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Economic growth and sectoral convergence in the SUDENE coverage area: the impact of tax incentives

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ABSTRACT: This paper explores the relationship between economic growth and tax incentives, while verifying the hypothesis of convergence in SUDENE's coverage area. Results indicate that tax incentives positively and significantly affect productivity growth at municipal level, both in the aggregate and in industrial sectors, and at state level, in the aggregate and in the sectors of services and public administration. As for convergence, there is municipal and state σ-convergence in the aggregate and in the sectors of industry, services, and public administration. β-convergence is found at municipal and state levels in the aggregate and in all sectors.

KEYWORDS: Economic growth; convergence; fiscal incentives; Sudene.
JEL Classification: O47; O25; C33.

INTRODUCTION

The Brazilian Northeast exhibits low rates of investment and growth, which underpinned the creation of the Superintendency for the Development of the Northeast (SUDENE) in the 1950s and stimulated the promotion of regional development policies aimed at regional convergence (Ribeiro *et al.*, 2020).

Glaeser (2001) discusses the rationale for adopting fiscal incentive (FI) policies, namely: i) increase in output and employment; ii) agglomeration economies: diversification of the production structure and, therefore, greater spillovers among sectors; a large number of small firms; attraction or formation of more skilled workers; iii) increase in future revenue; iv) attraction of firms that would not choose that location in the absence of the benefit; and v) corruption and influence. The author then points out that it is unlikely that firms choose their location solely based on benefits, and questions whether the revenue generated by the installation of firms offsets the initial subsidies, through increased income, employment or public services. Hence, the possibilities are: i) gains reach only the most affluent segment of the population, and the provision of

public goods to those most in need is not guaranteed; ii) elimination of inefficiency and waste. This analysis suggests a positive net balance, and that eventual distributional problems should be addressed at the federal, not municipal, level.

By studying the relevance of incentives related to the Industrial Development Fund (FDI) in Ceará, Luca and Lima (2007) conclude that the policy did attract companies, contributing to growth and creation of employment and income. They emphasize, however, the negative impact on public finances due to the high volume of tax waivers, resulting mainly from the fiscal war among states. Similarly, Vasconcelos *et al.* (2012) confirmed the attraction of firms to the *Zona da Mata Mineira* region due to tax incentives, in addition to increases in Gross Domestic Product (GDP), wages, and productive diversification.

Conversely, FIs can have negative effects, such as the fiscal war that occurred in the 1990s, which generated migration of firms and losses to companies that were not beneficiaries (Fazoli *et al.*, 2018). Furthermore, studies on the effects of the benefits in the Manaus Free Trade Zone indicate population concentration in the Amazonian capital, overburdening the provision of public services and restricting the supply of skilled labor in other municipalities (Gonçalves and Ehrl, 2021), as well as an expansion of cattle ranching in the sub-regions targeted by SUDAM incentives, but little effect on the manufacturing industry (Nascimento and Lima, 2005). Thus, there is little evidence that they generate diversification, also showing the potential to intensify intra-regional inequalities. Given these findings, the granting of FIs may involve criteria that go beyond sectoral or firm level efficiency, also being subject to indirect effects and developments not necessarily foreseen at the time of intervention formulation.

Studying the relationship between fiscal incentive policies and economic growth is possible using exogenous growth models, by testing the hypothesis of economic convergence, associated with diminishing marginal returns to capital. For this purpose, β-convergence and σ-convergence measures are applied to regional data, which include long-term economic growth determinants. Therefore, this research focuses on verifying the hypothesis of conditional convergence at the aggregate and sectoral levels.

We aimed to measure the extent to which the tax incentives contribute to economic growth, and how the speed of convergence is modified by their inclusion in the estimations. To this end, growth models were estimated using panel data for the municipalities and states within SUDENE's area of operation, between 2011 and 2020, expanding the existing literature by investigating how productivity benefits from the differentiated fiscal treatment, and under what circumstances convergence occurs.

In this regard, the contributions of this research are the study of convergence also at the sectoral level in municipal and state geographic segments, and the investigation of whether there is any contribution from SUDENE's FI policy to the increase in the speed of income convergence, indicating whether the policy is achieving its purpose of reducing intra-regional disparity. To the authors' knowledge, this analysis is scarce in empirical literature on economic growth and industrial policy, at least in the Brazilian context.

THEORETICAL BASIS

The Effects of Fiscal Incentives

Some literature highlights the direct impact on firms benefited by FIs, which may or may not spill over to the rest of society. Dos Santos *et al.* (2020) analyze process or product innovations enabled by tax incentives and conclude that the degree of technological intensity of the sector is related to the perceived effects. Regarding product innovation, this occurs more frequently in sectors of medium or high technological intensity. But when accounting for the introduction of processes, incentives positively impact on the innovation of firms in sectors of medium or low technological intensity. Also, incentives tend to induce companies to prioritize the introduction of new processes, to the detriment of existing ones (imitation).

Tax incentives positively affect the added value distributed to the government by benefited companies which, on average, contribute more than the non-benefited ones, according to Silva *et al.* (2020). However, this effect does not seem to generate an increase in aggregate income or a reduction in unemployment. Gonçalves and Ehrl (2021) support these findings when analyzing the effects of the Manaus Free Trade Zone, where the increase in the total Gross Value Added (GVA) of the benefited firms is not reflected on the aver-

age remuneration of workers. Therefore, incentives do not necessarily reach all of society, potentially intensifying inequalities.

Regarding innovation incentive policies in firms, Avellar (2009) concludes they generate increases in worker productivity, net revenue, and expenditure on R&D, but does not isolate the effect of each program on the set of companies studied. Colombo and Cruz (2018) support those findings when analyzing the impact of Law 11.196/2005, proving an increase in R&D spending and greater hiring of graduate researchers by the recipient firms.

Analyzing the PRODEPE tax incentives in Pernambuco, Oliveira and Silveira Neto (2020) observed an increase in employment (8.6%), but a reduction in the average wage (-10.3%). However, worker productivity was not affected, and the effects are only significant in areas of higher population density. An increase in employment and welfare is also found by Porsse *et al.* (2008), in the analysis of regional programs to attract investments.

Regarding tax incentives administered by SUDENE, Garsous *et al.* (2017) showed that the granting of incentives increased municipal employment in tourism by about 30%, with a growing and lasting effect. Braz and Irffi (2023) found positive effects of the 75% reduction in Corporate Income Tax (IRPJ) on the number of formal employment relationships and the average wage, considering all benefited sectors. Costa *et al.* (2024) evidenced that this effect is concentrated in the manufacturing sector. Carneiro *et al.* (2025) identified that the IRPJ reduction, isolated from other instruments of the National Regional Development Policy (PNDR), exerts a positive effect on per capita GDP and acts as a multiplier of the impacts of other instruments: development and constitutional funds.

However, tax incentives alone are insufficient to generate sustained economic growth. Ataliba *et al.* (2001) analyzed the relationship between income distribution, educational level, and growth, concluding that any development policies must include access to education and reduction of inequality. They emphasize that the granting of FIs to stimulate growth tends to exhaust itself quickly, and suggest tackling poverty by promoting employment opportunities, credit availability, and education. De Mello (2002) adds to these findings, stating that municipal growth in Brazil depends heavily on the public provision of goods and services, especially in health/sanitation. Lima and Lima (2010) point out that tax incentives are not sufficient as a development strategy in Brazilian states, while Leal *et al.* (2021) mention that other factors are decisive for investments, especially transport infrastructure, which guarantees access to raw materials and the flow of production to consumers.

Convergence Analysis Literature

Azzoni (2001) studies the convergence of *per capita* income in Brazil between 1939 and 1995, and finds a general decline, although interrupted by a sharp increase in the 1970s. To deepen the previous analysis, Azzoni and Barossi-Filho (2002) used time series approach to look for regional income convergence, finding evidence of stochastic income convergence at the macro-regional level, except for the North region.

Intra-regional convergence is not homogeneous in Brazil, but found in all states in North, Central-West, and Southeast regions, but not for all states in the Northeast and the South. By including breaks in the series, they allow for different periods of convergence or divergence, identified in Azzoni (2001).

