is notable, especially in some capitals and metropolitan regions, as well as in locations that stand out as important production hubs, such as the irrigated agriculture hub of Petrolina-Juazeiro. They are also present in municipalities with greater economic diversification, located in mesoregions such as northern Espírito Santo, northern Minas Gerais, south-central Bahia, eastern Maranhão, Jaguaribe and northwestern Ceará, western Rio Grande do Norte, among others.

Table 02, in turn, reveals the sectoral distribution of investments, indicating a strong focus of tax incentives on industry (71.3% of requests), while the FDNE is mainly allocated to infrastructure (73.4%). The FNE, in turn, has a higher concentration of resources in agriculture (38.8%), followed by services (24.0%), indicating an effort to strengthen productive and structuring activities in the region. The low participation of agriculture and services in tax incentives and the FDNE suggests that these sectors depend more on FNE credit, while industry, even though it is the most fiscally incentivized sector, receives a smaller share of direct financing. This may indicate a strategy of stimulation via tax relief, while infrastructure is strengthened by direct investments.

Therefore, there is a certain complementarity between the instruments, with the FNE, which has greater capillarity, playing a more comprehensive role in supporting the agricultural and service sectors, while the FDNE focuses on large-scale projects, mainly aimed at infrastructure. Tax incentives, on the other hand, function as a strategic mechanism to stimulate industrialization and the consolidation of specific productive hubs.

Figure 2 - Municipal distribution of GDP per capita in the SUDENE region in 2019.



Source: Prepared by the authors based on IBGE data.

Table 2 - Sectoral distribution of PNDR instruments.

Sector	Tax Incentives (% of requests)	FDNE (% R$)	FNE (% R$)
Industry	71.3	26.6	18.5
Infrastructure	19.9	73.4	18.8
Services	6.1	0	24.0
Agriculture and livestock	2.7	0.0	38.8

Source: Prepared by the authors based on data from SUDENE and BNB.

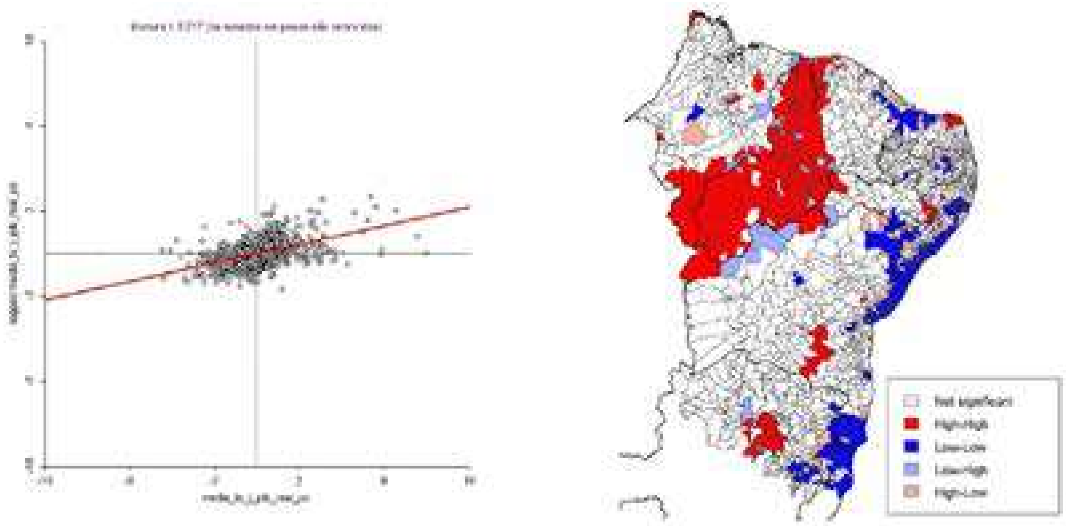
To verify whether GDP *per capita* growth rates and FNE values as a proportion of municipal GDP follow any systematic pattern across space, the presence of spatial autocorrelation was tested using Moran's Index (1948), global and local for FNE and FDNE values as a proportion of municipal GDP, and the number of incentive claims.

To consider the entire period analyzed, the AEDE was performed using the annual average of the respective values. In addition, the bivariate spatial correlation was calculated to verify whether the GDP per capita values of a municipality vary according to the presence of projects supported by the instruments in neighboring municipalities. The spatial weight matrix chosen was the one that obtained the highest Moran's I for the MQO model residuals, according to Baumont's (2004) procedure, with the second-order tower neighborhood criterion adopted.

The results of the AEDE can be seen in Graphs 04 and 05. All Moran values were positive and statistically significant at the 5% level. In the case of the univariate global Moran for GDP per capita growth rates, the moderate value of 0.217 indicates the presence of spatial autocorrelation, evidenced by the predominance of observations in the first and third quadrants of the scatter plot (High-High and Low-Low). This means that municipalities with high average growth rates tend to be close to other municipalities with high average growth rates, while municipalities with low average growth rates tend to cluster with other low-growth municipalities.

However, when analyzing the Moran Bivariate scatter plots, this configuration remains, but with less magnitude. When it comes to the influence of the FNE and FDNE on GDP per capita growth rates, this correlation becomes relatively weaker. Still, in general, municipalities with high GDP growth tend to be geographically close to other municipalities that also have large proportions of FNE or FDNE loans in relation to GDP, and vice versa. On the other hand, this relationship is not observed for tax incentives, since municipalities with high average GDP per capita growth rates tend to be surrounded by municipalities with low numbers of incentive claims, and vice versa.

