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HECIRLANE GOMES MARTINS

ON THE CROSS-CITY GROWTH DRIVERS OF THE MOST VULNERABLE REGION OF BRAZIL

FORTALEZA

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Thesis submitted to the Post-Graduation in Economics – CAEN of the Federal University of Ceará, as a partial requirement for obtaining the title of Doctor in Economics.

Advisor: Prof. Dr. Paulo Rogério Faustino Matos.
co-adviser: Prof. Dr. Felipe de Sousa Bastos

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To God.

To my Sandra Maria Gomes.

To my husband Jário.

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To my God, to Him be all honor and glory forever. If I walked this path today, it's because You, Lord, walked it for me. You formed me from my mother's womb and you designed me to be an instrument in Your hands. You gave me wisdom to learn and discern; joy and enthusiasm to convey to those by my side; courage to fight and perseverance to win. All this to share. To you my God, I give you all my gratitude.

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“Trust in the Lord with all your heart, and lean not on your own understanding. In all your ways acknowledge Him, and He shall direct your paths.”

(Proverbs 3:5-6)

ABSTRACT

We address the heterogeneous and worrying growth path of 925 cities located in the Northeast region of Brazil. This region has about 57 million inhabitants and has historically had the lowest socio - economic indicators in Brazil. We propose an innovative specification of the neoclassical growth model, by including additional and idiosyncratic sources of cross - city variation. We use growth drivers on human capital, financial system, business environment and social infrastructure. Considering 6452 observations for the period from 2009 to 2015, our main findings, suggest a robust and significant role played by the levels of education of formal workers (elementary, high school and higher education), rural financing (agricultural and livestock), real estate financing and FIRJAN indices (health, and employment). For cities with higher GDP per capita, water supply also seems to be relevant. In terms of convergence, Brazilian states seem to converge at a faster rate than cities in the Northeast. We expanded our investigation to the nine states of northeastern Brazil and despite finding results with low convergence and little significance in the variables studied, we were able to show the need for a closer look on the part of public policy makers on the most needy cities. These unprecedented conclusions are useful in the focused and strategic conduct of efficient and effective public policies.

Keywords: Economic Growth; Ceará; Determinants; Human Capital; Commerce; Industry; Panel Data.

RESUMO

Abordamos a trajetória de crescimento heterogênea e preocupante de 925 cidades localizadas na região Nordeste do Brasil. Essa região tem quase 57 milhões de habitantes e historicamente apresenta os menores indicadores socioeconômicos do Brasil. Propomos uma especificação inovadora do modelo de crescimento neoclássico, incluindo fontes adicionais e idiossincráticas de variação entre cidades. Usamos drivers de crescimento em capital humano, sistema financeiro, ambiente de negócios e infraestrutura social. Considerando 6.452 observações para o período de 2009 a 2015, nossos principais achados sugerem um papel robusto e significativo desempenhado pelos níveis de escolaridade dos trabalhadores formais (fundamental, médio e médio), financiamento rural (agrícola e pecuária), financiamento imobiliário e índices FIRJAN (saúde e emprego). Para cidades com maior PIB per capita, o abastecimento de água também parece ser relevante. Em termos de convergência, os estados brasileiros parecem convergir mais rapidamente do que as cidades do Nordeste. Expandimos nossa investigação para os nove estados do nordeste brasileiro e apesar de encontrarmos resultados com baixa convergência e pouca significância nas variáveis estudadas, conseguimos mostrar a necessidade de um olhar mais atento por parte dos formuladores de políticas públicas sobre as cidades mais carentes. Essas conclusões inéditas são úteis na condução focada e estratégica de políticas públicas eficientes e eficazes.

Palavras-chave: Crescimento econômico; Ceará; Determinantes; Capital humano; Comércio; Indústria; Dados do painel.

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DI	Diffusion Index
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
IBGE	Instituto Brasileiro de Geografia e Estatística
IBC-Br	Brazilian Economic Activity Index
IPEA	Institute of Applied Economic Research
RAIS	Annual List of Social Information
SUS	Unified Health System in Brazil
TARDI	Threshold Autoregressive Diffusion Index

LIST OF SYMBOLS

%	Porcentagem
&	E
©	Copyright
®	Marca Registrada

CONTENT

1 INTRODUTION

Almost a century ago, Ramsey (1928) provided insights on the permanent income and life cycle theory of consumption to model individual saving choices. These results were useful for the development of a theoretical growth literature in the 1950s and 1960s: the neoclassical model, developed by Solow (1956), Swan (1956), Cass (1965), and Koopmans (1965), among others. The most reported feature of this model is the conditional convergence property, derived from assuming diminishing returns to capital. The growth rate tends to be high if an economy begins far below its own target position, in terms of Gross Domestic Product (GDP) per capita. This convergence is conditional, since the steady state levels of capital and output per capita depend on the propensity to save, the growth rate of population, and the position of the production function.

Some of the extensions of this model have suggested the inclusion of additional sources of cross-economy variation, especially government policies, while other extensions, such as Lucas (1988), and Caballe and Santos (1993) have suggested broadening the definition of capital enabling to include human capital. According to Barro (1996), even these extended versions of the neoclassical growth model used to fail to fit the data, given that growth rates used to persist positive over a century or more, without downward trend. Such puzzling evidence was addressed by assuming that the long-run growth rate of the level of output depends on exogenous variables, as the growth rate of population, and the technological progress.

Recent work on endogenous growth theory aims to provide a theory for this technological progress, one of the central missing elements of the neoclassical model. In one of the most realistic settings, Romer (1987,1990) proposed incorporating research and development (R&D) theories and imperfect competition into the growth framework. However, a problem remains, even in the most realistic versions of endogenous growth theories: they do not seem to predict the robust conditional GDP convergence. Aiming to combine the long–run growth of the endogenous growth theories with the convergence behavior of the neoclassical growth model, Barro and Sala-i-Martin (1995) proposed a framework based on the diffusion of technology hypothesis.

Despite these breakthroughs, and even given the recognized relevance of the endogenous growth literature for providing possible explanations for long–term growth, recent cross-country, cross-state and cross-city empirical work on growth has received more

inspiration from the neoclassical model and its extensions. In other words, Barro (1996) argues that theories of basic technological change seem most important for understanding why the world can continue to grow indefinitely in per capita terms. However, these theories have less to do with the determination of relative rates of growth across countries, states, or cities.

To summarize, the augmented Solow-Swan neoclassical framework has been taken as a baseline empirical growth model, and many empirical studies have tried to find out which variables are able to drive long-run economic growth. In addition to the usual determinants – initial output, rates of physical and human capital accumulation, and population growth – the survey proposed by Durlauf, Johnson and Temple (2005) identifies 43 distinct growth theories and 145 proposed regressors as proxies. They argue that each of these theories is found to be statistically significant in at least one paper. This wide literature has proposed models to verify the existence of correlations or causalities between economic growth and sets of structural, demographic, political, institutional and financial variables that can lead countries to convergence to their steady state.

However, the choice of explanatory variables for the growth of regions, states and cities seems to be quite different. First, due to the availability of data and, second, because some of the growth drivers of countries do not apply to states or cities as they remain constant between them. Whether due to the availability of these data or due to the lower interest in the study of subnational federative entities, the truth is that the empirical growth literature comparing states and municipalities is not yet so extensive.

Concerning cross-state analysis, it only makes sense in countries with many states or regions. Restricting to some of the most recent contributions applied to different countries, Cai, Wang and Du (2002) analyze empirically determinants of economic growth in Chinese provinces during the period 1978-1998, while Papyrakis and Gerlagh (2007) analyze empirically determinants of economic growth in the United States using cross-sectional data on 49 states over the period 1986-2001. Ledyaeva and Linden (2008) have proposed a modification of Barro and Sala-i-Martin (1995) growth model aiming to examine the drivers of GDP per capita growth in 74 Russian regions during period of 1996-2005. Matos and dos Santos (2020) add to this empirical literature by using a dynamic balanced panel from 2003 to 2017 to study GDP growth of 27 states in Brazil.

Comparing cross-country and cross-state exercises, Barro and Sala-i-Martin (1992) find much more income convergence between states than between countries. Adding to this line of thinking about a more disaggregated analysis, Glaeser, Sheinkman and Schleifer (1995)

argue that looking at cities complements looking at countries and states in some ways. For instance, cities are more specialized economic units than states, and hence it may make more sense to study the movement of resources and convergence between cities than between states. It is also important understanding that recent studies of economic growth across countries have focused on political and social drivers of growth. For example, Alesina and Rodrick (1994) have argued that inequality is bad for growth. Therefore, the regional growth literature should use political and mainly social characteristics of cities to provide further evidence on the importance of them.

Despite this relevance, the interest in studying the growth path of cities seem to be more restricted, because it is necessary to find an interesting sample, with heterogeneity and idiosyncrasy able to justify the research. Some of the first articles on cross-city growth are from the time when the neoclassical growth theory emerged, such as Borts (1960), Kain and Neiderconr (1963) and Jacobs (1969). Three decades later, some of the rare and main contributions remain concentrated in the analysis of American cities, with emphasis on the line of research developed by Glaeser et al. (1992), Glaeser, Sheinkman and Schleifer (1995), Mills and Lubuele (1995) and Glaeser and Gotlieb (2009). To summarize some of the main findings reported in this related literature, Glaeser, Sheinkman and Schleifer (1995) argue that over the last 30 years, the growth experiences of United States cities have varied widely. They propose examining how the growth experiences of 203 large U.S. cities between 1960 and 1990 relate to their location, initial population, initial income, past growth, output composition, unemployment, inequality, racial composition, segregation, size and nature of government, and the education of their labor force. In a recent contribution, González-Val and Olmo (2015) analyze empirically the main existing theories on income and population city growth, considering a large database of urban, climatological and macroeconomic data from 1,173 US cities observed in 1990 and 2000.

In this thesis, we add to this discussion on cross-city empirical economic growth, by estimating an unbalanced dynamic panel for the most vulnerable region of Brazil. We propose including additional and specific sources of cross-city variation, enabling us to capture the essence and reality of this region. Our sample selection is given by the solution of a trade-off on the number of cities and the available explanatory variables. Considering our final choice, the analysis is based on 6452 observations extracted from a sample of 925 cities between 2009 and 2015. In order to reconciliate the regional growth literature and this availability of observable data, we decide to explain cross-city real GDP per capita in log, controlling for its

lagged value, and considering 15 explanatory variables on: human capital, financial system, business environment and social infrastructure.