Laurini *et al.* (2003) studied the evolution of the relative *per capita* income distribution. Results showed the formation of two convergence clubs, one of low income composed of municipalities of the North and Northeast regions, and another of high income, formed by the municipalities of the Central-West, Southeast, and South. Magalhães and Miranda (2009) also found an ergodic convergence process, resulting in two convergence clubs for municipalities, where the rich club is mainly composed of cities in the South, Central-West, and Southeast, with *per capita* income two to three times the average of the poor club's, mainly composed of cities in the North and Northeast. Focusing on the latter region, Magalhães and Miranda (2009) add that the impact on growth can be significant, depending on the impetus given to the economy, meaning that a large part of the economic potential of the Northeast is still unexplored and, therefore, its capacity for growth tends to be greater.

Ribeiro and Almeida (2012) investigated the processes of absolute, conditional, and local convergence for the Brazilian minimum comparable areas (AMCs). These analyses sought to verify the existence of β coef-

ficients and specific convergence speeds for each area. Differences found among the growth processes of Brazilian municipalities suggest that the Northeast region, by housing municipalities still distant from the equilibrium incomes, presents greater chances of reducing the inequality in income compared to the richer municipalities in the country.

Regarding the states, Gomes and Esperidião (2016) analyzed the hypothesis of *per capita* GDP convergence in the Brazilian regions from 1995 to 2009. To obtain greater homogeneity, Brazilian states were divided into four groups to estimate a dynamic panel. A plausible argument for the high convergence rates found for the Northeast region reinforces the previous conclusion: states distant from their steady state have greater potential to reduce inequality.

Días-Dapena *et al.* (2017) identified a transition point in the 1970s, when the historically high level of inequalities began to lower, reducing the gap between richer macro-regions of the South and Southeast on one hand, and the poorer ones of the Northeast, North, and Central-West, on the other. Economic growth, from year 2000 onwards, reduced convergence of regional GDP distribution and regional differences in the *per capita* GDP.

Given the GDP growth in the Northeast, Reis *et al.* (2020) analyzed whether this phenomenon occurred in a way that decreased income disparities among the municipalities, by testing the hypotheses of β-convergence and σ-convergence. Results indicate that, for the region, municipalities exhibit both types of beta convergence, in addition to sigma convergence. Conditional β-convergence proved to be more satisfactory, as the speed of convergence is greater than in absolute β-convergence, which confirms that variables used in conditional β-convergence (Firjan, health, and education) contribute to reducing income disparities among northeastern municipalities.

Almeida *et al.* (2021) analyzed convergence in economic and social melhor 'aspects', and stated that income convergence is not necessarily accompanied by social convergence, which is captured by selected indicators such as years of study, life expectancy at birth, and absence of crime. They find that *per capita* GDP has the highest dispersion among states and that its absolute convergence is relatively slow. Social conditions seem to converge to a single steady state at a half-life of 8 to 12 years.

Focusing on growth factors, human capital, the financial system, business environment, and social infrastructure, Matos *et al.* (2023) analyzed a sample of 925 northeastern cities. They verified that, in terms of convergence, the Brazilian states exhibit a faster speed than the cities in the Northeast, indicating that policymakers should pay greater attention to the poorest cities.

METHODOLOGICAL ASPECTS

Data Source and Description

Measures of aggregate and sectoral productivity per worker and per hours worked at state and municipal levels were constructed using GDP and sectoral GVA information in 2010 prices, provided by the Brazilian Institute of Geography and Statistics (IBGE). Data on formal employment ties and hours worked, both aggregate and sectoral, were calculated from the Annual Social Information Report (RAIS), the National Household Sample Survey (PNAD), and the Continuous PNAD (PNADC).

GDP and sectoral GVA are measures of an economy's production effort over a period. The ratios between these variables and the number of workers generate productivity measures at aggregate and sectoral levels. To make these variables for the municipal level, the number of formal employment ties from RAIS/MTE was used as a proxy for the number of workers, collected for its total value and by economic sectors. Thus, the number of formal jobs was collected for public administration, agriculture, industry (including the construction sector), and services sectors (excluding public administration). For the states, the occupied population was obtained from PNAD and PNADC.

Due to the availability of more recent data, the PNADC was prioritized and used for the years 2012 to 2020. By construction, it provides a sample that more precisely reflects the population profile (Ottoni and Barreira, 2016). However, the annual PNAD was also used to expand the sample until 2011. To allow the joint

use of these distinct surveys, the databases were made compatible according to the recommendations of Ottoni and Barreira (2016) and Veloso *et al.* (2019).

Although there is no consensus on the most appropriate productivity measure, this research opts for labor productivity because it is the most used proxy in empirical literature (Kucera and Roncolato, 2012; Martin *et al.*, 2018; Mcmillan and Rodrik, 2011; Naveed and Ahmad, 2016), and economic growth manuals such as Jones and Vollarth (2015) and Veloso *et al.* (2012). Alternatively, for state data – given its availability – a productivity measure based on hours worked is also used as a proxy.

Information on state and municipal foreign trade, used in the construction of the proxy for degree of trade openness – ratio between the sum of exports and imports and the GDP – was extracted from the Comex Stat database, from the Ministry of Industry, Foreign Trade, and Services (MDIC). Information on State and Municipal Tax Revenues, used for the construction of the proxy variable for tax burden – ratio between tax revenue and GDP – was obtained from the National Treasury Secretariat (STN/FINBRA).

Proxies for physical capital were constructed from distinct sources between states and municipalities, as public data on energy consumption at the municipal level are not available for some states under the SUDENE coverage area. For the state level, information on commercial and industrial energy consumption, in MWh, was collected and summed from the National Energy Balance (BEN) data of the Ministry of Mines and Energy (MME). For the municipal level, information obtained from RAIS on the number of commercial and industrial establishments as a proportion of the number of workers (RAIS) was used. Similarly, the proxy for municipal and state human capital corresponds to the percentage of workers with secondary education (RAIS).

Finally, the tax incentives variable was defined as the number of approved applications relative to the total number of formal employment ties. Information was obtained from SUDENE's Fiscal Incentives and Benefits System (SIBF), whose data availability restricted the analysis period. Due to the confidential nature of the monetary values of incentives, we used the quantity of incentives granted as a measure. Regarding the normalization of the variable by the number of workers, this is a strategy adopted to adjust for differences in the size of regions and their economic sectors, considering the expectation of a direct relationship between tax incentives and employment.

Table 1 presents a descriptive analysis of the variables at state and municipal levels. Municipalities in Alagoas reported, on average, the highest growth in output per worker (3.20%), followed by municipalities in Rio Grande do Norte and Ceará, but municipalities in Espírito Santo and Maranhão reported negative growth. By sector, municipalities in Piauí led the average growth in industry. Although low, only municipalities in Alagoas reported positive average growth and lead the productivity growth in agriculture (9.5%). Finally, municipalities in Ceará showed the highest average productivity growth in public administration.

Municipalities in Bahia presented an average percentage of workers with secondary education of 52.92% and an average share of tax revenue in GDP of 1.14%, the highest in the sample. Furthermore, municipalities in Maranhão recorded the highest GA, with an average of 5.94% – indicating that the municipalities in the region maintain a low volume of trade with the rest of the world – while municipalities of Rio Grande do Norte and Sergipe exhibit the lowest openness to foreign trade.

Analyzing state data, Maranhão leads the average productivity growth, approximately 3.69%, followed by Piauí. By sector, the performance of industry and services in Bahia stands out, with average growth of 4.80% and 8.31%, respectively. Similar to results found for municipalities, there is negative productivity growth in the services sector in 8 of the 11 states.

As for the average percentage of workers with secondary education, Bahia again leads the statistics, with 56.9%, followed by Maranhão, Rio Grande do Norte, and Ceará. The states with the highest average share of tax revenue in GDP are Sergipe, Pernambuco, and Bahia, with 2.15%, 2.08%, and 2.06%, respectively. Regarding trade openness, there's generally low engagement in international trade, with Espírito Santo presenting the highest average, approximately 6.36%.

Since the ratio between the number of approved incentive applications and the number of workers results in an extremely small number, the means of this variable report the value zero up to the fourth decimal place in both the municipal and state samples.