Figure 3 – Global Moran's Dispersion and Local Cluster Map (LISA), univariate, 2003-2019.



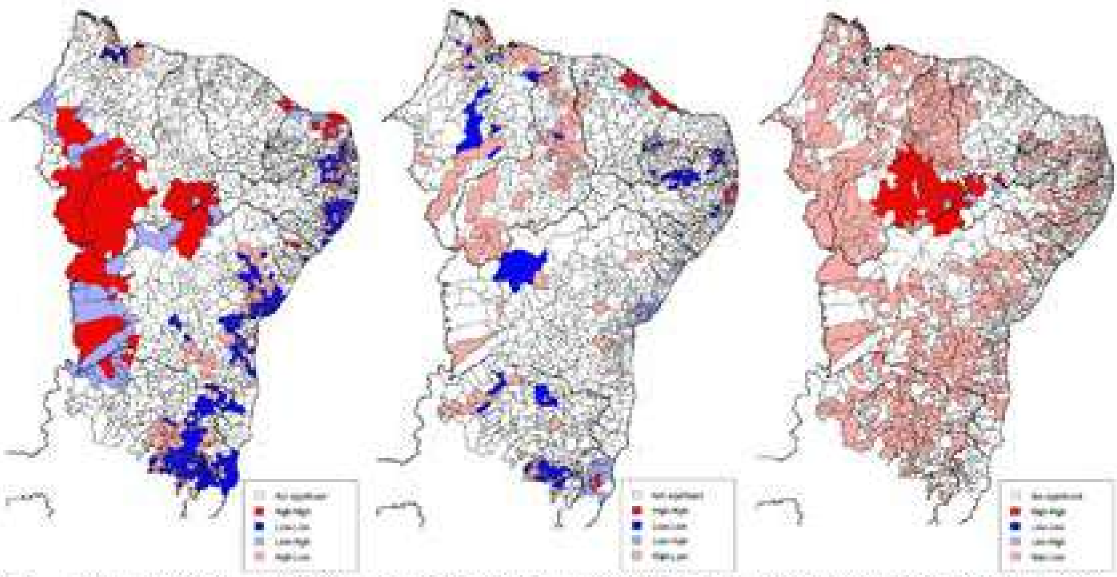
(a) Univariate Global Moran's I (0.217) - Average GDP per capita growth rate – 2003/2019

(b) Local Moran's I (LISA) Univariate – Annual average GDP per capita growth rate – 2003/2019

Source: Prepared by the authors.

Source: Prepared by the authors.

Figure 3 – Global Moran's I and Local (LISA) Cluster Map, univariate, 2003-2019.



(a) Local Moran's I (LISA) Bivariate - Annual Average GDP PC Growth Rate versus Average FNE/GDP – 2003/2019

(b) Local Moran's I (LISA) Bivariate - Annual Average GDP PC Growth Rate *versus* Number of Incentives – 2003/2019

(c) Bivariate Local Moran's I (LISA) - Annual Average GDP PC Growth Rate *versus* Average FDNE/GDP – 2003/2019

Source: Prepared by the authors.

Considering the Local Spatial Association Indicators, an extension of the global Moran's

I that allows the identification of spatial association clusters, it was possible to confirm the presence of positive clusters of municipalities with high GDP per capita growth rates in much of the state of Piauí, in the north of Minas Gerais, in the south-central region of Bahia, in eastern Rio Grande do Norte, in the Agreste region of Pernambuco, and in southern Maranhão. Negative growth clusters are observed in the mesoregions of northern Espírito Santo; Vale do Rio Doce, Pernambuco Forest, Paraíba Agreste, western Rio Grande do Norte, southern Bahia, and a portion of the northern coast of Bahia, passing through Sergipe and Alagoas.

4.2 Impact Assessment

The following are the results of the assessment of the effects of the FNE, FDNE, and tax incentives on the economic growth of municipalities between 2003 and 2019. Preliminary panel specification and unit root tests were performed, available in Appendix B, which attest to the stability of the series and the adequacy of the fixed effects approach. The incorporation of spatial dependence followed the GNR Model. The complete results of all estimates, as well as the tests performed, are also available in Appendices C and D.

Thus, Table 3 presents the direct, indirect, and total effects of regional policy instruments, FNE, FDNE, and Tax Incentives, on the growth rate of the beneficiary municipalities and their neighbors. The three instruments had positive effects on the increase in average municipal output. The estimation shows, for example, that a 10 percentage point increase in the ratio of FNE values to GDP raises the *per capita* GDP growth rate by 0.0112%.

In addition, no indirect effects of this financing were identified, suggesting that these lines of credit have a moderate impact, possibly conditioned by the presence of complementary factors, such as infrastructure and workforce skills. This finding is in line with the studies by Cravo, Resende, and Carvalho (2014), which pointed out that the impact of the FNE may be limited in regions with less economic dynamism. On the other hand, it differs from the results of Resende, Silva, and Silva Filho (2017), who identified more significant direct and indirect effects, possibly due to the economic typology of the municipalities analyzed.