More specifically, we use as financial system drivers: i) Number of bank branches of public or private banks (per 100 thousand inhabitants), ii) Loans and Discounted Securities in public or private banks (as a ratio of GDP), iii) Rural financing (agricultural or livestock) in public or private banks (as a ratio of GDP), iv) Real estate financing in public or private banks (as a ratio of GDP), and v) Savings deposits and term deposits in public or private banks (as a ratio of GDP). To control for human capital, we use: i) Percentage of formal workers with complete elementary education, ii) Percentage of formal workers with completed high school, and iii) Percentage of formal workers with higher education. In terms of infrastructure, we use: i) FIRJAN Municipal Development Index – Health, ii) Population served by water supply (% of total population), iii) Average per capita water consumption (liter/inhabitant.day), iv) Homicide rate (per 100 thousand inhabitants), and v) Incidence of dengue (per 100 thousand inhabitants). Finally, we summarize Business ambience, observing: i) FIRJAN Municipal Development Index - Employment and income, and ii) Number of commercial and industrial establishments per capita.

Our analysis aims to contribute to the recent studies on regional growth applied to Brazil. To the best of our knowledge, this is an innovative contribution, and the main differences between this scientific study and the others are the sample of cities, the period, the growth model and the estimation technique. For instance, Da Mata et al. (2005, 2007) explores population growth and its implications for economic dynamics and income generation among 123 urban agglomerations between 1970 and 2000. Bogoni, Hein and Beuren (2011) make inferences on the relationship between public spending and growth based on a cross-section with the 30 largest cities in the southern region of Brazil. Alves (2021) studies slum growth in contemporary urbanizations processes based on an empirical exercise looking at 1991-2010 changes in the allocation of two types of households (high and low income) across two types of houses (unserviced and serviced) in 272 Brazilian cities and the countryside .

In addition to the proposed empirical exercise, we add to academic discussion, in relation to growth between cities, when to presenting a second investigation focused on the municipalities of each state. The idea is to understand as a variable, apparently relevant to growth from northeast, behave when observing one state at a time, following the advice of Glaeser, Sheinkman and Schleifer (1995). This more detailed analysis can reveal which elements are most relevant within the small groups of the sample, that is, among the

municipalities of a state, more specifically each of the nine states in the northeast. In this way,it is possible to collect useful information to assist public policy makers in their decision making on the allocation of future investments for the economic growth of their city and/or state, considering the high heterogeneity since it is characteristic of the municipalities

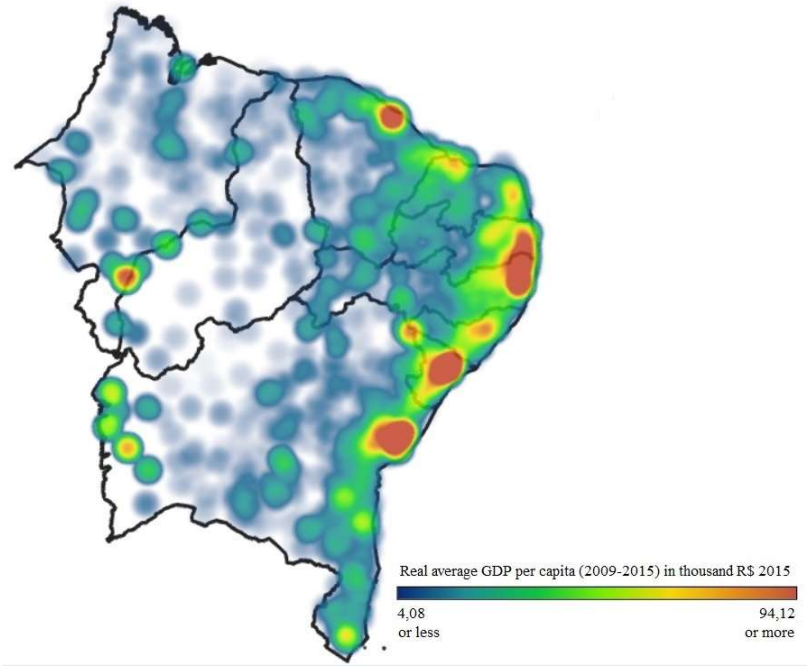
We understand that this research extension has an innovative contribution since considers the factors aggregated for a specific region (states) between the period from 2009 to 2015 approaching model and estimation technique not yet used by the scientific community.

Another advantage of this investigation is to verify the scientific argument in which it is expected that there is no convergence in municipal for such large samples. It is with this analysis based on Seo and Shin (2016) that we will be able to respond to possible criticisms related to the existence of a common convergence pattern between very heterogeneous cities. With the emergence of increasingly larger and complex panels that need to be analyzed in a short period of time, Seo and Shin (2016) address this challenging subject by designing a the dynamic threshold panel data model. In other words, they point how best to model nonlinear asymmetric dynamics and unobserved individual heterogeneity, simultaneously. We use this information in our thesis to make our results more robust.

Two recent studies are aligned with our thesis. Nogueira and Arraes (2018) propose measuring the effects of higher education institutions' teaching activities and institutional performance on the local economic growth of 22 cities in the Northeast Region of Brazil. Silva, Tabak and Laiz (2021) is a very interesting study on the role of credit to corporates sector based on an unbalanced panel data on 5555 Brazilian cities from 2003 to 2014. Some issues have motivated us to studying the Northeast region of Brazil. First, the heterogeneity of real GDP per capita and the respective growth rate, as we can see in the maps reported in figures 1 and 2.

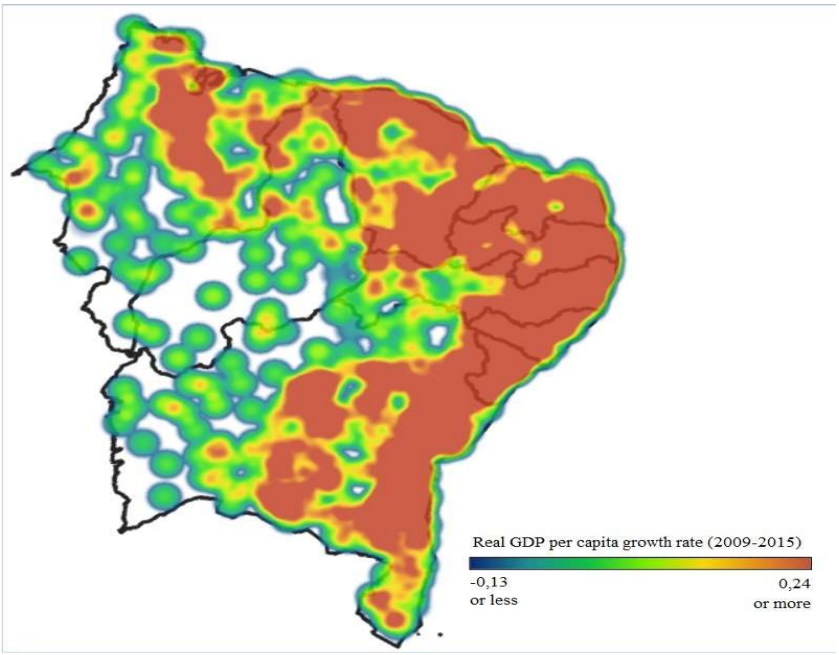
Figure 1 suggests a concentration of cities with the highest GDP per capita, around the metropolitan regions of the capitals located on the coast. The average GDP per capita is over R$ 10,000, with high heterogeneity. The real annual growth rate (Figure 2) shows less dispersion, oscillating between -13% and 24%, with concentration also characterized by the location in the cities of the northeastern coast.

Figure 1- Real average GDP per capita of 925 cities from the Northeastern region of Brazil



source**:** author himself, 2021.

Figure 2- Real GDP per capita growth rate of 925 cities from the Northeastern region of Brazil



source: author himself, 2021.

Second, according to the International Monetary Fund (IMF), Brazil ranked 76th in 2015 GDP per capita ranking, with Int$ 15,615 (international dollars, considering purchasing power parity). If we consider our sample – with 925 cities from the Northeastern region of Brazil – as a country, with a GDP per capita of Int$ 5,620, it would be 127th in that ranking, between East Timor and Myanmar, countries that have gone through rebellions and civil war, respectively. It would also lag behind countries like El Salvador, Guatemala, Angola, Congo, Bolivia, Vietnam and Nigeria, for instance. Observing the real GDP per capita of the northeastern states in 2009, with the exception of Sergipe (16th of 27 states), the other eight states in this region were among the nine states with the lowest real GDP per capita. In 2015, Sergipe became the 17th and the other northeastern states remained among the nine worst.

Moreover, according to the Brazilian Institute of Geography and Statistics (IBGE), the GDP per capita of 2015 in Brazil was almost R$ 28.9 thousand, while the average GDP per capita of the sample of 925 cities was R$ 10.76 thousand, with only 33 cities showing GDP per capita higher than the Brazilian average. Third, according to the Synthesis of Social Indicators for the year 2017, a report made by the IBGE, about 50 million Brazilians (25.4% of the population) live in the poverty line and have a family income equivalent to R$ 387.07 (US$ 5.5 per day), a value adopted by the World Bank to define whether a person is poor. This report also indicates that the highest poverty rate occurs in the Northeast Region of the country, where 43.5% of the population falls into this situation. It is important to note that these economic indicators seem to be robust over time, with the observed improvements not being able to make the income or GDP per capita of the Northeast converge to the standards of the rest of Brazil.

This context has motivated us to identify the role of the financial system, social infrastructure, education, and business environment to explain the growth in the cities of this vulnerable region in Brazil.

This thesis is structured as follows. In Section 2, there is a review of the literature on empirical growth applied to Brazil, while Section 3 illustrates the configuration of the empirical model. Section 4 analyzes the dataset presenting descriptive statistics and the main results and conclusions for the case of the Brazilian northeast region. Soon after, section 5 expands our investigation to each of the nine states in northeastern Brazil, presenting the descriptive statistics of each state and the main findings of the exercise. Finally, section 7 is dedicated to the discussion of public policies and final considerations.

2 LITERATURE REVIEW ON GROWTH APPLIED TO BRAZIL

The literature on macroeconomics in Brazil before the 1990s used to concentrate on issues such as economic plans, economic stability or combating hyperinflation. The literature on GDP growth in Brazil seems to be more recent, but it is extensive, since Brazilian inequalities and disparities offer a unique data set.

In this review of the growth literature applied to Brazil, we do not follow a chronological order, but rather try to identify some of the main contributions by issue. We start with very informative contributions on Brazil's historical macroeconomic context, such as Bugarin et al. (2003), and Bacha and Bonelli (2004), for instance. Among other contemporary studies, these papers aim to better understand why Brazil's GDP has grown at 7% yearly from 1940 to 1980 but at only 2.5% per year since then. In the past two decades, growth has been even worse, to the point of being called "lost decades".

Still with regard to studies on the country's growth path, in the 2000s we can see a line of researches based on a more econometrically refined approach, aiming to suggest an analysis of scenarios and forecasting. In Chauvet (2002), optimal probability inferences from a Markov switching model are used to define the different phases of cyclical economic fluctuations underlying quarterly real Brazilian production for the period from 1990 to 1999, while Ferreira, Bierens and Castelar (2005) suggest an interesting methodological extension. They propose using linear and nonlinear diffusion index models (DI), as well as a threshold DI (TARDI) model and a Markov-switching DI (MSDI) model to forecast quarterly Brazilian GDP growth rate for the period from 1975 to 2003.