Table 1: Descriptive Statistics for Municipalities and States in Sudene's Area of Operation

Var.	*Municipalities*										
	AL	*BA*	*CE*	*ES*	*MA*	*MG*	*PB*	*PE*	*PI*	*RN*	*SE*
Total	0.0320	0.0162	0.0238	-0.0146	-0.0136	0.0128	0.0160	0.0200	0.0162	0.0305	0.0194
	0.3837	*0.2856*	*0.2305*	*0.1326*	*0.6995*	*0.2746*	*0.3656*	*0.2531*	*0.4773*	*0.2934*	*0.2730*
Ind.	0.0440	0.0011	-0.0269	0.0008	-0.0096	-0.0074	0.0208	0.0247	0.0558	-0.0029	-0.0149
	0.7380	*0.6878*	*0.7117*	*0.3494*	*0.8929*	*0.6244*	*0.6354*	*0.6259*	*0.8602*	*0.7566*	*0.6663*
Serv.	0.0043	-0.0161	-0.0229	-0.0251	-0.0412	-0.0007	-0.0228	-0.0224	-0.0361	-0.0072	-0.0096
	0.2803	*0.2197*	*0.2199*	*0.1522*	*0.3626*	*0.2802*	*0.3249*	*0.2419*	*0.3789*	*0.3223*	*0.2913*
Agri.	0.0915	0.0007	0.0244	-0.0134	-0.0237	0.0067	0.0025	0.0058	0.0187	0.0155	0.0018
	0.6261	*0.4834*	*0.6976*	*0.3191*	*0.6156*	*0.7044*	*0.5597*	*0.6031*	*0.7654*	*0.5668*	*0.5085*
Public Adm.	0.0066	0.0357	0.0493	0.0004	-0.0123	0.0202	0.0174	0.0388	0.0243	0.0470	0.0383
	0.4588	*0.6829*	*0.4057*	*0.3300*	*1.1634*	*0.3902*	*0.6241*	*0.5196*	*0.8399*	*0.5431*	*0.5109*
Phys. Cap.	0.0372	0.0534	0.0400	0.0707	0.0421	0.0564	0.0380	0.0491	0.0544	0.0454	0.0357
	0.0291	*0.0293*	*0.0199*	*0.0213*	*0.0407*	*0.0231*	*0.0256*	*0.0260*	*0.0429*	*0.0275*	*0.0216*
Hum. Cap.	0.3746	0.5292	0.4336	0.4519	0.5151	0.4168	0.4384	0.4411	0.3693	0.4795	0.4074
	0.1387	*0.1253*	*0.1207*	*0.0685*	*0.1666*	*0.1035*	*0.1708*	*0.1565*	*0.1386*	*0.1413*	*0.1233*
Gov. Weight	0.0088	0.0114	0.0104	0.0099	0.0092	0.0086	0.0076	0.0096	0.0086	0.0101	0.0111
	0.0078	*0.0078*	*0.0067*	*0.0039*	*0.0089*	*0.0042*	*0.0043*	*0.0057*	*0.0083*	*0.0846*	*0.0113*
GA	0.0147	0.0292	0.0220	0.0259	0.0594	0.0224	0.0106	0.0227	0.0175	0.0097	0.0076
	0.0233	*0.0841*	*0.0471*	*0.0421*	*0.0760*	*0.0346*	*0.0135*	*0.0431*	*0.0837*	*0.0215*	*0.0118*
Incent.	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0001	*0.0003*	*0.0001*	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0003*	*0.0002*	*0.0005*	*0.0002*
Var.	*States*										
	AL	*BA*	*CE*	*ES*	*MA*	*MG*	*PB*	*PE*	*PI*	*RN*	*SE*
Total	0.0210	0.0250	0.0105	-0.0373	0.0369	-0.0020	0.0212	0.0056	0.0361	0.0012	-0.0086
	0.0550	*0.0376*	*0.0378*	*0.0845*	*0.0656*	*0.0373*	*0.0365*	*0.0514*	*0.0578*	*0.0324*	*0.0408*
Ind.	-0.0016	0.0480	-0.0023	-0.0756	0.0308	-0.0055	0.0187	0.0137	-0.0300	0.0062	-0.0149
	0.1217	*0.0741*	*0.0691*	*0.2744*	*0.1244*	*0.0820*	*0.0683*	*0.0928*	*0.1631*	*0.0868*	*0.1130*
Serv.	-0.0101	0.0123	-0.0056	-0.0168	0.0057	-0.0012	-0.0029	-0.0111	0.0161	-0.0013	-0.0131
	0.0332	*0.0488*	*0.0403*	*0.0409*	*0.0591*	*0.0411*	*0.0373*	*0.0605*	*0.0326*	*0.0495*	*0.0387*
Agri.	0.1635	0.0727	0.0986	0.0091	0.1467	0.0307	0.0940	0.0803	0.1418	0.1092	0.0483
	0.2012	*0.1765*	*0.1994*	*0.1134*	*0.2210*	*0.2077*	*0.1533*	*0.1167*	*0.3980*	*0.2080*	*0.1919*
Public Adm.	-0.0120	0.0831	0.0572	0.0461	0.1162	0.0491	0.1040	0.0928	0.0710	0.0348	-0.0092
	0.1642	*0.1734*	*0.1012*	*0.1395*	*0.1412*	*0.1045*	*0.1386*	*0.1469*	*0.1520*	*0.1989*	*0.2006*
Phys. Cap.	2,443.4	12,900.0	4,527.7	6,164.8	4,494.6	36,500.0	2,304.5	6,250.4	925.44	2,287.7	1,969.3
	486.75	*559.18*	*307.92*	*559.03*	*2,665.59*	*1,033.05*	*125.14*	*561.74*	*92.24*	*98.45*	*188.37*
Hum. Cap.	0.4102	0.5688	0.5066	0.4698	0.5444	0.4483	0.4173	0.4908	0.4445	0.5073	0.4617
	0.0392	*0.0190*	*0.0254*	*0.0191*	*0.0156*	*0.0340*	*0.0242*	*0.0251*	*0.0217*	*0.0203*	*0.0303*
Gov. Weight	0.0157	0.0206	0.0192	0.0181	0.0159	0.0183	0.0153	0.0208	0.0155	0.0192	0.0215
	0.0012	*0.0021*	*0.0023*	*0.0026*	*0.0014*	*0.0024*	*0.0017*	*0.0022*	*0.0021*	*0.0026*	*0.0042*
GA	0.0125	0.0319	0.0155	0.0636	0.0473	0.0329	0.0067	0.0212	0.0041	0.0037	0.0040
	0.0099	*0.0221*	0.0090	*0.0492*	*0.0388*	*0.0250*	*0.0061*	*0.0116*	*0.0013*	*0.0022*	*0.0027*
Incent.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: Compiled by the authors. Note: 1. Standard deviation in italics, below the means. 2. The municipal sample for the states of Espírito Santo and Minas Gerais includes only municipalities under the Sudene area of operation. a. In GWh.

Estimation Strategies

To study the σ -convergence hypothesis, the sample variance of the logarithm of productivity is:

$$\sigma_t^2 = \left(\frac{1}{N}\right)\sum_{i=1}^{N}\left[log(y_{i,t}) - \mu_t\right]^2 \quad (1)$$

where μ_t is the sample mean of $log(y_{i,t})$. Since σ-convergence is not a sufficient condition for the existence of β-convergence, a decreasing trend in *eq.(1)* can be observed without β-convergence occurring. Therefore, although related, they are distinct concepts of convergence, and in addition to studying the evolution of regional income dispersion, verifying β-convergence becomes relevant when investigating mechanisms that allow for income convergence and the speed at which it occurs.

Verification of conditional convergence is conducted by restricting the data to a set of similar economies or by including a vector of covariates related to economic growth. In the first case – assuming that regions within the same country have similar technology, preferences, and institutions – the non-linear equation[1] is estimated using Non-Linear Least Squares (NLS), which allows for the direct estimation of convergence speed (β) for individual units comprising SUDENE's area of operation:

$$\gamma_{i,t_0,t_0+T} = a - \left[\frac{\left(1-e^{-\beta T}\right)}{T}\right] \times log\left(y_{i,t_0,t_0+T}\right) + D\theta + u_{i,t_0,t_0+T} \quad (2)$$

where γ_{i,t_0,t_0+T} is the annual growth rate of the productivity measure between periods t_0 and $t_0 + T$, defined by $\left(\frac{1}{T}\right) log\left[\frac{y_{i,t_0+T}}{y_{i,t_0}}\right]$, D is a vector of time-invariant dummies to control for individual heterogeneities at the state level, and u_{i,t_0,t_0+T} is the mean of the error terms between periods t_0 and $t_0 + T$.