The FDNE had a more significant impact on municipal economic growth. The presence of FDNE-supported projects increased average output growth by 3.5%. The indirect effects were only significant at the 10% level, indicating the possible presence of *spillovers* to neighboring municipalities. This is in line with the findings of Ferreira, Irffi, and Carneiro (2024), who demonstrated that the FDNE had a positive impact on the income subindex in the beneficiary municipalities, albeit with a lesser effect on other development indicators.

Table 3 - Direct and indirect effects of regional policy instruments – GNR model

Dependent variable: GDP per capita growth rate							
Treatment	Effect	Coeff.	Standard Error	Z Stat	p-value	CI Min (95%)	Max CI (95%)
FNE/GDP	Direct	.0000122	1.55e-06	7.90	0.000	9.20e-06	.0000153
	Indirect	-1.01e-06	3.63e-06	-0.28	0.782	-8.12e-06	6.11e-06
	Total	.0000112	4.05e-06	2.78	0.006	3.30e-06	.0000192
FDNE	Direct	.0098703	.0077449	1.27	0.203	-.0053095	.0250501
	Indirect	.0251877	.0136879	1.84	0.066	-.0016402	.0520155
	Total	.0350579	.0153251	2.29	0.022	.0050213	.0650945
IF	Direct	.0213117	.0038742	5.50	0.000	.0137184	.028905
	Indirect	.0163558	.0078557	2.08	0.037	.0009589	.0317527
	Total	.0376675	.0089301	4.22	0.000	.0201649	.0551702

Source: Research results. Note: *p-value < 0.05.

Sudene's tax incentives had the greatest overall impact on economic growth, both directly and indirectly, reinforcing their effectiveness in attracting productive investments and boosting the local economy. Having incentivized enterprises accelerates growth by 3.8%. The indirect effects were also significant, indicating that the benefits of the incentives spread to nearby regions. These findings are consistent with the results of Garsous et al. (2017), who identified significant employment growth in the tourism sector in regions benefiting from tax incentives, as well as with the studies by Carneiro et al. (2023), who highlighted the improvement in the productive efficiency of the beneficiary companies.

However, unlike the study by Carneiro et al. (2024), which presented inconclusive results on tax incentives, the present analysis suggests a robust positive effect. This difference can be attributed to the incorporation of spatial effects in the modeling used in this study, which better captures the interactions between municipalities.

4.3 Robustness Analysis

Since the choice of the most appropriate spatial model specification is subject to uncertainty, we decided to compare the results of the main estimation with those produced by the other specifications in order to check for possible inconsistencies between them. In general, the results, available in Table 4, seem to corroborate the main estimation, especially regarding the effects on the FNE and Tax Incentives. They also seem to support the existence of only indirect effects of the FDNE. The magnitude of the effects varies slightly between specifications, with the chosen approach, the GNR Model, being more conservative in most cases.

In addition to the specifications, we chose to use a second-order "tower" type spatial contiguity weight matrix, which considers the links between immediate neighbors and neighbors of neighbors. Thus, to capture possible global effects beyond these boundaries, we re-estimated the model considering the inverse distance matrix. This matrix uses the distance between units as a weighting factor for the spatial connection between units, allowing interactions between all municipalities in the sample.

The results with this new matrix, for all spatial model specifications, can be seen in Table 5. Once again, the positive effects of the FNE and Tax Incentives are confirmed, in particular the direct effects. Still in the FNE, the global specifications also suggest the existence of positive indirect effects of the FNE. On the other hand, the FDNE has no significant effect for most of the specifications tested. Therefore, the use of an alternative spatial weight matrix largely corroborates the results of the main estimation.

The checks performed show that the model results are robust to variations in the specification of spatial effects and in the range considered by the weighting matrix. In particular, the effects of Tax Incentives and, especially, the FNE are consistent across all specifications tested, reinforcing their relevance in regional economic dynamics. These results are in line with the literature on the role of financial incentives in local development, which points to the importance of targeted credit mechanisms and fiscal policies in promoting economic growth.

In addition, the persistence of the positive effects of the FNE, both direct and indirect, suggests that this instrument can play a structuring role in reducing regional inequalities by stimulating investments in municipalities that might otherwise have difficulty accessing productive financing. Thus, the findings of this study corroborate the view that well-targeted regional development policies can generate positive externalities, influencing not only the municipalities that benefit directly, but also neighboring municipalities.

Table 4 - Direct and indirect effects of regional policy instruments for different spatial specifications.