More recently, we highlight a more specific line of research that aims to create and predict growth indicators. Issler, Notini and Rodrigues (2013) create a new coincident index for the Brazilian economic activity, which enables them to establish a chronology of recessions in the recent past of the Brazilian economy. Issler and Notini (2016) test a myriad of interpolation models, useful to choose the most appropriate monthly indicator for Brazilian GDP, which is compared to an economic activity indicator widely used by practitioners in Brazil—the Brazilian Economic Activity Index (IBC-Br).

Although this research on the Brazilian GDP modeling is relevant, there are recent studies on the most reported feature of neoclassical model: the conditional convergence between per capita income and GDP of the Brazilian states. A motivation is that Barro and Sala-i-Martin (1992) find much more income convergence between states than between countries.

The biggest problem found in this literature is that the data for state GDPs are not available, on a compatible basis, for a long period. One of the first papers addressing this issue is Ferreira and Ellery Jr (1996), whose findings suggest a robust process of convergence between the Brazilian states between 1970 and 1990, which seems to be slower than that evidenced for the American states reported by Barro and Sala-i-Martin (1992). The main findings reported by Azzoni (2000) add to this discussion, since his results indicate the presence of signs of regional income convergence in Brazil during the period from 1939 to 1995, however with oscillations in the evolution of inequality over time, and across regions within Brazil. In one of the most recent papers on convergence, De Almeida and Moreira (2019) use a dynamic panel to find that the speed of convergence increased from 1.7% in the absolute version to 2.8% in the conditional version between 2001 and 2014.

However, this literature also has identified other worrying features of this convergence pattern across Brazilian states. First, Ferreira (2000) finds that sigma-convergence was an unequivocal feature of the regional growth experience in Brazil, between 1970 and 1986, and that after 1986, the process of convergence seems, however, to have slowed down almost to a halt. He also suggests that the relative per capita incomes of a significant number of states and the number of 'very poor' and 'poor' states were, in 1995, already quite close to their steady state values. Second, based on time series methodology proposed by Phillips and Sul (2007), Penna and Linhares (2009) do not find a total convergence, but a partial one, with the formation of two clubs convergence. A first group formed mostly by the great most states in the South, Southeast and Midwest of the country, and a second one formed mainly by the states of the North and Northeast.

Following the literature on cross-country growth drivers, there is also a wide literature proposing models to verify the existence of correlations or causalities between cross-state economic growth in Brazil and sets of structural, demographic, political, institutional and financial variables. Concerning the role of government, Rocha and Giuberti (2007) find for the period 1986-2003 a positive role played by defense, education, transportation and communication expenditures, and that the relationship between capital expenditures and the growth rate is positive and apparently nonlinear.

On the perspective of trade, Daumal and Özyurt (2011) find that trade openness for the period from 1989 to 2002 contributed to growth on Brazilian states with a higher level of industrialization, human capital and stocks of private capital. Using a similar econometric approach, Fraga and Bacha (2013) analyze the relationship between human capital of employed individuals, commercial opening and economic growth of the Brazilian states in the period from 1995 to

2006. They find that an increase in level of trade opening of 1%, on average, increases GDP per capita growth rate of Brazilian states between 0.09% and 0.13%, while an increase of one year in the average level of education of workers generates an increase between 0.06% and 0.07%.

Regarding the role of credit market, Galeano and Feijó (2012) have identified a statistically significant and positive correlation between total credit volume and GDP growth. More recently, Matos and dos Santos (2020) add to this empirical literature by using a dynamic balanced panel from 2003 to 2017. They find that Brazilian cross-state growth depends more on the evolution of household credit than on credit to firms, however they also find a negative role played by government credit to GDP given by the significant elasticity of −0.87.

Finally, in the last 15 years, another extension of this regional growth literature has brought very interesting results, based on cities, or urban agglomerations, or even slums. In other words, a more disaggregated analysis aimed at capturing the existing heterogeneities and idiosyncrasies. It is exactly in this literature that is our innovative contribution. The main differences between this scientific study and the others are the sample of cities, the period, the growth model and the estimation technique. Regarding the sample, for instance, Da Mata et al. (2005, 2007) explore population growth for 123 urban agglomerations, while Bogoni, Hein and Beuren (2011) use a cross-section with the 30 largest cities, and Alves (2021) studies slum growth in 272 Brazilian cities.

Considering all the studies, the most recent one analyzes the growth until the year 2010, and none of them studies exactly the Northeast region. The exceptions are Nogueira and Arraes (2018). They use the same period, aiming to estimate a growth model quite different from ours, with a greater emphasis on education, and based on a smaller sample of cities, 22 cities. Their results of the dynamic panel estimation considering 22 cities suggest that the efficiency of higher education public institutions is a relevant economic growth driver of the cities where they are located, through teaching activities. There was no significant effect on the teaching activities of private institutions. We also highlight the sample of cities used in Silva, Tabak and Laiz (2021), which is the widest possible in Brazil. Our analysis in this thesis is based on 6452 observations extracted from a sample of 925 cities located in Brazil's Northeast region between 2009 and 2015. Reconciling the regional growth literature and this availability of observable data, we decide to explain cross-city real GDP per capita in log, controlling for its lagged value besides 15 explanatory variables on: human capital, financial system, business environment and social infrastructure.

3 THE MODEL

As mentioned by Barro (1996), theories of basic technological change are most important for understanding why the world and the economies at the technological frontier can grow in the long run. However, these theories have less to do with the determination of relative rates of growth across economies; that is, with the relations studied in cross-country, cross–region or cross-city statistical analyses.

Here, we follow the empirical literature on growth across economies, by using a framework that embodies the idea of conditional convergence derived from an extended version of the neoclassical growth model.

The literature on the empirical determinants of economic growth is interested in estimating:

$$\frac{ln(y_{i,t}) - ln(y_{i,0})}{t} = c\ ln(y_{i,0}) + \beta \boldsymbol{x}_{i,t} + \varepsilon_{i,t},, i = 1, \ldots, N\ and\ t = 1, \ldots, T \qquad (1)$$

where $y_{i,0}$ is the initial value of GDP per capita, $y_{i,t}$ represents the GDP per capita in t of economy i, $\boldsymbol{x}_{i,t}$ is a vector of choice and environmental variables that determine the target or the log run output level of economy i, and $\varepsilon_{i,t}$ is the residual, as usual.

This regression follows the model estimated in Barro (1991), for instance, and the null hypothesis is that the growth rate, $\frac{\ln(y_{i,t}) - \ln(y_{i,0})}{t}$, is diminishing in $y_{i,0}$, for given steady state level, and rising in the long-run position for given current GDP per capita. This estimating equation can be derived from a generic one-sector growth model, developed by Solow (1956), Swan (1956), Cass (1965) and Koopmans (1965).

According to Moral-Benito (2012), although Penn World tables of worldwide aggregate series span around fifty years (from 1960 to 2010), for instance, cross-country growth regressions are commonly estimated from small-T panels, and the data are typically split into five- or ten-year intervals to focus on long run economic growth. In particular, a panel variant of the baseline empirical growth regression in (1) is usually considered:

$$\ln(y_{i,t}) = \alpha \ln(y_{i,t-1}) + \beta \boldsymbol{x}_{i,t} + \eta_i + \zeta_t + \varepsilon_{i,t}, i = 1, \ldots, N\ and\ t = 1, \ldots, T \qquad (2)$$

where $\alpha = (1 + c)$, η_i is an economy-specific fixed effect that allows considering unobservable heterogeneity across economies, and ζ_t represents a period-specific shock

common to all economies.

In addition to the usual determinants used by the neoclassical framework – initial output, rates of physical and human capital accumulation, and population growth – the survey proposed by Durlauf, Johnson and Temple (2005) identifies 43 distinct growth theories and 145 proposed regressors as proxies. To summarize, there is a wide literature proposing models to verify the existence of correlations or causalities between economic growth and sets of structural, demographic, political, institutional and financial variables that can lead countries to convergence to their steady state. However, the choice of explanatory variables for the growth of regions, states and cities seems to be quite different, due to the availability of data or given that some of the growth drivers of countries do not apply to states or cities as they remain constant between them. In other words, we may need to use additional sources of cross-city variation.

In this thesis, we add to the discussion on regional growth applied to Brazil, by proposing and estimating a model, and suggesting public policies based on these results. Regarding the model to be proposed and estimated here, this literature mentions two main problems.

First, we have to deal with endogeneity of the long-run output drivers, due to the omitted variables (city-specific effects) or reverse causality between GDP growth and the regressors. Although the main evidence turns out to come from the a cross-economy approach such as in Barro (1991), the main reason to extend to a panel setup is to expand the sample information, enabling to capture the within-economy dimension and thus providing some additional information. The prospects for reliable generalizations in cross-economy growth regressions are often constrained by the limited number of countries, regions or cities available; therefore, the use of within-economy variation to multiply the number of observations is a natural response to this constraint. Using panel data methods allows solving the inconsistency of empirical estimates arising due to the existence of omitted country specific effects, which, if not uncorrelated with other regressors, lead to a misspecification of the underlying dynamic structure.

The second problem is due to the lack of theoretical guidance on the choice of regressors to include in the vector $\boldsymbol{x}_{i,t}$. For instance, if we have M possible explanatory variables, we will have 2^M possible combinations of regressors. In this context, and given our purpose to better understand the cross-city empirical economic growth of the most vulnerable region of Brazil, our sample selection may be given by the solution for a trade-off on the number

of cities and the available and intuitive explanatory variables. This is the main reason for the final model proposed here, and we deal with this trade-off by reconciling the regional growth literature and this availability of observable data, following two steps.

First, according to Durlauf, Kourtellos and Tan (2008), the different candidate growth drivers should be grouped by growth theories. This is useful, for instance, to account for interdependencies among them when eliciting model priors in Bayesian Model Averaging approaches, as used by Moral-Benito (2012). The set of growth drivers used for us is only a subset of that identified by Durlauf, Johnson and Temple (2005), and we group them into four strands: human capital, financial system, business environment and social infrastructure. Second, Ciccone and Jarocinski (2010) show that the fewer the potential growth determinants considered, the smaller the sensitivity of the results, i.e., it is advisable to avoid the inclusion of several proxies for the same growth theory. Therefore, we have looked for a parsimonious model, and the final choice of variables in each group aims to satisfy the availability, relevance and representativeness of the variables. Thus, we propose estimating the following classical Barro-style growth regression:

$$\begin{aligned}\ln\left(RGDP_PER_{i,t}\right) = \alpha \ln\left(RGDP_PER_{i,t-1}\right) + \varphi_{BB}BANK_BRA_{i,t} + \\ +\varphi_{LO}LOAN_GDP_{i,t} + \varphi_{RU}RURA_GDP_{i,t} + \varphi_{RE}REST_GDP_{i,t} + \\ +\varphi_{SA}SAVI_GDP_{i,t} + \varphi_{EE}ELEM_EDU_{i,t} + \varphi_{HS}HIGH_SCH_{i,t} + \\ +\varphi_{SE}SECO_EDU_{i,t} + \varphi_{HE}HEALTH_IN_{i,t} + \varphi_{WA}WATER_{i,t} + \\ +\varphi_{WC}WAT_CONS_{i,t} + \varphi_{HO}HOMICIDE_{i,t} + \varphi_{DE}DENGUE_{i,t} + \\ +\varphi_{EM}EMPLO_IN_{i,t} + \varphi_{ES}ESTAB_PC_{i,t} + \varepsilon_{i,t}, i = 1, \dots, N \; and \; t = 1, \dots, T,\end{aligned} \tag{3}$$

where the subscript i refers to each Brazilian city among 925 cities, and t to each year of our sample, from 2009 to 2015. As usual, ε refers to the residual. In Table 1, we report the source and the brief description of the endogenous and exogenous variables. We now discuss on the rationale for choosing the groups of growth drivers.