In the second case, the estimation changes to conditional convergence with the inclusion of a vector of covariates described in the empirical literature as determinants of economic growth, in addition to the proxy variable measuring SUDENE's tax incentives, as described by the equation:

$$\gamma_{i,t_0,t_0+T} = a - \left[\frac{\left(1-e^{-\beta T}\right)}{T}\right] \times log\left(y_{i,t_0,t_0+T}\right) + X_t\delta + D\theta + u_{i,t_0,t_0+T} \quad (3)$$

where X_t is the vector of control variables, including the proxies for human capital, physical capital, tax burden, and trade openness, as well as tax incentives. *Eq.(2)* and *eq.(3)* will only be estimated at the municipal and sectoral levels. Since Sudene's area of operation corresponds to 11 states, cross-sectional estimations would have a very reduced sample. In addition, linear versions of *eq.(2)* and *eq.(3)* were estimated using panel data for all regional and sectoral levels through the following equations:

$$log\,(y_{it}) - loglog\,(y_{it-1}) = a_i - bloglog\,(y_{it-1}) + \varepsilon_{it} \quad (4)$$

$$log\,(y_{it}) - loglog\,(y_{it-1}) = a_i - bloglog\,(y_{it-1}) + X_t\varphi + \varepsilon_{it} \quad (5)$$

where the greater b is, the faster the speed of convergence, provided that $b \in (0,1)$ in absolute value.

ANALYSIS AND DISCUSSION OF RESULTS

σ-Convergence

For σ-convergence to occur, a decreasing trend in the dispersion of output per worker must be observed. For the municipal level sample, a downward trend in the initial variance was observed for both aggregate output per worker and the services sector. Although the slight downward trend in the variance of labor pro-

[1] Nonlinear estimation is desirable because the coefficient of the logarithm of productivity $b=(1-e^{-\beta T})$ is a decreasing function of the amplitude of the estimation period (Barro and Sala-i-Martin, 1992).

ductivity in industry appears to revert from 2016, it is still possible to say that σ-convergence is verified for this sector, as the final variance is lower than the initial one. Productivity convergence was not observed in agriculture and public administration. In agriculture, the dispersion of productivity remained stable from 2011 to 2020. Similarly, in the public administration sector, there is strong growth in the variance of productivity in 2015, 2016, and from 2018 onward.

Regarding the state-level sample, σ-convergence can be assured for aggregate, industry, services, and public administration productivities Only in agriculture is a growth trend in productivity variance observed. For the sample utilizing output per hour worked (Figure 3b), a decrease in dispersion of the measure is observed for all sectors, except for public administration; however, the decline in the industry sector is not as clear as when productivity is measured by output per worker.

β-Convergence and the Determinants of Economic Growth

The first estimations to test β-convergence were performed with the NLS estimator for a cross-section dataset constructed from municipal information, disaggregated by major economic sectors for 2011 and 2020, and results are shown in Table 2. Due to its functional form, convergence in this case is observed when the estimator of β is significantly positive. Convergence of output per worker is verified in all cases: aggregate output per worker, without the inclusion of covariates, reports a convergence speed of 14.2%, which is higher than the convergence speed observed in industry, services, and agriculture sectors. Conversely, the estimated convergence speed for public administration is almost twice as high, suggesting that the greater convergence speed observed in aggregate output per worker is largely explained by public administration. The inclusion of the covariate vector causes a reduction of just over 1 p.p. in the convergence speed of aggregate labor productivity, an unexpected result not observed in sectoral estimations. However, no significant changes associated with the inclusion of the covariate vector were observed; thus, it is reasonable to say that the convergence speed is insensitive to the inclusion of these variables.

Physical capital has a positive impact on the growth of aggregate output per worker and for agriculture and public administration sectors, but a negative impact on labor productivity in the services sector. The primary hypothesis regarding this result is that the services sector in the region is more labor-intensive, thus benefiting little from an increase in physical capital. Another possibility is that physical capital is concentrated in areas of little use for the predominant services in the locality. Lastly, greater investment in capital-intensive activities may displace qualified labor and other resources, leading to lower development of the services sector.

In contrast, the percentage of workers with secondary education only positively affects public administration. It may be that public sector absorbs more labor with intermediate qualifications than the private sector for executing management and bureaucratic functions. Thus, the increase in high school graduates means a gain in productivity in the public sector, but not necessarily in industry or services, which employ more labor with higher (knowledge production) or lower (manual, repetitive work) qualifications.

The tax burden has a negative impact on aggregate output per worker and in services, agriculture, and public administration. This indicates that higher tax burdens may generate distortions in production and consumption choices, affecting services and agriculture. Furthermore, if taxes are not converted into investments like infrastructure and education (Ataliba *et al.*, 2001; Leal *et al.*, 2021), its effect on productivity may not materialize.

Tax incentives show a positive impact on labor productivity in the aggregate and industry. Those incentives are granted to companies from various sectors, in municipalities within SUDENE's area of operation, pointing to possible heterogeneities in effects, including by type of benefited enterprise. The extent of their impact, therefore, is conditioned by the local structure and the quality of further public policies.

Additionally, using a fixed effects panel (Table 3), convergence was observed in all estimations, except for public administration, which reports coefficients with absolute values greater than one. The physical capital had a positive impact in most cases, being statistically insignificant only in the services sector and in the agriculture estimation that includes the GA variable.

Human capital positively impacts aggregate output per worker in agriculture and public administration, but its impact is negative in services. Government share, in turn, negatively affects the growth of aggregate

Table 2: Municipal Convergence of Output per Worker (Nonlinear Model)

Variables	Aggregate			Industry			Services			Agriculture			Public Administration		
β^	0.142*	0.051*	0.135*	0.0648*	0.0481*	0.0649*	0.0575*	0.0558*	0.0657*	0.0323*	0.0224*	0.0354*	0.264*	0.214*	0.335*
	(0,0077)	*(0,0102)*	*(0,0069)*	*(0,0041)*	*(0,0090)*	*(0,0041)*	*(0,0023)*	*(0,0057)*	*(0,0027)*	*(0,0025)*	*(0,0048)*	*(0,0026)*	*(0,0291)*	*(0,0477)*	*(0,0446)*
Phys. Capital		-0,0494	0.670***		0,131	0,0995		-0.404***	-0.238***		0,179	0.482***		0.418**	1.482***
		(0,1290)	*(0,0321)*		*(0,2870)*	*(0,1030)*		*(0,1070)*	*(0,0402)*		*(0,2790)*	*(0,1030)*		*(0,1730)*	*(0,0480)*
Hum. Capital		0,0145	-0.0248***		-0,00376	-0.0795***		-0.0906***	-0.0266***		0,0375	-0,0205		0.108***	0.0177*
		(0,0277)	*(0,0075)*		*(0,0556)*	*(0,0245)*		*(0,0226)*	*(0,0093)*		*(0,0575)*	*(0,0239)*		*(0,0371)*	*(0,0107)*
Tax Burd.		-1.132***	-0.618***		0,194	-0,416		-1.367***	-0.862***		-0,234	-1.366***		-1.031***	0,191
		(0,2880)	*(0,1300)*		*(0,5900)*	*(0,4270)*		*(0,2330)*	*(0,1590)*		*(0,5790)*	*(0,3610)*		*(0,3770)*	*(0,1830)*
Trade Open.		0.256***			1.369***			0.364***			0,187			0,165	
		(0,0770)			*(0,4760)*			*(0,0639)*			*(0,1560)*			*(0,1020)*	
Incentives		42.76***	30.00***		95.47***	69.69***		-5,545	-13,83		-10,63	-18,26		3,536	8,859
		(11,480)	*(7,544)*		*(22,720)*	*(21,080)*		*(9,291)*	*(9,157)*		*(22,790)*	*(20,880)*		*(15,190)*	*(10,600)*
Intercept		0.476***	0.883***	0.546***	0.386***	0.584***	0.516***	0.570***	0.603***	0.381***	0.256***	0.415***	1.122***	1.018***	1.100***
		(0,0734)	*(0,0235)*	*(0,0278)*	*(0,0766)*	*(0,0312)*	*(0,0171)*	*(0,0455)*	*(0,0203)*	*(0,0264)*	*(0,0580)*	*(0,0290)*	*(0,0292)*	*(0,0751)*	*(0,0239)*
N	1990	283	1.898	1565	278	1.559	1975	283	1.890	1428	270	1.400	1961	282	1.875
R-squared	0,435	0,232	0,526	0,244	0,278	0,255	0,370	0,441	0,386	0,180	0,175	0,199	0,437	0,435	0,647

Source: Prepared by the authors. Notes: 1. White-corrected standard errors in parentheses. 2. * p-value < 0.05 e ** p-value < 0.10.