	Effects	FE	SAR	SEM	SLX	SAC	SDM	SDEM	GNR
FNE/GDP*	Direct	-	.0000132*	-	.000013*	.0000117*	.0000127*	.0000125*	.0000122*
		-	(1.61e-06)	-	(1.64e-06)	(1.50e-06)	(1.62e-06)	(1.62e-06)	(1.55e-06)
	Indirect	-	8.92e-06*	-	8.51e-06	-5.05e-06*	7.47e-06	2.17e-06	-1.01e-06
		-	(1.14e-06)	-	(5.75e-06)	(6.54e-07)	(9.06e-06)	(6.20e-06)	(3.83e-06)
	Total	.0000129*	.0000222*	.0000124*	.0000215	6.61e-06*	.0000202*	.0000147	.0000112
		(1.64e-06)	(2.72e-06)	(1.57e-06)	(5.98e-06)	(8.54e-07)	(.0000105)	(6.80e-06)	(4.05e-06)
FDNE	Direct	-	.0208289*	-	.0096138	.0060213	.0092792	.0101326	.0098703
		-	(.0072831)	-	(.0080741)	(.0075902)	(.0077014)	(.0076628)	(.0077449)
	Indirect	-	.0140409	-	.0642036*	-.0026071	.0715744*	.0539769*	.0251877*
		-	(.0049387)	-	(.01677)	(.0032864)	(.0270562)	(.0195005)	(.0136879)
	Total	.0213632	.0348608	.0118119	.0738174	.0034142	.0808536*	.0641095	.0350579
		(.0074216)	(.0122043)	(.0076443)	(.0156035)	(.0043043)	(.0274219)	(.0207401)	(.0153251)
IF	Direct	-	.0146941*	-	.0174982*	.0181480*	.019092*	.0192057*	.0213117*
		-	(.0038942)	-	(.004034)	(.0037367)	(.0039226)	(.0039373)	(.0038742)
	Indirect	-	.0099054*	-	.0046714*	-.007858*	.0230337	.020912	.0163558*
		-	(.002651)	-	(.01065)	(.0016232)	(.0181178)	(.0122502)	(.0078557)
	Total	.0155508	.0245994	.0174246	.0221697	.0102909*	.0421257	.0402077	.0376675
		(.0039682)	(.006529)	(.0038757)	(.0108218)	(.0021222)	(.0190344)	(.0134637)	(.0089301)

Source: Research results. Note: Standard errors in parentheses. *p-value < 5%.

Table 5 - Direct and indirect effects of regional policy instruments for different spatial specifications – Distance Matrix

	Effects	FE	SAR	SEM	SLX	SAC	SDM	SDEM	GNR
FNE/ GDP	Direct	-	.0000133*	-	.0000131*	.0000126*	.0000126*	.000013	.0000151*
		-	(1.60e-06)	-	(1.64e-06)	(1.58e-06)	(1.59e-06)	(1.58e-06)	(1.71e-06)
	Indirect	-	-.0000323*	-	.0002977*	.0000612*	.00008*	.0002337*	.0024367*
		-	(4.65e-06)	-	(.0000495)	(.0000182)	(.0000333)	(.0000801)	(.0007659)
	Total	.0000129	-.0000189	.0000122	.0003108*	.0000737*	.0000926*	.0002467*	.0024517*
		(1.64e-06)	(3.45e-06)	(1.57e-06)	(.0000496)	(.000019)	(.0000332)	(.0000803)	(.0007666)
FDNE	Direct	-	.0223546*	-	.0110073	.0146423	.0097279	.0134434	.0125269
		-	(.0072462)	-	(.008379)	(.0077144)	(.0081066)	(.0082605)	(.0081521)
	Indirect	-	-.064091*	-	.310871*	.0713002	.0066501	.1546525	.9559941
		-	(.0180524)	-	(.1010577)	(.0422221)	(.0624301)	(.164622)	(1.071918)
	Total	.0213632	-.0201443	.0157529	.3218783*	.0859425	.0163781	.168096	.968521
		(.0074216)	(.0061712)	(.0079322)	(.0975474)	(.0492177)	(.0649023)	(.1625547)	(1.06975)
IF	Direct	-	.0141895*	-	.0183882*	.0167030*	.0133972*	.0178101	.0178093*
		-	(.0038744)	-	(.0040408)	(.0039075)	(.0039168)	(.0039136)	(.0039507)
	Indirect	-	-.0343338*	-	-.1239987	.0813391*	-.1475974*	-.3753013*	-1.078002
		-	(.0097806)	-	(.0635435)	(.0290362)	(.0423847)	(.0957401)	(.7375115)
	Total	.0155508	-.0201443*	.0176853	-.1056106	.0980431*	-.1342002*	-.3574912*	-1.060192
		(.0039682)	(.0061712)	(.0039026)	(.0629977)	(.0317382)	(.0425315)	(.0960549)	(.7380524)

Source: Survey results. Note: Standard errors in parentheses. *p-value < 5%

4.4 Sectoral Analysis

To understand the transmission mechanisms of regional development instruments, we chose to disaggregate municipal GDP into its different components in order to identify which one accounts for the majority of the observed effect.

The results shown in Table 6 for the growth rates of sectoral GVA per capita reveal that the effects of the FNE cover the agriculture, services, and industry sectors, which is consistent with the sectoral scope of this instrument. On the other hand, both the FDNE and Tax Incentives seem to act predominantly in the industrial sector, which is also consistent with the guidelines for the use of these instruments. In all cases, the sectoral effects appear to be only direct, which leads to the conclusion that the indirect effects observed for some instruments in the main estimation are due to diffuse links between sectors, which spill over to municipalities surrounding those benefiting from the policy.

The zero effects on public sector spending can be understood as a placebo test, since this sector does not directly benefit from any of the regional policy instruments. However, there is a noticeable increase in tax collection, particularly for the FNE and Tax Incentives, which may derive from the greater economic dynamism caused by these instruments.

PNDR instruments contribute to municipal economic growth not only by generating employment and income, as demonstrated by several studies on the FNE and tax incentives, but also by strengthening production in key sectors of the economy. These findings corroborate the results of Carneiro et al. (2024), who identified an association between economic growth and FNE and FDNE resources. However, they diverge partially with regard to tax incentives, for which the results found in this study indicate more robust positive effects.