Theories on the relevance of human capital and the financial system through credit are already traditional and even consensual. Since Romer (1986), Lucas (1988), and Caballe and Santos (1993), among others, the growth literature has broadened the definition of capital enabling to include human capital. In this research we consider that by observing the percentage of the formal workers with complete elementary education, high school and higher education. Later, De Gregorio and Guidotti (1995) have collaborated to the discussion on finance and growth by including variables to assess possible effects of financial markets development, using total credit to the private sector as a share of GDP as proxy.

Table 1 - Definitions of variables

Variable	Source	Code
Endogenous		
Real GDP per capita (R$ 2015)	Brazilian Institute of Geography and Statistics (IBGE)	RGDP_PER
Financial system		
Number of bank branches processed in any monthly transaction carried out over the year in public or private banks (per 100 thousand inhabitants)	Central Bank of Brazil	BANK_BRA
Loans and Discounted Securities in public or private banks (as a ratio of GDP)	Central Bank of Brazil	LOAN_GDP
Rural financing (agricultural or livestock), with costs, commercialization and investments in public or private banks (as a ratio of GDP)	Central Bank of Brazil	RURA_GDP
Real estate financing in public or private banks (as a ratio of GDP)	Central Bank of Brazil	REST_GDP
Savings deposits and term deposits in public or private banks (as a ratio of GDP)	Central Bank of Brazil	SAVI_GDP
Human capital		
Percentage of the formal workers with complete elementary education	Annual List of Social Information of the Min. of Economy (RAIS, Brazil)	ELEM_EDU
Percentage of the formal workers with completed high school	Annual List of Social Information of the Min. of Economy (RAIS, Brazil)	HIGH_SCH
Percentage of the formal workers with higher education	Annual List of Social Information of the Min. of Economy (RAIS, Brazil)	SECO_EDU
Social Infrastructure		
FIRJAN Municipal Development Index - Health	Federation of Industries of the State of Rio de Janeiro (FIRJAN)	HEALTH_IN
Population served by water supply (% of total population)	National Sanitation Information System (SNIS, Brazil)	WATER
Average per capita water consumption (liter/ inhabitant.day)	National Sanitation Information System (SNIS, Brazil)	WAT_CONS
Homicide rate (per 100 thousand inhabitants)	DATASUS Ministry of Health	HOMICIDE
Incidence of dengue (per 100 thousand inhabitants)	Ministry of Health	DENGUE
Business environment		
FIRJAN Municipal Development Index - Employment and income	Federation of Industries of the State of Rio de Janeiro (FIRJAN)	EMPLO_IN
Number of commercial and industrial establishments (per thousand inhabitants)	Annual List of Social Information of the Min. of Economy (RAIS, Brazil)	ESTAB_PC

source**:** author himself, 2021.

More recently, Beck et al. (2012) addressed the distinction between the role played by enterprise and household credit in economic growth. Here, we propose using available data on earmarked and non-earmarked resources credit, as a ratio to GDP, measures of saving deposits to GDP, and the number of bank branches.

The choice of social infrastructure variables is peculiar due to its relevance as a source of cross-city variation in this vulnerable region. Concerning social infrastructure, while developed countries have eradicated dengue deaths; Brazil broke a negative record in 2015, with more than one million and 600 thousand cases, which means an increase of 180.9% over the previous year, according to the Ministry of Health.

In fact, England has improved and expanded its basic sanitation services in the 19th century, influencing other European countries. For instance, in US, more than 99% of population has access to "complete plumbing facilities" – hot and cold piped water, bathtub or shower, and flush toilet –, while in the Northeast region of Brazil, the lack of basic hygiene conditions remains an unsolved basic problem. Based on the Diagnosis of Water Services and Sewers, from the Ministry of Health's National Secretariat for Environmental Sanitation of the Cities, the average water consumption in the country in 2014 ranged from 118.9 l/inhabitant.day in the Northeast to 187.9 l/inhabitant.day in the Southeast. Considering the sample of 925 cities observed in this study, the average consumption from 2009 to 2015 is 107 liters per inhabitant per day, with 662 cities presenting average water consumption lower than 110 liters established by World Health Organization (WHO).

According to data from the National Household Sample Survey (PNAD) of IBGE, in terms of garbage collection, on average 90% of the Brazilian population has this service, while in the Northeast only 79% has. This is the same percentage of the Northeastern population with access to water supply. The sewage system in Brazil, represented by the households that count channeling wastewater and waste or draining via a septic tank connected to the network, reached a coverage of 43% in the Northeast region.[1]

According to IBGE, in 2015, considering 571 cities with GDP per capita above the 5000th position, 505 were in the Northeast region, and these cities with lower GDP per capita have in common the relevance of some economic activities, as public health. Given the absence of relevant disaggregated data available by city and on an annual basis, we have chosen to summarize health data through the FIRJAN Municipal Development Index in the area health.[2]

[1] We recognize the importance of analyzing the role of access to sanitary sewage services. However, considering the time period from 2009 to 2015, there was data for this variable for about 30% of the cities in our sample composed by 925 cities.

[2] FIRJAN indices are based on official public statistics. They range from 0 and 1, and a higher value means a better situation.

It takes into account the following variables: proportion of suitable prenatal care, deaths due to ill-defined causes, infant deaths due to preventable causes, and attention-sensitive hospitalization basic.

According to the Atlas of Violence, a survey of homicides reported by the Unified Health System in Brazil (SUS) in 2017, while there was a residual decrease (in the homicide rate) in the Southeast and Midwest regions, there was a certain stability of the index in the South region and marked growth in the North and Northeast in recent years. In 2017, all northeastern states reached the top of the ranking, and the homicide rate reached 48 deaths per 100 thousand inhabitants in this region. In a conservative calculation by the Institute of Applied Economic Research (IPEA), violence consumes 5.9% of Brazil's GDP per year.

Finally, in terms of the main business of our sample of cities, we try following the intuition used by Glaeser et al. (1992), when they propose a regional growth empirical exercise for US based on a cross-section of city-industries, because industry would be the main driver of economic growth. The question here is what are the main economic activities in the Northeast region, whose share in Brazil's GDP in 2015 is 14.2%, according to the IBGE? This answer may help us to define and summarize the business environment in this sample of cities, based on two insights.

First, according to IBGE, the gross added value at basic prices of economic activity groups in 2015 in Brazil is: agriculture (5.0%), industry (22.5%) and services (72.5%). This scenario is extreme in the Northeast, especially in cities in the countryside, where economic activity is essentially focused on trade, in addition to the provision of public services. This context has motivated us to propose using the number of commercial and industrial establishments per capita, reported by the Annual List of Social Information of the Min. of Economy (RAIS, Brazil).

Second, Marinho, Linhares and Campelo (2011) find for the period 2000 to 2008 that employment is an especially important determinant as a public policy to combat poverty, affecting more directly the poor with incomes closer to the poverty line, while cash income transfer programs does not seem to play a significant role to face poverty. Given the role played by employment and wages in the most vulnerable regions, we use the FIRJAN Municipal Development Index in the area employment and income, which is based on generation of formal employment, rate of formalization of labor market, income generation, real wage bill in the market formal work, Gini index of inequality income in formal work.

4 EMPIRICAL EXERCISE: CASE OF THE BRAZILIAN NORTHEAST REGION

4.1 Data

Brazil's Northeast region has 1794 cities in all. However, after defining the final version of the model, we found out that we had data available for 925 cities (52% of the total). Looking at states, Piauí is the state with the lowest relative representation (21% of the total cities), while 70% of Bahian cities entered the sample. In population terms in 2015 according to IBGE, there are almost 57 million inhabitants living in this region. More than 84% of this population are included in the sample used here.

Further details of our sample by state are reported in Table 2.

Table 2 - Sample information

	Number of cities			Estimated population (millions - 2015)		
State	Full	Sample	Sample (%)	Full	Sample	Sample (%)
Alagoas	102	57	56%	3.36	2.91	87%
Bahia	417	290	70%	15.27	13.77	90%
Ceará	184	117	64%	8.96	8.01	89%
Maranhão	217	118	54%	6.95	5.52	79%
Paraíba	223	75	34%	3.99	2.87	72%
Pernambuco	185	124	67%	9.41	8.19	87%
Piauí	224	47	21%	3.21	2.12	66%
Rio Grande do Nort	167	51	31%	3.47	2.33	67%
Sergipe	75	46	61%	2.26	1.91	84%
Total	**1794**	**925**	**52%**	**56.89**	**47.62**	**84%**

Source: IBGE (2015)

Considering the period of seven years between 2009 and 2015, we should have 6475 observations for each variable. However, we chose to estimate an unbalanced panel, as there are still unobserved values for some of the variables. Based on the endogenous variable, GDP per capita, the final sample has 6452 observations, (99.6% of the 6475 observations). All explanatory variables have 6452 observable values, with the exception of water supply and water consumption, which have 5.8% and 7.9% of unobservable values, respectively.

We report in Table 3 the summary statistics of the variables used here.

Our main purpose when analyzing basic descriptive statistics is to make it clear to those interested in this development literature how heterogeneous, and poorly assisted is the population of this region, in comparison with Brazil and developed countries. Northeastern

states are among the Brazilian states with the lowest GDP per capita. The average GDP per capita of R$ 10,430.37 is about 1/3 of the average GDP per capita in Brazil. We highlight that Brazil was the 76th country in the ranking of GDP per capita in 2015, according to the IMF. As worrying as the low average value is heterogeneity. The standard deviation reported in Table 3 is high and the range is characterized by a difference between R$ 3,300 and almost R$ 119,000. There is no northeastern city among the 25 Brazilian cities with the highest GDP per capita. The GDP per capita of these 25 richest cities ranges approximately from R$ 125,000 to R$ 513,000, in 2015. The GDP per capita of the 25 poorest cities in 2015 ranges from R$ 3,300 to almost R$ 4,700, all of which are from the Northeast, with one exception.