Table 3: Municipal Convergence of Output per Worker

Variables	Aggregate			Industry			Services			Agriculture			Public Administration		
Ln (y_(i,t-1))	-0.857*	-0.745*	-0.82*	-0.651*	-0.741*	-0.662*	-0.564*	-0.542*	-0.571*	-0.607*	-0.582*	-0.607*	-1.044*	-1.041*	-1.011*
	(0,0199)	*(0,0505)*	*(0,0159)*	*(0,0160)*	*(0,0761)*	*(0,0164)*	*(0,0160)*	*(0,0484)*	*(0,0174)*	*(0,0184)*	*(0,0356)*	*(0,0189)*	*(0,0158)*	*(0,0267)*	*(0,0138)*
Phys. Capital		8.845***	9.307***		5.150**	2.141***		-1,399	-0,113		1,969	2.054***		21.55***	18.80***
		(0,9350)	*(0,3200)*		*(2,4020)*	*(0,4150)*		*(0,9600)*	*(0,1400)*		*(1,7700)*	*(0,3930)*		*(2,8820)*	*(0,8370)*
Hum. Capital		0.212*	0,000		-0,165	-0,008		-0,018	-0.0807**		0.731***	0.149*		0.621**	0,062
		(0,1100)	*(0,0297)*		*(0,2520)*	*(0,0885)*		*(0,1440)*	*(0,0345)*		*(0,2090)*	*(0,0772)*		*(0,2480)*	*(0,0554)*
Tax Burd.		-9.631***	-4.085***		-23.30***	-12.57***		-0,040	-0,073		-0,016	-0,126		0.126***	0,037
		(1,5400)	*(0,7600)*		*(4,2600)*	*(2,0570)*		*(0,0281)*	*(0,0776)*		*(0,0218)*	*(0,1210)*		*(0,0095)*	*(0,0349)*
Trade Open.		-0.707***			-0,844			0.264*			-0.832*			0.322**	
		(0,1720)			*(0,7040)*			*(0,1450)*	*(7,3770)*		*(0,4900)*			*(0,1370)*	*4,7950*
Incentives		-11,260	18.77***		121.1*	54.95***		-20,560	-6,389		-32,810	-10,260		-16,400	-9,210
		(26,7400)	*(6,1830)*		*(64,5500)*	*(19,9400)*		*(29,9600)*			*(48,6700)*	*(22,2200)*		*(26,0400)*	
Intercept		8.026***	8.918***	7.536***	8.366***	7.673***	6.712***	6.243***	6.814***	7.660***	6.362***	7.475***	11.56***	10.31***	10.28***
	(0,2260)	*(0,5750)*	*(0,1830)*	*(0,1850)*	*(0,8980)*	*(0,2040)*	*(0,1910)*	*(0,5770)*	*(0,2090)*	*(0,2310)*	*(0,4380)*	*(0,2410)*	*(0,1750)*	*(0,4090)*	*(0,1560)*
N	17.906	2.244	16539	14.893	2.231	14370	17.844	2.245	16509	13.624	2.182	12929	17.732	2.241	16442
R^2	0,44	0,554	0,703	0,336	0,448	0,344	0,31	0,281	0,311	0,307	0,288	0,312	0,512	0,592	0,762
Number of Municipalities	1.990	409	1.902	1.866	409	1.832	1.989	409	1.901	1.693	394	1.647	1.988	409	1.901

Source: Prepared by the authors. Notes: 1. White-corrected standard errors in parentheses. 2. * p-value < 0.05 and ** p-value < 0.10.

and industry labor productivity, while its impact is positive in the public administration. Lastly, the effect of SUDENE-associated tax incentives is positive on the growth of aggregate and industry productivity.

At the state level (Table 4a), convergence is observed in all estimations, except for that on labor productivity in agriculture without a vector of covariates. The proxy for physical capital has no impact in any of the cases, but human capital positively impacts productivity growth in the aggregate, industry, agriculture, and public administration. The share of tax revenue in GDP has a negative impact on the aggregate and public administration. SUDENE's tax incentives have a positive impact on productivity growth in the public administration sector.

The existence of unobserved β-convergence can indicate the perpetuation of high and low-income subregions in different sectors due to network externalities or economies of scale. This result is consistent with the convergence clubs' hypothesis, as pointed out in studies such as Laurini *et al*. (2003), and Magalhães and Miranda (2009).

For robustness, state-level labor productivity was also constructed in terms of hours worked (Table 4b). Similarly, convergence is observed in all estimations, with coefficients associated with higher convergence speeds in the estimation of aggregate output per hour worked, and in the case of public administration.

The convergence speeds and half-life are greater when conditioned on a vector of covariates, except for the industry sector (Table 5a). Furthermore, it can be inferred that this speed varies among sectors, being highest in services (73.81%), which implies a half-life of 0.94 years. Among the estimations reporting β-convergence, aggregate productivity reported the lowest speed. Convergence speed is higher in most estimations carried out using output per hour worked (Table 5b), which implies lower half-lives in these estimations. Similarly to the estimates using output per worker, the convergence speeds are higher in the estimations that include a vector of covariates.

At the municipal level, there is no pattern of higher convergence speed associated with the inclusion of a covariate vector. In the NLS estimation (Table 2), great variation is observed in convergence speeds, with public administration being the sector that seems to converge fastest to the steady state, with a convergence speed of 33.5% and a half-life of 1.7 years.

Except for the non-conditional state-level estimation for agriculture, β-convergence was observed in the other estimations. Since β-convergence is a necessary but not sufficient condition for σ-convergence, in addition to agriculture at the state level, no decline in the dispersion of labor productivity was found for the agriculture and public administration sectors at the municipal level. This evidence of β-convergence in SUDENE's coverage area corroborates the results of Azzoni (2001), Laurini *et al*. (2003), and Ribeiro and Almeida (2012). The hypothesis of β-convergence and σ-convergence also reinforces the results of Reis *et al*. (2020).

The results found for the tax burden variable were predominantly negative and, in line with Moura (2000), suggest a crowding-out effect on private investment that exceeds its positive effects associated with the expansion of public investments in infrastructure.

The positive impact of tax incentives on the growth of aggregate productivity, industry, public administration, and services (when output per hour worked is used as proxy) corroborates the findings of Avellar (2009).

In Table 5a, when estimating a fixed-effect panel data model for municipalities, the estimation of aggregate output per worker reports a higher convergence speed, with a convergence coefficient of 194% in the non-conditional estimation, which corresponds to a half-life of 0.36 years. Due to differences in estimation methodology and sample used, the results of the municipal estimations are not directly comparable.

The high convergence speed observed in the municipalities and states under SUDENE's area of operation suggests that this region is still distant from its steady state and, therefore, could reduce its inequality in terms of output per worker compared to richer regions, corroborating the findings of Gomes and Esperidião (2016) for the Northeast.

Since this paper restricts the sample space to a region within the same country with similar characteristics, all evidence of β-convergence found refers to conditional, not absolute convergence.