Table 6 - Results of the GNR model for sectoral per capita GVA growth.

Dependent variable: Per capita GVA growth rate						
Treatment	Effect	Agriculture	Services	Industry	Public Administration	Tax
FNE/GDP	Direct	-3.45e-06	.0000127*	.0000468*	1.09e-06	.0000313*
		(3.84e-06)	(1.64e-06)	(4.65e-06)	(6.70e-07)	(2.70e-06)
	Indirect	.0001341	.0000198	-.0001773	-1.88e-06	.0000416
		(.0001475)	(.000032)	(.0001468)	(.0000158)	(.0000459)
	Total	.0001307	.0000325	-.0001305	-7.94e-07	.0000729
		(.0001491)	(.0000325)	(.0001485)	(.000016)	(.0000467)
FDNE	Direct	.0174512	.0033981	.0409076**	.001419	-.0024285
		(.0177337)	(.0079721)	(.0235322)	(.0032436)	(.0140455)
	Indirect	.3082596	.094824	.5604579	.029035	.05152
		(.3392066)	(.0742305)	(.3631248)	(.0362257)	(.1161154)
	Total	.3257108	.0982221	.6013655**	.030454	.0490914
		(.3400335)	(.0737587)	(.3630292)	(.0360675)	(.1152006)
IF	Direct	.04628	.0018158	.0200631**	.0008478	.0138157*
		(.0090548)	(.0039848)	(.0122498)	(.0016249)	(.0071225)
	Indirect	.2194977	-.0701973	-.1051112	.0168001	-.0631873
		(.244746)	(.0531595)	(.259977)	(.0260151)	(.0829924)
	Total	.2657777	-.0683815	-.085048	.0176479	-.0493716
		(.2471124)	(.0537132)	(.2622726)	(.0262631)	(.0838805)

Source: Research results. Note: Standard errors in parentheses. * p-value < 5%; ** p-value < 10%.

5. CONCLUSION

Regional inequality in Brazil, especially in the Northeast, persists as a historical and structural challenge (Furtado, 1959; Cano, 1977). Factors such as the concentration of investments in more developed regions (Krugman, 1991), infrastructure limitations (Baer, 2003), and unequal access to credit (Stiglitz and Weiss, 1981) have contributed to the reproduction of these disparities. Given this scenario, public policies aimed at financing and encouraging productive activities in less developed regions emerge as fundamental instruments for promoting regional economic growth (Crocco et al., 2006; Além and Madeira, 2015).

The literature suggests that mechanisms such as subsidized financing and tax incentives can stimulate investment and boost regional economic growth (Linhares et al., 2014; Resende, 2012). However, the joint evaluation of these instruments and their spatial impacts still has gaps (Ferreira, Irffi, and Carneiro, 2024). There are positive effects of funds and incentives on economic growth and tax collection (Carneiro et al., 2023; Garsous et al., 2017), but they often neglect the spillover dynamics between municipalities (Resende, Silva, and Silva Filho, 2017).

The results of the main estimation indicated that all the instruments analyzed had positive and significant impacts on municipal economic growth. The FNE had direct and indirect positive effects, with impacts distributed across the agricultural, service, and industrial sectors. The FDNE showed significant effects, especially in industry, suggesting that investments in infrastructure and industrial transformation play a crucial role in regional economic growth. Tax incentives, in turn, had a significant influence on agriculture, indicating that tax relief may have driven the sector's expansion. Robustness tests confirmed the consistency of the results, highlighting the persistence of the positive effects of the FNE and tax incentives in different specifications.

The sectoral analysis reinforced the differentiated scope of the instruments. The FNE had more significant impacts on agriculture and services, while the FDNE and tax incentives proved to be more relevant for industrial growth. In addition, spatial spillovers were identified, especially for tax incentives and the FDNE, indicating that their effects extend beyond the municipalities directly benefited, generating economic externalities for neighboring regions.

The study's findings have important implications for public policy formulation. First, they reinforce the need for strategic targeting of resources to regions with lower economic dynamism in order to maximize their impact. In addition, they highlight the importance of regional coordination in the allocation of investments, optimizing spillover effects. The distinction between sectoral impacts suggests that policies more tailored to local characteristics may be more effective in promoting growth.

Although this study has made relevant contributions, some issues could be improved in future research. The analysis covers the period from 2003 to 2019, enabling a detailed assessment of the impacts of PNDR instruments, but does not consider more recent structural changes. In addition, the spatial approach used was effective in capturing spillover effects ( ), although causal identification could be complemented by alternative methods, such as approaches based on instrumental variables. Future studies could expand this analysis to other regions of the country and explore new regional development instruments, allowing for an even deeper understanding of the effectiveness of public policies in reducing regional inequalities.

BIBLIOGRAPHICAL REFERENCES

ALÉM, Ana Cláudia; MADEIRA, Rodrigo Ferreira. As instituições financeiras públicas de desenvolvimento e o financiamento de longo prazo. 2015.

ALMEIDA, Eduardo. Econometria espacial. Campinas–SP. Alínea, v. 31, 2012.

ANSELIN, Luc. Interactive techniques and exploratory spatial data analysis. 1996.

BAER, Werner. A economia brasileira. NBL Editora, 2003.