Regarding the financial drivers, we can see some intuitive but uncomfortable evidences reported in a recent applied literature on household credit in Brazil. Brazilian economists used to say: “there are two nations in the same territory”; this usually refers to income. However according to Matos et al. (2013), based on an application of the Phillips and Sul (2007) framework to Brazilian states, it is also possible to prove the existence of a discriminatory credit policy. These authors are able to illustrate the formation of two clubs strongly characterized by a regional bias with a representative presence of states located in the Northeast and North regions included in the second group. Moreover, according to Matos et al. (2015), poverty and unemployment play a significant role in household decisions to honor a financial commitment or not.

Matos and Correia (2017) propose a panel model to estimate relationships between real per capita Brazilian household credit and a set of relevant social, economic and financial variables. Their main findings based on cross-state data from 2004 to 2013 suggest that demand for credit plays a more relevant role than the supply thereof. Still according to this literature, it is worrying to see that in the Southeast or South of the country, there are approximately three times the number of bank branches per inhabitant, in relation to the value observed in our sample. There is also a disparity in the savings pattern between the regions in the country, and the evidence that the country's richest states have the savings per capita whose order is two to three times the savings in the northeastern states is robust.

Table 3 - Summary statistics

Variable	Mean	SD	Maximum	Minimum	Observ.
Endogenous					
Real GDP per capita (R$ 1000) using 2015 as base year	R$ 10.4	R$ 9.2	R$ 118.9	R$ 3.3	6,452
Financial system					
Number of bank branches of public or private banks (per 100 thousand inhabitants)	6.27	5.03	95.45	0.00	6,452
Loans and Discounted Securities in public or private banks (as a ratio of GDP)	1.05%	1.95%	41.19%	0.00%	6,452
Rural financing (agricultural or livestock) in public or private banks (as a ratio of GDP)	0.40%	1.82%	52.47%	0.00%	6,452
Real estate financing in public or private banks (as a ratio of GDP)	0.26%	1.03%	21.70%	0.00%	6,452
Savings deposits and term deposits in public or private banks (as a ratio of GDP)	1.58%	2.97%	72.26%	0.00%	6,452
Human capital					
Percentage of the formal workers with complete elementary education	34.41%	14.56%	93.22%	0.00%	6,452
Percentage of the formal workers with completed high school	49.37%	14.64%	98.63%	0.00%	6,452
Percentage of the formal workers with higher education	16.11%	10.65%	93.73%	0.00%	6,452
Social Infrastructure					
FIRJAN Municipal Development Index - Health	0.61	0.15	0.96	0.18	6,452
Population served by water supply (% of total population)	61.39%	23.60%	100.00%	0.00%	6,076
Average per capita water consumption (liter/ inhabitant.day)	107.07	50.56	1,083.50	0.20	5,939
Homicide rate (per 100 thousand inhabitants)	27.24	22.56	166.51	0.00	6,452
Incidence of dengue (per 100 thousand inhabitants)	298.62	669.68	10,712.86	0.00	6,452
Business environment					
FIRJAN Municipal Development Index - Employment and income	0.47	0.13	0.94	0.00	6,452
Number of commercial and industrial establishments (per thousand inhabitants)	6.66	5.21	72.85	0.20	6,452

Notes: 6,452 observations of 925 cities from the Northeastern region of Brazil (2009 - 2015). Source**:** author himself, 2021.

If, on the one hand, it is worrying to see that credit values for households and companies (per capita, or as a ratio of GDP) are lower in the region that most needs this growth driver, at least it is comforting to see that these numbers have upward trend. Comparing the years 2009 and 2015, loans and Discounted Securities in public or private banks (as a ratio of GDP) raised from 0.73% to 1.2%. Most importantly, the earmarked credit also increased from 2009 to 2015. Rural financing went from 0.41% to 0.51 % of GDP, while real estate loans went from 0.08% to 0.51% of GDP. The average values of 0.4% and 0.26%, respectively, are still lower than the values of the rest of the country and the range of both variables shows extreme values.

Regarding the education of formal workers, the average values are compatible with that observed in Brazil. It is important to note that the percentage of workers with elementary school went from 40% to almost 30%, while the workers with completed high school went from 47% to 51% and the ratio with higher education went from 13% to almost 20%, from 2009 to 2015. It is worrying realizing that in 2015, there are still cities, such as Apim-Açu and Bacuri, in Maranhão, with less than 1% of formal workers with complete higher education.

Regarding the social infrastructure, based on the Diagnosis of Water Services and Sewers, the average water consumption from 2009 to 2015 is 107 liters per inhabitant per day, with 662 cities presenting average water consumption lower than the established by WHO (110 liters), and some of them with almost null consumption of water. The percentage of population with access to water supply was 61%, lower than the average of Brazil.

Values on violence and dengue cases are high and heterogeneous, when compared to the rest of Brazil.

Possibly, the unique good news concerning social infrastructure is that our sample from the Northeast has a reasonable average value for the FIRJAN health index, which is based on suitable prenatal care, deaths due to ill-defined causes, infant deaths due to preventable causes, and attention-sensitive basic hospitalization.

Concerning business environment, since the services account for more than 73% of the region's total GDP, we believe it is a relevant information see that the number of commercial and industrial establishments (per thousand inhabitants) has raised from 5.5 (2009) to 7.5 (2015). On the other hand, we need to measure the role played by the reduction of FIRJAN employment index over time, from 0.51 to 0.38.

In the Table 4 we report the correlations between endogenous and exogenous variables.

Table 4 - Raw correlation

	RGDP_PER	BANK_BRA	LOAN_GDP	RURA_GDP	REST_GDP	SAVI_GDP	ELEM_EDU	HIGH_SCH	SECO_EDU	ESTAB_PC	EMPLO_IN	HOMICIDE	DENGUE	HEALTH_IN	WATER	WAT_CONS
RGDP_PER		-0.058	-0.068	-0.040	0.019	-0.057	0.135	-0.051	-0.108	0.478	0.455	0.249	0.022	0.239	0.240	0.106
BANK_BRA	-0.058		0.392	0.389	0.193	0.266	-0.016	-0.006	0.032	-0.062	-0.189	-0.178	0.019	-0.064	-0.001	-0.042
LOAN_GDP	-0.068	0.392		0.637	0.825	0.818	-0.073	0.060	0.023	0.036	-0.039	-0.007	0.030	0.020	0.074	0.018
RURA_GDP	-0.040	0.389	0.637		0.353	0.364	-0.018	0.025	-0.007	-0.018	-0.051	-0.057	0.012	-0.045	0.002	0.002
REST_GDP	0.019	0.193	0.825	0.353		0.828	-0.037	0.036	0.005	0.116	0.020	0.081	0.036	0.101	0.103	0.038
SAVI_GDP	-0.057	0.266	0.818	0.364	0.828		-0.056	0.055	0.005	0.067	-0.016	-0.014	0.052	0.021	0.094	0.010
ELEM_EDU	0.135	-0.016	-0.073	-0.018	-0.037	-0.056		-0.717	-0.358	0.125	0.243	0.151	-0.014	0.001	0.066	-0.063
HIGH_SCH	-0.051	-0.006	0.060	0.025	0.036	0.055	-0.717		-0.360	0.022	-0.101	-0.102	0.014	-0.134	0.026	0.048
SECO_EDU	-0.108	0.032	0.023	-0.007	0.005	0.005	-0.358	-0.360		-0.189	-0.189	-0.058	0.003	0.192	-0.124	0.021
ESTAB_PC	0.478	-0.062	0.036	-0.018	0.116	0.067	0.125	0.022	-0.189		0.519	0.300	0.125	0.228	0.515	0.124
EMPLO_IN	0.455	-0.189	-0.039	-0.051	0.020	-0.016	0.243	-0.101	-0.189	0.519		0.277	0.005	0.189	0.309	0.107
HOMICIDE	0.249	-0.178	-0.007	-0.057	0.081	-0.014	0.151	-0.102	-0.058	0.300	0.277		0.051	0.253	0.256	0.013
DENGUE	0.022	0.019	0.030	0.012	0.036	0.052	-0.014	0.014	0.003	0.125	0.005	0.051		0.057	0.122	-0.024
HEALTH_IN	0.239	-0.064	0.020	-0.045	0.101	0.021	0.001	-0.134		0.228	0.189	0.253	0.057		0.132	0.048
WATER	0.240	-0.001	0.074	0.002	0.103	0.094	0.066	0.026	-0.124	0.515	0.309	0.256	0.122	0.132		-0.002
WAT_CONS	0.106	-0.042	0.018	0.002	0.038	0.010	-0.063	0.048	0.021	0.124	0.107	0.013	-0.024	0.048	-0.002	

Notes: 6,452 observations of 925 cities from the Northeastern region of Brazil (2009 - 2015). Source**:** author himself, 2021.

The correlation matrix in Table 4 points to some obvious and some less obvious results. It is intuitive finding a strong linear relationship between GDP per capita and the business environment indicators, which characterize the essence of the relevant service sector in the Northeast. A positive linear relationship between the health indicator and the water consumption indicators would also be expected.

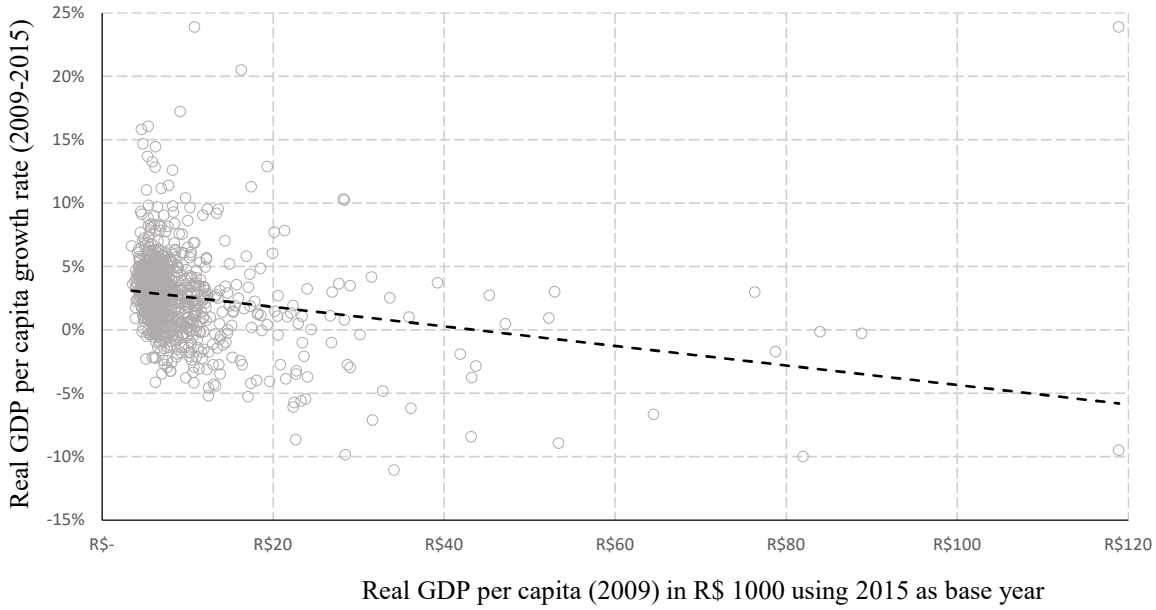
However, this matrix also shows that northeastern cities with higher real GDP per capita tend to have a smaller financial system, except for the positive, but almost no correlation with real estate financing. It also does not seem so obvious that cities with higher GDP have a positive correlation only with the percentage of formal workers with elementary education. Likewise, it is puzzling to see a positive (albeit low) correlation between dengue cases and GDP per capita, and even more to see a 0.249 correlation between homicides and GDP. Obviously, more important than this first analysis is to observe the relation between GDP growth and GDP in the first year of the sample, and mainly the results in the estimation of the proposed model.