It is worth mentioning that, according to Constitutional Amendment No. 132/2023, consumption taxation will migrate to a dual-VAT (IBS/CBS) charged at the destination, prohibiting new consumption incentives and gradually extinguishing ICMS/ISS benefits until 2033. This arrangement tends to end fiscal war, at least

Table 4a: State-Level Convergence of Output per Worker

Variables	Aggregate			Industry			Services			Agriculture			Public Administration		
ln(y_(i,t-1))	-0.176*	-0.22**	-0.186*	-0.449*	-0.422*	-0.393*	-0.4*	-0.542*	-0.522*	-0.00896*	-0.239*	-0.228*	-0.322*	-0.42*	-0.402*
	(0.061)	(0,1020)	*(0,0729)*	*(0.070)*	*(0,0919)*	*(0,0637)*	*(0.095)*	*(0,1530)*	*(0,1550)*	*(0,062)*	*(0,0800)*	*(0,0698)*	*(0.038)*	*(0,0613)*	*(0,0564)*
Phys. Capital		0,00000	0,0000		0,00000	0,0000		0,00000	0,0000		0,00000	0,0000		0,00000	0,0000
		(0,0000)	*(0,0000)*		*(0,0000)*	*(0,0000)*		*(0,0000)*	*(0,0000)*		*(0,0000)*	*(0,0000)*		*(0,0000)*	*(0,0000)*
Hum. Capital		1.316**	1.029***		1,941	1.393*		0,0389	-0,156		5.098***	4.669***		3.833***	4.031***
		(0,4390)	*(0,3020)*		*(1,2000)*	*(0,7140)*		*(0,2900)*	*(0,2880)*		*(1,5340)*	*(1,3100)*		*(0,8710)*	*(0,7510)*
Tax Burd.		-7.283**	-7.611*		-5,178	-6,043		-2,736	-3,044		1,951	0,84		-32.79***	-32.98***
		(3,1410)	*(3,6420)*		*(9,3030)*	*(11,0200)*		*(3,9350)*	*(3,8460)*		*(14,6000)*	*(14,2500)*		*(6,5060)*	*(5,9500)*
Trade Open.		0,971			2,091			0,761			1,371			-0,971	
		(0,7690)			*(2,3840)*			*(0,5720)*			*(2,0970)*			*(1,1320)*	
Incentives		143,8	-209,2		2.521	1.929		-503,4	-749,8		5.057	4.548		5,640**	5,797**
		(1174,0000)	*(820,0000)*		*(2739,0000)*	*(2043,0000)*		*(654,0000)*	*(607,5000)*		*(5008,0000)*	*(4842,0000)*		*(2522,0000)*	*(2464,0000)*
Intercept	1.794**	1.782*	1.530*	4.600***	3.609***	3.486***	4.074***	5.558***	5.417***	0,172	-0,19	-0,14	3.116***	2.769***	2.548***
	(0,615)	*(0,9790)*	*(0,7890)*	*(0,721)*	*(0,9090)*	*(0,7430)*	*(0,965)*	*(1,6640)*	*(1,6990)*	*(0,563)*	*(0,7710)*	*(0,8390)*	*(0,360)*	*(0,5800)*	*(0,4280)*
N	99	99	*99*	99	99	*99*	99	99	*99*	99	99	*99*	99	99	*99*
R^2	0,061	0,173	0,143	0,251	0,314	0,292	0,189	0,273	0,247	0,000	0,187	0,183	0,349	0,537	0,534
Number of States	11,000	11	11	11,000	11	11	11,000	11	11	11,000	11	11	11,000	11	11

Source: Prepared by the authors. Notes: 1. White-corrected standard errors in parentheses. 2. * p-value < 0.05 and ** p-value < 0.10.

Table 4b: State-Level Convergence of Output per Hour Worked

Variables	Aggregate			Industry			Services			Agriculture			Public Administration		
$ln\,(y_{i,t-1})$	-0.398*	-0.418*	-0.389*	-0.383*	-0.477*	-0.466*	-0.441*	-0.457*	-0.477*	-0.315*	-0.485*	-0.463*	-0.500*	-0.535*	-0.513*
	(0.066)	*(0.0851)*	*(0.0752)*	*(0.050)*	*(0.0659)*	*(0.0527)*	*(0.068)*	*(0.0944)*	*(0.1010)*	*(0.121)*	*(0.0989)*	*(0.0938)*	*(0.045)*	*(0.0346)*	*(0.0474)*
Phys. Capital		0.0000	0.0000*		0.00000	0.0000		0.0000	0.0000		0.00000	0.0000		0.0000	0.0000
		(0.0000)	*(0.0000)*		*(0.0000)*	*(0.0000)*		*(0.0000)*	*(0.0000)*		*(0.0000)*	*(0.0000)*		*(0.0000)*	*(0.0000)*
Hum. Capital		1.021*	0.520**		0.304	-0.311		0.862*	0.702**		3.417*	2.621**		1.419	1.555*
		(0.4300)	*(0.2800)*		*(1.1400)*	*(0.6770)*		*(0.3670)*	*(0.3590)*		*(1.1140)*	*(1.3400)*		*(0.7960)*	*(0.6610)*
Tax Burd.		-9.437*	-9.922*		-10.96	-11.72		-6.023**	-6.212**		15.65	13.9		-20.87*	-20.73*
		(3.5440)	*(4.0180)*		*(8.6570)*	*(9.7980)*		*(2.7530)*	*(2.8420)*		*(18.260)*	*(16.330)*		*(8.0700)*	*(7.8940)*
Trade Open.		1.559*			2.174			0.685*			2.713			-0.783	
		(0.5540)			*(2.1440)*			*(0.2630)*			*(1.7030)*			*(0.9990)*	
Incentives		1,899*	1,411*		2,731	2,102		1,255**	1,067**		8,338	7,474		4,898*	5,047*
		(833.0)	*(498.7)*		*(2608.0)*	*(1844.0)*		*(603.4)*	*(543.6)*		*(5192)*	*(5369)*		*(1286)*	*(1253)*
Intercept	6.856*	6.864*	6.551*	5.959*	7.490*	7.518*	7.371*	7.330*	7.721*	4.552*	5.006*	4.961*	6.959*	7.039*	6.713*
	(1.135)	*(1.3740)*	*(1.2850)*	*(0.776)*	*(1.1320)*	*(1.0300)*	*(1.127)*	*(1.5050)*	*(1.6200)*	*(1.733)*	*(1.3940)*	*(1.4420)*	*(0.623)*	*(0.5070)*	*(0.5350)*
N	99	99	*99*	99	99	*99*	99	99	*99*	99	99	*99*	99	99	*99*
R^2	0.285	0.484	0.408	0.234	0.336	0.307	0.390	0.455	0.44	0.093	0.319	0.304	0.456	0.542	0.54
Number of States	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

Source: Prepared by the authors. Notes: 1. White-corrected standard errors in parentheses. 2. * p-value < 0.05 and ** p-value < 0.10.

Table 5a: Speed of Convergence and Half-Life for States and Municipalities

Sector	Estimated Model	States		Municipalities			
		$\theta(b)$ %	$\tau(b)$ years	$\theta(b)$ %[a]	$\tau(b)$ years[a]	$\theta(b)$ %	$\tau(b)$ years
Total	Unrestricted	19.36	3.58	14.20	4.53	194	0.36
	with *GA*	24.85	2.79	5.10	13.24	137	0.51
	without *GA*	20.58	3.37	13.50	4.78	171	0.40
Industry	unrestricted	59.60	1.16	6.48	10.35	105	0.66
	with *GA*	54.82	1.26	4.81	14.06	135	0.51
	without *GA*	49.92	1.39	6.49	10.33	108	0.64
Services	unrestricted	51.08	1.36	5.75	11.70	83	0.84
	with *GA*	78.09	0.89	5.58	12.07	78	0.89
	without *GA*	73.81	0.94	6.57	10.20	85	0.82
Agriculture	unrestricted	-	-	3.23	21.11	93	0.74
	with *GA*	27.31	2.54	2.24	30.60	87	0.79
	without *GA*	25.88	2.68	3.54	19.23	93	0.74
Public Adm.	unrestricted	38.86	1.78	26.40	2.26	-	-
	with *GA*	54.47	1.27	21.40	2.88	-	-
	without *GA*	51.42	1.35	33.50	1.70	-	-

Source: Prepared by the authors. Note: The calculations of the speed of convergence and the half-life were obtained, respectively, from the equations $\theta(b) = -\frac{ln\,(1+Tb)}{T}$ and $\tau(b) = -\frac{lnln\,(2)}{lnln\,(1+b)}$, where T refers to the number of periods between growth rates, equal to 1 in this case. [a] Obtained from the NLS estimations.