BANCO DO NORDESTE. **Relatório de Gestão do FNE: exercício 2019**. Banco do Nordeste do Brasil, 2020.

BAUMONT, Catherine. Spatial effects in housing price models: do housing prices capitalize urban development policies in the agglomeration of Dijon (1999)?. 2004. Tese de Doutorado. Laboratoire d'économie et de gestion (LEG).

BRASIL. Produto interno bruto dos municípios 2021 / IBGE, Coordenação de Contas Nacionais, IBGE: Rio de Janeiro, 2023

BRAZ, Marleton Souza; IRFFI, Guilherme. Impactos dos incentivos fiscais da Sudene sobre o mercado de trabalho local. XXVIII Encontro Regional de Economia. Fortaleza. Anais… Fortaleza, Anpec, 2023.

CANO, Wilson et al. Raízes da concentração industrial em São Paulo. São Paulo: Difel, 1977.

CARNEIRO, D. Determinantes da Eficiência da Aplicação dos Recursos do FNE pelos municípios beneficiados. Fortaleza, Banco do Nordeste do Brasil, ago. 2018 (Artigos ETENE).

CARNEIRO, Diego; COSTA, Eduardo; IRFFI, Guilherme; VELOSO, Pedro; BRAZ, Mariana; DIAS, Tiago; ANDRADE, Vânia. Avaliação de Eficiência das Empresas Beneficiadas pela Política de Incentivos Fiscais Conduzida pela Sudene. In: 51º ENCONTRO NACIONAL DE

ECONOMIA, Rio de Janeiro, 2023. Disponível em: https://www.anpec.org.br/encontro/2023/submissao/files_I/i10a86c184e25910350378a0acdd40d8846.pdf. Acesso em: 27/04/2024

CARNEIRO, Diego; VELOSO, Pedro; Ferreira, Wendel; IRFFI, Guilherme. Análise do Impacto dos Instrumentos da PNDR sobre a Economia dos Municípios Nordestinos. 2024.

CRAVO, Tulio Antonio; RESENDE, Guilherme Mendes; CARVALHO, A. Y. The Impact of Brazilian Regional Development Funds on Regional Economic Growth: A spatial panel approach. In: CONGRESSO ERSA, 54., 2014. São Pertersburgo. Anais … São Pertersburgo: ERSA, 2014. p. 26-29.

CROCCO, Marco et al. Polarização regional e sistema financeiro. CROCCO et al. Moeda e território: uma interpretação da dinâmica regional brasileira. Belo Horizonte: Autêntica, p. 231-269, 2006.

DO MONTE, K.; IRFFI, G.; BASTOS, F.; CARNEIRO, D. Análise do Fundo Constitucional de Financiamento do Nordeste (FNE) sobre Indicadores Econômicos Municipais no Período 2010-2020. 51º Encontro Nacional de Economia, Rio de Janeiro, 2023.

ELHORST, J. Paul; ELHORST, J. Paul. Spatial panel data models. Spatial econometrics: From cross-sectional data to spatial panels, p. 37-93, 2014.

FERREIRA, Wendel; CARNEIRO, Diego; IRFFI, Guilherme. A PNDR E O DESENVOLVIMENTO ECONÔMICO DO NORDESTE: UMA ANÁLISE DO FDNE E DOS INCENTIVOS FISCAIS DA SUDENE. 2024

FURTADO, Celso. Formação econômica do Brasil. Companhia das Letras, 2020.

GARSOUS, Grégoire et al. Tax incentives and job creation in the tourism sector of Brazil's SUDENE area. World Development, v. 96, p. 87-101, 2017.

HAUSMAN, Jerry A. Specification tests in econometrics. Econometrica: Journal of the econometric society, p. 1251-1271, 1978.

HIRSCHMAN, A. The strategy of economic development. New Haven: Yale University Press, 1958.

IRFFI, Guilherme et al. Avaliação de impacto do financiamento do FDNE na construção de Parques Eólicos e seus efeitos no mercado de trabalho e indicadores econômicos dos municípios na área de atuação da Sudene. CADERNOS DE FINANÇAS PÚBLICAS, v. 25, n. 1, 2025.

KRUGMAN, P. Geography and Trade. Leuven-London: Leuven University Press/MIT Press, Boston, 19

Lee, L.-F., and J. Yu. 2010a. Estimation of spatial autoregressive panel data models with fixed effects. Journal of Econometrics 154: 165–185. https://doi.org/10.1016/j.jeconom.2009.08.001.

LESAGE, James P.; PACE, R. Kelley. Spatial econometric models. In: Handbook of applied spatial analysis: Software tools, methods and applications. Berlin, Heidelberg: Springer Berlin Heidelberg, 2009. p. 355-376.

LEVIN, Andrew; LIN, Chien-Fu; CHU, Chia-Shang James. Unit root tests in panel data: asymptotic and finite-sample properties. Journal of econometrics, v. 108, n. 1, p. 1-24, 2002.

LINHARES, Fabrício Carneiro; SOARES, Ricardo Brito; GONÇALVES, Marcos Falcão; VIANA, Luiz Fernando Gonçalves. Brazil's Northeast Financing Constitutional Fund: Differentiated effects on municipal economic growth. CEPAL Review, v. 2014, n. 113, p. 175-192, 2014.

Manski, C. F. (1993). Identification of endogenous social effects: The reflection problem. The review of economic studies, 60 (3): 531-542.