4.2 Preliminary analysis: convergence hypothesis

According to the extensive theoretical literature on the neoclassical model, the convergence property derives from the diminishing returns to capital. In a didactic way, economies that have less capital per worker (relative to their long run capital per worker) tend to have higher rates of return and higher growth rates. In this context, we perform a useful, but preliminary and unconditional empirical exercise, based on the scatter plotted in Figure 3. We find that based on data from 918 cities from the Northeastern region of Brazil, there seems to be a negative linear relation between the real GDP per capita growth rate from 2009 to 2015 (per year) and the start point, i.e., the real GDP per capita in 2009. Although, we do not find this result using an estimation, this is a comfortable and expected evidence, since it corroborates the stylized fact reported in this literature about the convergence.

Moreover, we know that the convergence is conditional because the steady state levels of capital and output per worker depend in the neoclassical model on an array of choice and environmental variables. Therefore, in the next subsection, we report and analyze our main results, based on the estimation of the unbalanced dynamic panel regression described in (3).

Figure 3 - Scatter based on data from 918 cities from the Northeastern region of Brazil



Source**:** author himself, 2021.

4.3 Main Results

The Table 5 presents the results of the estimation of our dynamic unbalanced panel described by the model (3), based on a sample covering 925 cities over the period from 2009 to 2015. In this kind of panel setting, weak exogeneity implies that current values of the regressors are uncorrelated with future realizations of the shocks to growth. Blundell and Bond (1998) have argued that lagged levels may be only weak instruments for the equation in first-differences with persistent series such as GDP. In order to solve this problem, Bond et al. (2001) proposed, in the context of growth models, the use of the system-GMM estimator introduced by Arellano and Bover (1995). Another common issue in this empirical literature is that the number of countries or states is limited, and the cross-section dimension in growth data sets is not very large so that finite sample performance of fixed T and large N consistent estimators such as first-differenced GMM can be worrying. In this exercise, we do not have to worry about it, since we have a sample with of fixed $T = 7$ and large $N = 925$.

In the first column, we report our main results based on the full sample, while in the second column we report the results considering only cities with real GDP per capita lower than the median, and in the last column, the cities with real GDP per capita higher than the median.

Table 5 - Dynamic unbalanced panel GMM estimation: Augmented Solow model with additional sources of cross-city variation

	Full sample	Subsample - GDP per capita	
		< median	> median
	(1)	(2)	(3)
Lagged endogenous			
Real GDP per capita (R$ 2015) in log	0.409 **	0.256 *	0.788 ***
	[0.043]	[0.091]	[0.000]
Financial system			
Number of bank branches of public or private banks (per 100 thousand inhabitants)	-0.002	0.002	$2x10^{-4}$
	[0.916]	[0.900]	[0.91690
Loans and Discounted Securities in public or private banks (as a ratio of GDP)	-22.171	16.114	-12.020
	[0.444]	[0.290]	[0.527]
Rural financing (agricultural or livestock) in public or private banks (as a ratio of GDP)	53.402 **	33.876 **	37.545 *
	[0.045]	[0.026]	[0.073]
Real estate financing in public or private banks (as a ratio of GDP)	54.170 **	3.351	9.097
	[0.047]	[0.856]	[0.479]
Savings deposits and term deposits in public or private banks (as a ratio of GDP)	-3.785	-8.236	-5.851
	[0.780]	[0.499]	[0.392]
Human capital			
Percentage of the formal workers with complete elementary education	4.490 ***	6.100 ***	1.308
	[0.005]	[0.000]	[0.295]
Percentage of the formal workers with completed high school	4.143 ***	5.821 ***	1.084
	[0.007]	[0000]	[0.437]
Percentage of the formal workers with higher education	3.910 ***	5.718 ***	0.780
	[0.010]	[0000]	[0.577]
Social Infrastructure			
FIRJAN Municipal Development Index - Health	0.536 *	0.349	0.663 **
	[0.061]	[0.118]	[0.021]
Population served by water supply (% of total population)	0.008	-0.148	0.205 *
	[0.962]	[0.576]	[0.074]
Average per capita water consumption (liter / inhabitant.day) (1st diff.)	0.003	0.002	$-7x10^{-4}$
	[0.189]	[0.182]	[0.661]
Homicide rate (per 100 thousand inhabitants) (1st diff.)	-0.002	-0.004	0.004 *
	[0.613]	[0.172]	[0.079]
Incidence of dengue (per 100 thousand inhabitants) (1st diff.)	$1x10^{-5}$	$9x10^{-6}$ *	$6x10^{-6}$
	[0.109]	[0.083]	[0.478]
Business environment			
FIRJAN Municipal Development Index - Employment and income	1.691 ***	0.629 *	0.707
	[0.004]	[0.090]	[0.117]
Number of commercial and industrial establishments (per thousand inhabitants) (1st diff.)	0.009	0.068	$2x10^{-4}$
	[0.838]	[0.164]	[0.995]

Notes: [a] Analysis based on a large unbalanced panel-data set including: 6,452 observations of 925 cities from the Northeastern region of Brazil during the period from 2009 to 2015. [b] Instruments set: lag of *EMPLO_IN, ESTAB_PC, HEALTH_IN, WATER, WAT_CONS, HOMICIDE, RGDP_PER (ln), ELEM_EDU, HIGH_SCH, SECO_EDU, DENGUE*. [c] Respective p-values are reported in the brackets.*** p<0.01, ** p<0.05, * p<0.1. Source**:** author himself, 2021.

The coefficient on lagged real GDP per capita in log has expected sign and significant effects, in all three exercises, indicating an evidence of a faster convergence for the subsample composed of cities with lower values of GDP, while this convergence is slower when we consider only cities with higher GDP values.

We will begin the discussion of the results by the two groups of growth drivers, which are more classic in this literature. Regarding the financial system, as an inducer of growth, we find a significant and positive role played only by the earmarked credit (which are long-term and have lower interest rates). Both rural and real estate financing seem to be able to boost growth, with slightly higher elasticity of the real estate financing. In the subsample exercises, only rural credit appears as significant, with the lower of elasticity. The column 1 regression confirms the previous and very robust finding of a positive and significant relationship between human capital of formal workers and GDP per capita. The parameter values have a similar order of magnitude, with a greater impact on the fundamental level of education. This evidence is corroborated only for the sub-sample with the lowest GDP per capita, with even greater elasticities.

Due to the unprecedented nature of this study, it is difficult, but will try to make a parallel with some previous results. Comparing with Matos and dos Santos (2020), Brazilian states seem to converge at a faster rate than cities in the Northeast. Corroborating our findings in some sense, they find that both household and enterprise credit to GDP enter consistently with a positive coefficient, while Silva, Tabak and Laiz (2021) find that non-earmarked credit to the corporate sector is associated with municipal economic growth more strongly than earmarked credit. Unlike our results, Matos and dos Santos (2020) find no relationship between years of schooling and growth. Still on the impact of human capital, our finding on the relevance of this growth driver for cities in the Northeast from 2009 to 2015 corroborates the evidence reported in Nogueira and Arraes (2018).

Regarding the social infrastructure, only FIRJAN health index proved to be significant in the complete sample and for the sub-sample with the richest cities. Even though our main conclusions are based on the results in column 1, it is important to highlight the role of basic sanitation, more specifically, of the portion of the population served with water in northeastern cities with GDP above the median. Corroborating the previous finding reported by Marinho, Linhares and Campelo (2011), we find a positive and significant role played by the labor market, through the FIRJAN Municipal Development Index in the area employment and income. This finding seems to be robust considering the cities with lower values of GDP in the region.

Table 6 - Tests and information from the data in table 5

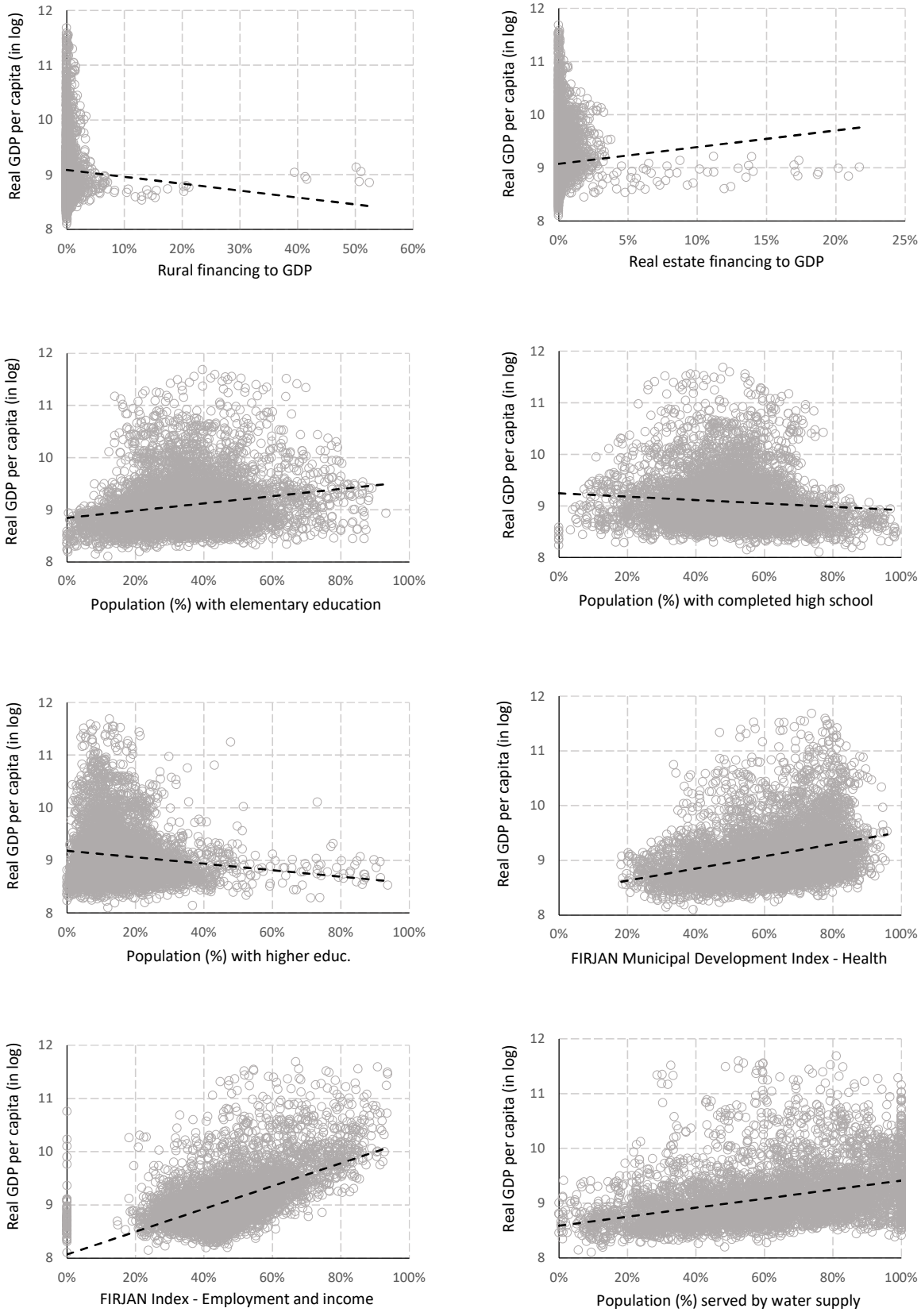
	Full sample	Subsample - GDP per capita	
		< median	> median
	(1)	(2)	(3)
Tests and information			
Arellano-Bond test for AR(1) in first differences	[0.570]	[0.169]	[0.003]
Arellano-Bond test for AR(2) in first differences	[0.310]	[0.888]	[0.143]
Sargan test of overidentified restrictions	[0.076]	[0.331]	[0.198]
Hansen test of overidentified restrictions	[0.941]	[0.955]	[0.711]
Difference-in-Hansen test of exogeneity of instruments: excluding group	[0.826]	[0.804]	[0.663]
Difference-in-Hansen test of exogeneity of instruments: difference	[0.854]	[0.912]	[0.562]
Observations	4110	1854	2256
N. of cities	880	471	565