Table 5b: Speed of Convergence and Half-Life for States and Municipalities, Hours Worked, and NLS

Sector	Estimated Model	States	
		$\theta(b)$ %	$\tau(b)$ years
Total	Unrestricted	50.75	1.37
	with *GA*	54.13	1.28
	without *GA*	49.27	1.41
Industry	Unrestricted	48.29	1.44
	with *GA*	64.82	1.07
	without *GA*	62.74	1.10
Services	Unrestricted	58.16	1.19
	with *GA*	61.06	1.14
	without *GA*	64.82	1.07
Agriculture	Unrestricted	37.83	1.83
	with *GA*	66.36	1.04
	without *GA*	62.18	1.11
Public Administration	Unrestricted	69.31	1.00
	with *GA*	76.57	0.91
	without *GA*	71.95	0.96

Source: Prepared by the authors. Note: The calculations of the speed of convergence and the half-life were obtained, respectively, from the equations $\theta(b) = -\frac{ln\,(1+Tb)}{T}$ and $\tau(b) = -\frac{lnln\,(2)}{lnln\,(1+b)}$, where T refers to the number of periods between growth rates, equal to 1 in this case.

at the inter-state level, and rearrange logistics chains previously organized to exploit ICMS differences, impacting the location of warehouses and distribution centers (Cucolo, 2024). However, it is possible that the fiscal war could be transferred to the municipal level through the calibration of local IBS rates (Coutinho *et al.*, 2024) or even at the state level through different incentives.

Nevertheless, SUDENE's incentives focus on income – via IRPJ – and not consumption, and therefore remain in effect for new projects whose applications occur until 31/12/2028 (Senado Federal, 2023). This means that while consumption subsidies lose relevance in the transition, SUDENE's federal incentives remain an active instrument of regional policy, justifying the analysis of their effects on growth even in the context of a new regime induced by the reform.

FINAL REMARKS

This article tested for the existence of β-convergence and σ-convergence of labor productivity at aggregate and sectoral levels. Generally, both β-convergence and σ-convergence are observed for aggregate and sectoral labor productivity, at least at some level of aggregation – municipal or state.

In this sense, convergence in the agricultural sector appears to be sensitive to the sample set used. In this sector, σ-convergence is only observed when using output per hour worked, and β-convergence is not observed in the unrestricted state-level estimation.

Similarly, in public administration, σ-convergence is only observed in the state-level estimation of output per worker. Furthermore, as in the municipal *within groups* estimations, the coefficient of the natural logarithm of labor productivity is greater than 1 in absolute terms, a situation defined in Sala-i-Martin (2000) as "systematic overtaking". That would mean municipalities with lower labor productivity systematically surpass municipalities with higher productivity in public administration, an unlikely result that should be further investigated.

Finally, tax incentives granted by SUDENE to companies through the reduction of IRPJ also positively impact aggregate and industrial labor productivity at the municipal level, as well as aggregate, services, and industrial productivity at the state level.

These results reinforce the importance of public policies that combine fiscal instruments and investments in human capital to promote the reduction of intra-regional inequalities in the Northeast. In particular, the evidence that human capital exerts a greater impact than physical capital suggests that educational and professional qualification policies must be prioritized in the PNDR strategy. Furthermore, the positive effect of tax incentives on aggregate and industrial productivity indicates that such instruments can be relevant for stimulating strategic sectors, but their design must consider monitoring and targeting mechanisms to prevent excessive concentration in locations or segments.

This study faces some limitations. Firstly, the unavailability of monetary data on tax incentives restricts the analysis to the quantity of approved applications, preventing the assessment of the financial magnitude of the benefits – which would allow for a direct consideration of the heterogeneity in the incentive levels received by each region. Secondly, the relatively short time series limits the observation of long-term effects. Finally, the analysis concentrated on municipalities and states within SUDENE's area of operation, precluding direct comparisons with non-benefited regions. Future research could overcome these limitations by exploring more complete databases, conducting counterfactual exercises, and investigating the heterogeneous effects of tax incentives across different sectors and municipalities. Furthermore, the presumed association between negative externalities and fiscal incentive policies, such as the misallocation of resources and/or increase in deforestation, could deepen the analysis.

REFERENCES

Afonso, A. et al. (2005), "Quality of public finances and growth". Available at: http://ssrn.com/abstract=663965.

Almeida, R.D.C. et al. (2021), "Social and economic convergence across Brazilian states between 1990 and 2010", Social Indicators Research, Vol. 157, pp. 225-246. doi: 10.1007/s11205-021-02659-x