MARSHALL, A. Principles of economics. London: Macmillan, 1890.

MORAN, Patrick AP. Notes on continuous stochastic phenomena. Biometrika, v. 37, n. 1/2, p. 17-23, 1950.

MYRDAL, Gunnar. Teoria econômica e regiões subdesenvolvidas. Rio de Janeiro: ISEB, 1960 (1957).

ODLAND, John. Spatial autocorrelation. 2020.

OLIVEIRA, Rodrigo; NETO, Raul da Mota Silveira. Estrutura produtiva ou escolaridade? Uma análise dos fatores explicativos da desigualdade de renda entre as regiões Sudeste e Nordeste por quantil para o período entre os anos de 1970 e 2010. Revista Econômica do Nordeste, p. 74-91, 2016.

RESENDE, Guilherme Mendes. Micro e macroimpactos de políticas de desenvolvimento regional: o caso dos empréstimos do FNE-industrial no estado de Ceará. Brasília: IPEA, 2012. (Texto para Discussão nº 1777)

RESENDE, Guilherme Mendes; DA SILVA FILHO, Luís Abel. Avaliação dos Impactos Econômicos do Fundo Constitucional de Financiamento do Nordeste (FNE): o caso da Bahia, 2004-2010. Revista Desenbahia, n. 20, 29-58, 2014.

RESENDE, Guilherme Mendes; SILVA, Diego Firmino Costa; SILVA FILHO, Luís Abel. Avaliação econômica do Fundo Constitucional de Financiamento do Nordeste (FNE): uma análise espacial por tipologia da PNDR entre 1999 e 2011. Revista Econômica do Nordeste, v. 48, n. 1, p. 9-29, 2017.

RIBEIRO, L. C. S. et al. Regional funding and regional inequalities in the Brazilian Northeast.

RÜTTENAUER, Tobias; AKSOY, Ozan. When Can We Use Two-Way Fixed-Effects (TWFE): A Comparison of TWFE and Novel Dynamic Difference-in-Differences Estimators. arXiv preprint arXiv:2402.09928, 2024.

SALA-I-MARTIN, Xavier X. Regional cohesion: evidence and theories of regional growth and convergence. **European economic review**, v. 40, n. 6, p. 1325-1352, 1996.

SEIFI, A., MOTAGHI, S., EBRAHIM, S., & AHMADI, M. S. (2020). Effect of terrorism activities on capital flight in the Middle East. In E3S Web of Conferences (Vol. 157, p. 03017). EDP Sciences.

STIGLITZ, Joseph E.; WEISS, Andrew. Credit rationing in markets with imperfect information. **The American economic review**, v. 71, n. 3, p. 393-410, 1981.

SUDENE, Relatório de Gestão do exercício de 2023. Aesso em 13/02/2025: https://www.gov.br/sudene/pt-br/acesso-a-informacao/institucional/gestao-institucional/arquivos/sudene-rg2023.pdf

WALD, Abraham. Tests of statistical hypotheses concerning several parameters when the number of observations is large. Transactions of the American Mathematical society, v. 54, n. 3, p. 426-482, 1943.

WOOLDRIDGE, Jeffrey M. Econometric analysis of cross section and panel data. MIT press, 2010.

APPENDIX

Appendix A - Choice of spatial weight matrix

Type	Tower	Tower	Queen	Queen
Neighbors	1	2	1	2
I-Moran	59.29	65.69	60.62	63.98
p-value	0.0000	0.0000	0.0000	0.0000

Source: Research results. Note: *p-value < 0.05.

Appendix B – Diagnostics of the panel data model.

Test	Statistic	p-value	Conclusion
Hausman (1978)	4368.13	0.0000	Fixed Effects
Levin-Lin-Chu (2002)	-906.325	0.0000	Absence of Unit Root in Dependent Variable
I-Moran (1948)	144.17	0.0000	Spatial dependence (spatial autocorrelation) exists

Source: Research results. Note: *p-value < 0.05.

Appendix C – LR test for comparing spatial models.

			Restricted Model (H0)						
			OLS	SAR	SEM	SLX	SAC	SDM	SDEM
Unrestricted Model	SAR	LR	2369						
		gl	*1*						
		p-value	0.000*						
	WITHOUT	LR	2537.16						
		gl	*1*						
		p-value	0.000*						
	SLX	LR	777.64						
		gl	*8*						
		p-value	0.000*						
	Customer Service	LR	3361.38	992.38	824.22				
		gl	*2*	*1*	*1*				
		p-value	0.000*	0.000	0.000				
	SDM	LR	2595.9	226.9	58.74	1818.26			
		gl	*9*	*8*	*8*	*1*			
		p-value	0.000*	0.000	0.000	0.000			
	SDEM	LR	2584.94		47.78	1807.3			
		gl	*9*		*8*	*1*			
		p-value	0.000*		0.000*	0.000			
	GNR	LR	3626.32	1257.32	1089.16	2848.68	264.94	1030.42	1041.38
		gl	*10*	*9*	*9*	*2*	*8*	*1*	*1*
		p-value	0.000*	0.000	0.000	0.000	0.000	0.000	0.000*

Source: Prepared by the authors. Note: *p-value < 0.05.