Notes: [a] We have used system-GMM estimator introduced by Arellano and Bover (1995). [b] Respective p-values are reported in the brackets.*** p<0.01, ** p<0.05, * p<0.1. Source**:** author himself, 2021.

As complementary results, we also report in Table 6 the results for Sargan–Hansen test for the overall validity of the instruments by analyzing the sample of the moment conditions used in the estimation process. We fail to reject the null hypothesis that such restrictions are valid for all three estimations. Moreover, following Arellano and Bond's (1991) test we fail to reject the null hypotheses of no autocorrelation of the error term for autoregressive process in the models, except for the AR(1) term using cities with high GDP. We also fail to reject the null hypothesis of both tests performed on exogeneity instruments in all estimations.

Aiming to add to the debate on the unconditional impact of the explanatory variables, whose elasticities were significant, we plot in Figure 4 the scatter between each of them and the real GDP per capita in log.

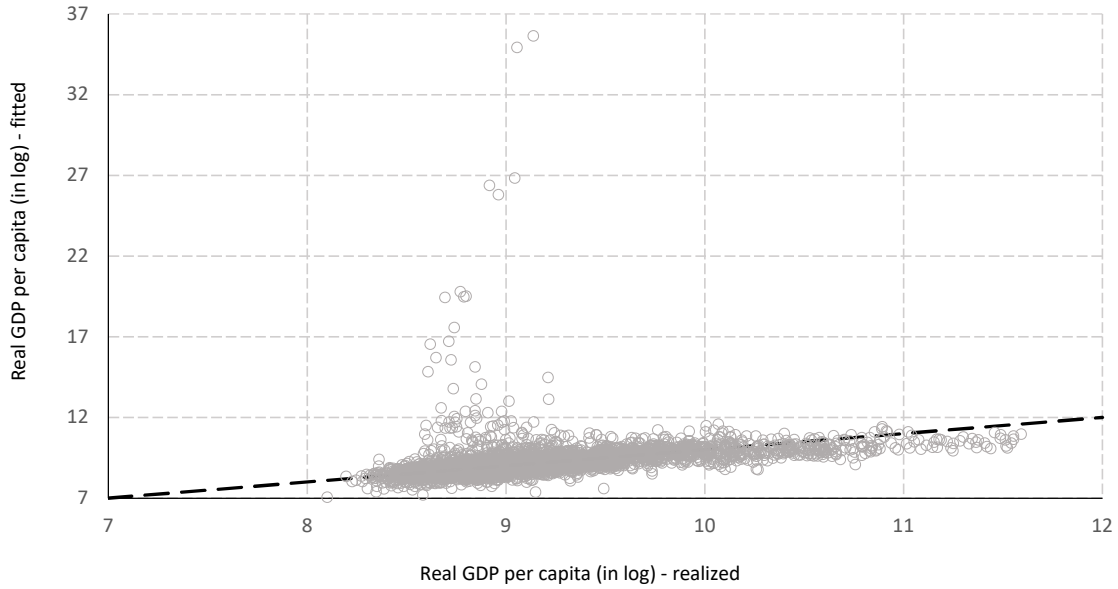
Figure 4 - Scatter based on 6,452 observations of 925 cities from the Northeastern region of Brazil (2009–2015)



Source**:** author himself, 2021.

Finally, we plot in the Figure 5 a scatter between realized and fitted values of real GDP per capita in log. This kind of result is very important, since it is able to summarize our main findings, suggesting that our empirical exercise provides a very good overall fitting performance, with less than 1% of the observations located very far from the 45º line, along which the cloud with the absolute majority of the observations clusters.

Figure 5 - Scatter based on data from 918 cities from the Northeastern region of Brazil



Source**:** author himself, 2021.

5 EMPIRICAL EXERCISE: CASE FOR THE NINE NORTHEASTERN STATES

5.1 Descriptive statistics for each of the nine states northeastern Brazilian

With the aim of observing the individual characteristics, we present in table 7 the descriptive statistics of the growth variables for each of the nine states that make up the Brazilian northeast within the period from 2009 to 2015.

When analyzing the results of GDP per capita, it is possible to see that all states have an average lower than the average for Brazil, which is natural to expect from less developed economies. The states that came closest to the national average were Sergipe and Rio Grande do Norte, with an average of R$17550.30 and R$12869.44, respectively. However, these same states have a high standard deviation, being R$16852.76 and R$7424.08, respectively.

Regarding financial drivers, the state that has the largest number of bank branches is Paraíba with approximately 8 branches per 100 thousand inhabitants, followed by Bahia, Sergipe and Piauí with approximately 7 branches and Rio Grande do Norte with approximately 6 branches, for 100 thousand inhabitants. The variable loans and discounted securities was higher for the state of Paraíba with values above 2%, followed by Piauí and Rio Grande do Norte with values slightly above 1%, all the other six states had average values of 1%. The standard deviation of this variable was higher for the state of Paraíba with approximately 5%. All other states had a standard deviation of less than 2%. In relation to rural and real estate financing variables, all variables presented an average lower than 1%. The standard deviation of these variables was also less than 1% for all states, with the exception of the state of Paraíba, which showed a standard deviation of approximately 5% for the rural financing variable and 3% for the real estate financing variable. The state that presented the highest percentage of savings was the state of Paraíba with an average above 3%, its standard deviation was also the highest with 8.55%. Already the state with the lowest savings was Maranhão, with an average and standard deviation of less than 1%.

Concerning the group of human capital variables, the elementary education variable presented average values between 32% and 42%, approximately for all states. The only exception was the states of Alagoas and Maranhão with the highest and lowest average observed, being 48% and 25%, respectively. All states showed dispersion above 10%. In relation to secondary education, the average values were between 41% and 51%, for six of the nine states, with dispersion between 10 and 15%. With the exception of the states of Maranhão and Bahia,

with an average of 58 and 53 percent and a standard deviation of approximately 17 and 12 percent, and the state of Alagoas, which showed the lowest average of 38% with a dispersion of 14%. In relation to higher education, the averages are around 11 and 21 percent with a standard deviation between 8 and 13 percent, approximately.

With respect to the group of social infrastructure variables, the average of the FIRJAN index variable was above 0.5 and below 0.8, with a dispersion between 10% and 15%, for all states. The variable that shows the percentage of the population with water supply service presented averages above 50% for most states, the exception was for the state of Maranhão, which only has 41% of the population with this availability. The standard deviation of this variable is between 17% and 20%, approximately, for all states. Regarding the average water consumption per liter, the states Ceará, Maranhão, Paraíba, Piauí and Rio Grande do Norte showed an average consumption of more than 100 liters per inhabitant, with Maranhão being the state that leads the largest consumption of water, with 136 liters per inhabitant. The other states had consumption below 100 liters per inhabitant, with Pernambuco being the state that consumes the least, being just 89 liters per inhabitant. With reference to the rate of violence, the state with the highest rate is Alagoas with 51 homicides per 100,000 inhabitants, followed by Sergipe with 35 and Pernambuco with 33 homicides per 100,000 inhabitants. The state of Piauí proved to be the state with the lowest rate of violence, with 11 homicides for every 100,000 inhabitants. Regarding the incidence of dengue, the results are frightening when we look at the states of Alagoas and Rio Grande do Norte with more than 428 incidences of dengue cases per 100 thousand inhabitants, followed by Bahia, Ceará and Pernambuco with more than 318 cases per 100 thousand inhabitants. The other states showed averages slightly below 164 cases per 100,000 inhabitants. In all states the dispersion was very high, especially for Alagoas.

Concerning the group of business environment variables, the Firjan index showed averages between 0.41 and 0.51, with low dispersion. As for the variable number of commercial and industrial establishments, the states of Bahia and Rio Grande do Norte are highlighted for having an average above 8 establishments per thousand inhabitants. The state with the lowest average is Maranhão with approximately 3 establishments per thousand inhabitants. The other states had averages between 5 and 7 establishments per thousand inhabitants.

Therefore, as can be seen, all indicators in all states showed high dispersion, these characteristics show the how heterogeneous the northeastern Brazilian states are. In addition, the average values show us how precarious are the indicators of an underdeveloped region that needs more attention from public policy makers to offer a better quality of life to the population.