Ataliba, F.et al. (2001), "Desigualdade de renda e crescimento econômico no Nordeste brasileiro", Repositório UFC, Universidade Federal do Ceará.
Avellar, A.P. (2009), "Impacto das políticas de fomento à inovação no Brasil sobre o gasto em atividades inovativas e em atividades de P&D das empresas", Estudos Econômicos, Vol. 39 No. 3, pp. 629–649, July. doi: 10.1590/S0101-41612009000300007
Azzoni, C.R. (2001), "Economic growth and regional income inequality in Brazil", The Annals of Regional Science, Vol. 35, pp.133-152. doi: 10.1007/s001680000038
Azzoni, C.R. and Barossi-Filho, M. (2002), "A time series analysis of regional income convergence in Brazil", Anais do XXX Encontro Nacional de Economia. ANPEC – Associação Nacional dos Centros de Pós-Graduação em Economia.
Barro, R.J. and Sala-i-Martin, X. (1992), "Convergence", Journal of Political Economy, Vol. 100 No. 2, pp.223-251. doi: 0022-3808/92/0002-0001$01.50
Braz, M.S. and Irffi, G. (2023), "Impactos dos incentivos fiscais da Sudene sobre o mercado de trabalho local", Anais do XXVIII Encontro Regional de Economia, Anpec, Fortaleza.
Carneiro et al. (2025), "Análise do impacto dos instrumentos da PNDR sobre a economia dos municípios nordestinos", Revista Brasileira de Planejamento e Orçamento, Vol. 15, e2501, pp.1-25. Available at: RBPO – Assecor
Colombo, D.G. and Cruz, H.N. (2018), "Impacts of the Brazilian innovation tax policy on the composition of private investments and on the type of innovation", Revista Brasileira de Inovação, Campinas, Vol. 17 No. 2, pp.377-414, July-December. doi: 10.20396/rbi.v17i2.8651500
Costa, E.M. et al. (2024), "Effects of SUDENE's tax incentives on job creation in the Northeast region of Brazil", Applied Economics Letters, pp.1-6. doi: 10.1080/13504851.2024.2402927
Coutinho, J.H. et al. (2024), "O IBS e a perspectiva de guerra fiscal entre os municípios", Revista de Direito Tributário da APET, No. 50, pp.367-391. Available at: https://revistas.apet.org.br/index.php/rdta/article/view/681
Cucolo, E. (2024), "Reforma acaba com turismo tributário e muda distribuição de galpões e centros logísticos", Folha de S.Paulo, 16 October. Available at: https://www1.folha.uol.com.br/blogs/que-imposto-e-esse/2024/10/reforma-acaba-com-turismo-tributario-e-muda-distribuicao-de-galpoes-e-centros-logisticos.shtml
De Mello, L.R. (2002), "Public finance, government spending and economic growth: the case of local governments in Brazil", Applied Economics, Vol. 34 No. 15, pp. 1871-1883. doi: 10.1080/00036840210128726
Díaz Dapena, A. et al. (2017), "Convergence in Brazil: new evidence using a multilevel approach", Applied Economics, Vol. 49 No. 50, pp. 5050-5062. doi: 10.1080/00036846.2017.1299101
Dos Santos, U.P. et al. (2020), " Impacts of tax incentives on innovation of large companies: an evaluation based on ABDI innovation survey", Nova Economia, Vol. 30 No. 3, pp.803-832. doi: 10.1590/0103-6351/5687
Fazoli, J.C. et al. (2018), "Incentivos fiscais como política pública de desenvolvimento industrial: uma análise empírica dos efeitos econômicos da concessão de crédito presumido de ICMS para as indústrias têxteis do estado de Santa Catarina", Revista Catarinense da Ciência Contábil, Vol. 17 No. 51. doi: 10.16930/2237-7662/rccc.v17n51.2508
Garsous, Grégoire et al. (2017), "Tax incentives and job creation in the tourism sector of Brazil's SUDENE area", World Development, Vol. 96, pp.87-101. doi: 10.1016/j.worlddev.2017.02.034
Glaeser, E.L. (2001), "The Economics of Location-Based Tax Incentives", 1932, Harvard Institute of Economic Research. doi: 10.2139/ssrn.289834
Gomes, R.R. and Espiridião, F. (2016), "Convergência de renda: uma análise em painel para as regiões brasileiras no período 1995-2009", Ensaios FEE, Vol. 37 No. 1, pp.115-144.
Gonçalves, R. and Ehrl, P. (2021), "Efeitos econômicos da Zona Franca de Manaus", Pesquisa e Planejamento Econômico, Vol. 51 No. 3, pp.251-279. doi: 10.38116/ppe51n3art8
IBGE (2010), Pesquisa Nacional de Amostras em Domicílios. Available at: https://www.ibge.gov.br/estatisticas/sociais/populacao/9127-pesquisa-nacional-por-amostra-de-domicilios.html?=&t=o-que-e
Jones, Ch.I. and Vollrath D. (2015), Introdução à teoria do crescimento econômico, 3. ed., Elsevier, Rio de Janeiro.
Kucera, D. and Roncolato, L. (2012),"Structure matters: sectoral drivers of growth and the labour productivity-employment relationship", International Labour Organization, Geneva.
Laurini, M.et al. (2003), "Clubes de Convergência de Renda para os Municípios Brasileiros: uma Análise Não-Paramétrica", Insper Working Paper, Insper Instituto de Ensino e Pesquisa, São Paulo.
Leal, É. et al. (2021), "Os incentivos fiscais da SUDENE no Norte do Espírito Santo: notas introdutórias", Anais..., VIII Encontro de Economia do Espírito Santo, Vitória, ES.
Lima, A.C. and Lima, J.P. (2010), "Programas de desenvolvimento local na região Nordeste do Brasil: uma avaliação preliminar da 'guerra fiscal'", Economia e Sociedade, Vol. 19 No. 3 (40), pp. 557-588. doi: 10.1590/S0104-06182010000300006
Luca, M.M. and Lima, V.F.L. (2007), "Efeito dos Incentivos Fiscais do patrimônio das entidades beneficiárias do Programa FDI, do Governo do Estado do Ceará", Contextus – Revista Contemporânea de Economia e Gestão, Vol. 5 No. 1, pp. 29-44, 29.
Magalhães, J.C.R. and Miranda, R.B. (2009), "Dinâmica da renda per capita, longevidade e educação nos municípios brasileiros", Estudos Econômicos, Vol. 39, pp.539-569. doi: 10.1590/S0101-41612009000300004
Martin, Ron et al. (2018), "The city dimension of the productivity growth puzzle: the relative role of structural change and within-sector slowdown", Journal of Economic Geography, Vol. 18 No. 3, pp. 539-570. doi: 10.1093/jeg/lby008
Matos, P.R.F. et al. (2023), "On the cross-city growth drivers of the most vulnerable region of Brazil", Journal of Financial Economic Policy, Vol. 15 No. 2, pp.77-103. doi: 10.1108/JFEP-01-2022-0013
McMillan, M. and Rodrik, D. (2011), "Globalization, structural change, and productivity growth", NBER Working Paper No. 17143. doi: 10.3386/w17143
Mendonça, H.F. and Peçanha, M.S. (2021), "Fiscal management performance and local economic development: evidence from a large emerging economy", Journal of Economic Studies, Vol. 48 No. 3, pp.641-659. doi: 10.1108/JES-08-2019-0386

Moura, N.F. (2000), Política de incentivos fiscais e crescimento: discussão e evidências. Monograph. Universidade Federal do Ceará, Fortaleza, June 2000.
Nascimento, L.R.C. and Lima, J.P.R. (2009), "Incentivos Fiscais (SUDAM e SUFRAMA) e a dinâmica industrial e agropecuária na região Norte", Análise Econômica, Vol. 23 No. 43. doi: 10.22456/2176-5456.10804
Naveed, A. and Ahmad, N. (2016), "Labour productivity convergence and structural changes: simultaneous analysis at country, regional and industry levels", Journal of Economic Structures, Vol. 5, issue 19, pp.1-17. doi: 10.1186/s40008-016-0050-y
Oliveira, T.G. and Silveira Neto, R.M. (2020), "Incentivos Fiscais Territoriais ao Desenvolvimento Local: uma Avaliação do Programa de Desenvolvimento do Estado de Pernambuco – Prodepe". Anais..., 48o Encontro Nacional de Economia – ANPEC.
Ottoni, B. and Barreira T. (2016), "Metodologia de Retropolação da Pesquisa Nacional por Amostra de Domicílios Contínua de 1992 a 2012", Nota Técnica do IBRE, Instituto Brasileiro de Economia, FGV IBRE, Rio de Janeiro.
Porsse, A. et al. (2008), "Economic Effects of Regional Tax Incentives: A General Equilibrium Approach", Latin American Business Review, Vol. 7 No. 3-4, pp.195-216. doi: 10.1300/J140v07n03_09
Reis, L.D.R. et al. (2020), "Uma nota sobre as disparidades de renda dos municípios nordestinos". Revista Brasileira de Economia, Vol. 74, pp.65-74. doi: 10.5935/0034-7140.20200004
Ribeiro, E.C. and Almeida, E.S. (2012), "Convergência local de renda no Brasil", Economia Aplicada, Vol. 16, pp. 399-420. doi: 10.1590/S1413-80502012000300003
Ribeiro, L.C. et al. (2020), "Regional funding and regional inequalities in the Brazilian Northeast", Regional Science Policy and Practice, Vol. 12 No. 1, pp. 43-59. doi: 10.1111/rsp3.12230
Sala-i-Martin, X. (2000), Apuntes de Crecimiento Económico, 2. ed., Antoni Bosch Editor, Barcelona.
Senado Federal (2023), "Sancionado prazo maior para incentivos na área da Sudene e da Sudam", Senado Notícias, Brasília, 26 December. Available at: https://www12.senado.leg.br/noticias/materias/2023/12/13/sancionado-prazo-maior-para-incentivos-na-area-da-sudene-e-da-sudam (accessed 10 October 2025).
Silva, B.S.et al. (2020), "Efeito dos Incentivos Fiscais na geração e distribuição de riqueza das companhias de capital aberto brasileiras", Revista de Contabilidade & Controladoria, Vol. 12 No. 1. doi: 10.5380/rcc.v12i1.73754
Solow, R.M. (1956) "A Contribution to the Theory of Economic Growth", The Quarterly Journal of Economics, Cambridge, MA, Vol. 70 No. 1, pp. 65-69. doi: 10.2307/1884513
Swan, T. (1956), "Economic Growth and Capital Accumulation", Economic Record, Vol. 32, pp.334-361. doi: 10.1111/j.1475-4932.1956.tb00434.x
Vasconcelos, C.R.F. et al. (2012), "A sensibilidade da decisão de localização das firmas a argumentos fiscais e não fiscais: evidências empíricas para municípios selecionados", Revista Análise Econômica, Vol. 30 No. 58, pp.259-279. doi: 10.22456/2176-5456.18867
Veloso, F. et al. (Ed.s) (2012), Desenvolvimento econômico: uma perspectiva brasileira, GEN Atlas, Rio de Janeiro. ISBN 9788595154759
Veloso, F. et al. (2019), "Nota metodológica dos indicadores anuais de produtividade do trabalho setorial no Brasil", Nota Técnica do IBRE, Instituto Brasileiro de Economia, FGV IBRE, Rio de Janeiro.

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CONFLICTS OF INTEREST
The authors have no conflicts of interest to declare.

DATA AVAILABILITY
The entire dataset supporting the findings of this study is available upon request from the corresponding author.

AUTHORS' CONTRIBUTION
Felipe Bastos: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – proofreading, and editing.
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