Appendix D – Results of Spatial Econometric Model Estimates

Dependent Variable: GDP per capita growth rate

0.000	FE	SAR	SEM	SLX	SAC	SDM	SDEM	GNS
lag_fns_gdp	.0000129*	.000013*	.0000124*	.000013	.0000113*	.0000126	.000125	.0000125
	(1.54e-06)	(1.59e-06)	(1.57e-06)	(1.64e-06)	(1.45e-06)	(1.56e-06)	(1.62e-06)	(1.61e-06)
lag_d_fdne	.0213632*	.0295192*	.0118119	.0098135	.0058121	.0076254	.0101326	.0122883
	(.0074216)	(.0071748)	(.0076443)	(.0080741)	(.0073266)	(.0077859)	(.0076628)	(.0077737)
lag_d_if	.0155588	.0144795	.0114246	.0174987	.0175183*	.0169088	.0192967	.0208825
	(.0039682)	(.0038363)	(.0038757)	(.004034)	(.0036069)	(.0038898)	(.0039573)	(.0039839)
lag_l_real_gdp_pc	-.3366932*	-.3261462	-.3343734	-.3373754	-.3084557*	-.336779	-.3368072	-.3343495
	(.0042938)	(.004173)	(.0042801)	(.0044628)	(.0041375)	(.0043033)	(.0042983)	(.00437)
lag_l_average_education_work	-.0048015	-.005507	-.0033179	-.0032029	-.0066888	-.0024577	-.0017164	-.0015682
	(.0076531)	(.0074034)	(.0074354)	(.0077142)	(.0068155)	(.0074383)	(.0075335)	(.0075154)
lag_l_links_pc	.1890269*	.177673	.1838244	.1886212	.139503*	.1895243	.1887026	.1787381
	(.0150441)	(.0145457)	(.0147531)	(.0153445)	(.013779)	(.0147969)	(.0149604)	(.0151491)
lag_l_num_emp	.0295169	.0273352	.0250834	.0199907	.0147687	.0176168	.0196803	.0154044
	(.0032665)	(.0031583)	(.0033382)	(.0035041)	(.0031737)	(.0033789)	(.0033454)	(.0034053)
lag_l_population_density	-.1060254*	-.0951546	-.094525	-.1039757	-.0821612*	-.0971589	-.098884	-.0956608*
	(.0099138)	(.0095851)	(.0098334)	(.0102225)	(.0092489)	(.009858)	(.0098854)	(.0098443)
W(ln_l_real_gdp_pc)	-	.4119053*	-	-	-.7040784*	.4513262*	-	-.8631615*
	-	.0096275		-	(.0179078)	(.0109643)		(.0177178)
W(e.ln_l_pib_real_pc)	-	-	.4590914*	-	.8501337*	-	.4524962*	.8713409*
	-	-	(.0100812)	-	(.007836)	-	(.0101116)	(.0070737)
W(lag_fns_gdp)	-	-	-	8.52e-06	-	-1.47e-06	2.18e-06	6.11e-06
	-	-	-	(3.73e-06)	-	(3.50e-06)	(6.21e-06)	(6.42e-06)
W(lag_d_fdne)	-	-	-	.064298*	-	.0367967*	.0540562*	.0509882*
	-	-	-	(.0167947)	-	(.0162059)	(.0195291)	(.0238427)
W(lag_d_if)	-	-	-	.0046753	-	.0040724	.0209428	.0450773*
	-	-	-	(.0109656)	-	(.0103541)	(.0122982)	(.0139353)
W(lag_l_real_gdp_pc)	-	-	-	-.0559583*	-	.12376	-.2714585	-.2716653*
	-	-	-	(.0110946)	-	(.0114242)	(.015327)	(.0171025)
W(lag_l_education_average_work)	-	-	-	.0162676	-	.0164875	.0144489	.0008538
	-	-	-	(.0217058)	-	(.0208295)	(.0247588)	(.0276138)
W(lag_l_vinculos_pc)	-	-	-	.1890473*	-	.0582794	.1064331*	.3160108*
	-	-	-	(.0409152)	-	(.0395276)	(.0479616)	(.055313)
W(lag_l_num_emp)	-	-	-	.0571455*	-	.0238195*	.0322056*	.0129342
	-	-	-	(.0080093)	-	(.0077583)	(.0098533)	(.012723)
W(lag_l_population_density)	-	-	-	-.120907*	-	-.0297748	-.06785*	-.1148862*
	-	-	-	(.0238416)	-	(.0238755)	(.0279901)	(.0327598)
Observations	34748	34748	34748	34748	34748	34748	34748	34748
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Moran's Statistic (Residuals)	2915.44	1651.79	1775.36	4974.92	1507.67	1613.09	3413.56	4476.06*
Wald (Spatial Terms)	-	1869.15	2167.15	115.36	11764.57	2164.79*	3108.74	17,116.41*
Log likelihood	25263.71	23648.42	23732.5	22852.74	24144.61	23,761.87	23,756.39	24,277.08
AIC	-50,477.42	-47,244.83	-47,412.99	-45,639.48	-48,235.21	-47,455.74	-47,444.79	-48,484.16
BIC	-50,266.02	-47,024.98	-47,193.14	-45,360.44	-48,006.9	-47,168.24	-47,157.29	-48188.2

Source: Prepared by the authors. Note: Standard errors in parentheses. *p-value < 0.05.