Table 7 - Descriptive statistics of the growth model variables for each of the nine Brazilian northeast states in the period (2009 - 2015)

	Alagoas	Bahia	Ceará	Maranhão	Paraíba	Pernambuco	Piauí	Rio Grande do Norte	Sergipe
Lagged endogenous									
Real GDP per capita (R$ 2015) in log	9454.62 [4693.40]	10514.53 [9542.52]	9323.13 [5854.32]	8223.49 [9116.72]	9651.07 [5354.81]	10961.03 [9959.58]	9604.11 [7297.92]	12869.44 [7424.08]	17550.3 [16852.76]
Financial system									
Number of bank branches of public or private banks (per 100000 inhabitants)	5.17 [2.95]	6.92 [4.34]	5.22 [4.36]	5.31 [3.37]	8.19 [9.08]	5.06 [4.50]	7.08 [6.21]	6.47 [3.49]	7.79 [6.14]
Loans and Discounted Securities in public or private banks (as a ratio of GDP)	0.88% [0.92%]	0.90% [1.65%]	0.84% [0.53%]	0.80% [0.77%]	2.16% [5.27%]	0.98% [1.46%]	1.59% [0.89%]	1.38% [0.96%]	0.74% [0.54%]
Rural financing (agricultural or livestock) in public or private banks (as a ratio of GDP)	0.29% [0.51%]	0.45% [1.10%]	0.20% [0.49%]	0.32% [0.52%]	0.95% [5.44%]	0.20% [0.45%]	0.92% [2.75%]	0.22% [0.28%]	0.22% [0.28%]
Real estate financing in public or private banks (as a ratio of GDP)	0.27% [0.52%]	0.18% [0.68%]	0.15% [0.29%]	0.12% [0.46%]	0.88% [2.86]	0.22% [0.96%]	0.25% [0.41%]	0.33% [0.64%]	0.29% [0.58%]
Savings deposits and term deposits in public or private banks (as a ratio of GDP)	1.09% [1.11%]	1.8% [2.39%]	1.25% [0.82%]	0.95% [0.91%]	3.42% [8.55%]	1.35% [1.59%]	1.7% [1%]	1.23% [1.10%]	1.14% [0.91%]
Human capital									
Percentage of the formal workers with complete elementary education	48.04% [17.41%]	34.22% [12.20%]	33.12% [11.44%]	24.92% [14.74%]	34.19% [16.32%]	36,12% [13.87%]	36.15% [13.64%]	32.31% [12.05%]	42.49% [14.49%]
Percentage of the formal workers with completed high school	38.20% [14.15%]	53.71% [11.86%]	45.69% [11.82%]	58.13% [17.59%]	46.90% [16.54%]	45.77% [13.41%]	43.69% [12.62%]	50.45% [10.69%]	41.12% [12.55%]
Percentage of the formal workers with higher education	13.75% [9.62%]	12.06% [8.27%]	21.19% [11.74%]	16.09% [13.03%]	18.90% [8.95%]	18.09% [10.59%]	20.15% [9.44%]	17.24% [8.17%]	16.39% [11.66%]
Social Infrastructure									
FIRJAN Municipal Development Index - Health	0.59 [0.12]	0.51 [0.14]	0.75 [0.09]	0.52 [0.11]	0.67 [0 .12]	0.69 [0.13]	0.59 [0.11]	0.69 [0.10]	0.70 [0.10]
Population served by water supply (% of total population)	59% [23,95%]	68.16% [21.72%]	50.99% [21.10%]	41.02% [26.69%]	63.32% [20.78%]	63.57% [19.59%]	58.57% [17.67%]	69.61% [20.34%]	76.53% [17.66%]
Average per capita water consumption (liter/inhabitant.day) (1st diff.)	99.07 [43.06]	99.99 [30.33]	123,14 [46.57]	136.08 [76.14]	109.69 [39.17]	89.80 [30.30]	108.96 [21.06]	107.12 [53.19]	98.79 [19.02]
Homicide rate (per 100 thousand inhabitants) (1st diff.)	50.78 [26.73]	24.79 [23.14]	28.59 [21.04]	18.05 [15.57]	25.45 [19.84]	33.53 [18.26]	11.22 [9.69]	27.61 [24.20]	35.48 [23.44]
Incidence of dengue (per 1thousand inhabitants)(1st diff.)	444.56 [961.45]	358.79 [738.06]	352.33 [608.17]	69.92 [136.94]	287.65 [639.11]	317.54 [812.63]	164.30 [244.48]	428.2 [656.96]	147.20 [472.04]
Business environment									
FIRJAN Municipal Development Index - Employment and income	0.48 [0.14]	0.49 [0.12]	0.48 [0.13]	0 .41 [0.15]	0.46 [0 .12]	0.49 [0.13]	0.45 [0.12]	0 .49 [0.11]	0 .51 [0.11]
Number of commercial and industrial establishments(per 1000 inhabitants)(1st diff.)	5.37 [3.17]	8.04 [5.30]	5.27 [3.81]	3.55 [3.28]	6.01 [4.24]	7.20 [7.04]	6.90 [4.4]	9.18 [6.26]	7.60 [3.53]

Note: The table shows mean and standard deviation values, [S-D]. Source**:** author himself, 2021.

5.2 Results analysis for each of the nine states northeastern brazilian

Following the advice of Glaeser, Sheinkman and Schleifer (1995) who believe that cities are the main economic center capable of influencing the macro economy (owing to their ability to organize themselves in a specialized and more efficient way), this work sought to deepen the investigation on the growth variables analyzing the 9 northeast states individually. In other words, the behavior of economic variables among the cities of each northeastern state will be examined. The purpose of this is to respond to possible criticisms related to the existence of a common convergence pattern between very heterogeneous cities.

The results found in this empirical exercise are shown in table 8, which indicates the estimated coefficients and their respective test statistics for each variable under study in the period from 2009 to 2015. The calculation was developed for each of the nine states in northeastern Brazil, evaluating the elements of growth among municipalities in their respective state.

The coefficient on lagged real GDP per capita has an expected sign and significant effects in all nine states. The information obtained indicates a slow convergence of the GDP, in all cases. The states Pernambuco, Rio Grande do Norte and Sergipe, which present values above 1 (one), indicating that there is no convergence, while the state of Paraíba has a convergence of approximately 0.1. The states of Bahia, Ceará and Piauí have a convergence between 0.14 and 0.15, approximately, while Alagoas and Maranhão converge between 0.24 and 0.38, approximately. These results differ from previous studies, and may indicate that the northeast states may be dedicating themselves to investing in sectors that have little influence on the local economy.

Regarding the influence of the financial system on the growth of municipalities in each state, there was a significant role played only by the number of bank branches in the state of Alagoas, by real estate financing in the state of Pernambuco and by savings in the state of Maranhão. These variables were able to influence the growth of cities with a significance between 5 and 10 percent. Despite being significant, these results made us a little concerned about the sign of the coefficients that indicate that greater investments in increasing bank branches, real estate credit and savings can negatively influence GDP. However, this characteristic directs us to the warning that despite influencing GDP, these variables should be viewed with caution by the administrator of public policies. The latter must care, first of all, in applying its efforts to basic variables such as human capital, for example, due to the precarious situation of underdeveloped states.

With regard to human capital, was not found relationship between years of study and growth in 6 of the 9 states analyzed, thus corroborating, with the research by Matos and dos Santos (2020). Only the states of Ceará and Paraíba were positive and significant at 10% for basic (elementary) education, while the states of Alagoas and Ceará were positive and significant for secondary education. The state of Ceará stands out due to the efforts in its educational policies that range from early childhood to high school. The education model followed in Ceará had its first laboratory in the city of Sobral under the management of Cid Gomes in the 90's. After a few years it was possible to notice the efficiency of these policies whose results were so encouraging that the state government decided to implement in other municipal units. The success was such that it led Brazil to look at Ceará as a model state in education, giving it the title of state of the federation that most evolved in the early years of elementary school between 2005 and 2015 and continues to this day. There has also been evolution towards final education and other states have sought to follow this policy. Including, the 2020 constitutional amendment 108, which provides for changes to the Basic Education Financing Fund (Fundeb), requires that state administrations approve norms that coincide with those already practiced in Ceará.

Regarding the social infrastructure group, there was no statistical significance in the variables despite the lack of social indicators in the states.

Regarding the last group called business ambience, we obtained positive and significant coefficients for the FIRJAN index with significance at 10 and 5 percent for the states of Alagoas and Maranhão, respectively. This variable was not significant for other states. Already the variable that presents the number of commercial and industrial establishments per municipality (per 100 thousand inhabitants) was only positive and significant for the state of Ceará at the level of 1 percent. According to Marinho, Linhares and Campelo (2011), employment is the more important determinant of growth, empirically, than aid monetary from social programs. The authors found that between the period of 2000 to 2008, employment was the most efficient public policy in the fight against poverty, especially when referring to the next ones of the poverty line, while income transfer did not play such a significant role. This argument appears to go against the results presented in this thesis. However, we corroborate exactly with the authors' thinking, because the lack of significance of the variations can exactly come from the lack of educational qualification, that is, the level of human capital found in the northeast regions, so that it is no use increasing the number of jobs available if there are no qualified people for the intended office.

Table 8 - Dynamic unbalanced panel GMM estimation: Augmented Solow model with additional sources of cross-city variation for each of the nine states northeastern Brazilian

	Alagoas	Bahia	Ceará	Maranhão	Paraíba	Pernambuco	Piauí	Rio Grande do Norte	Sergipe
Lagged endogenous									
Real GDP per capita (R$ 2015) in log	0.620***	0.864***	0.845***	0.764***	0.916***	1.025***	0.863***	1.035***	1.023***
	[0.008]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Financial system									
Number of bank branches of public or private banks (per 100000 inhabitants)	-0.042**	-0.003	0.005	0.003	-0.001	-0.012	-0.008	0.005	0.008
	[0.059]	[0.898]	[0.735]	[0.735]	[0.869]	[0.229]	[0.503]	[0.670]	[0.768]
Loans and Discounted Securities in public or private banks (as a ratio of GDP)	-7.603	11.930	10.462	9.525	-1.908	22.212	9.945	-7.383	-3.062
	[0.676]	[0.677]	[0.733]	[0.624]	[0.764]	[0.136]	[0.509]	[0.632]	[0.950]
Rural financing (agricultural or livestock) in public or private banks (as a ratio of GDP)	2.878	10.579	-1.937	-5.492	1.893	-15.328	4.939	8.124	-10.527
	[0.861]	[0.502]	[0.914]	[0.813]	[0.661]	[0.182]	[0.531]	[0.861]	[0.749]
Real estate financing in public or private banks (as a ratio of GDP)	6.925	-4.550	24.396	25.124	1.923	-41.514**	-28.791	-17.931	-2.255
	[0.595]	[0.881]	[0.245]	[0.232]	[0.724]	[0.087]	[0.433]	[0.127]	[0.883]
Savings deposits and term deposits in public or private banks (as a ratio of GDP)	4.042	-11.103	5.486	-29.904**	0.267	20.282	3.122	16.996	-6.807
	[0.570]	[0.489]	[0.673]	[0.016]	[0.740]	[0.329]	[0.758]	[0.331]	[0.775]
Human capital									
Percentage of the formal workers with complete elementary education	3.220	1.097	2.555*	1.974*	0.643	-0.505	0.978	-0.159	-1.401
	[0.127]	[0.554]	[0.084]	[0.090]	[0.424]	[0.720]	[0.628]	[0.908]	[0.569]
Percentage of the formal workers with completed high school	3.580*	0.970	2.880*	1.539	0.514	-0.674	1.149	-0.534	-0.301
	[0.075]	[0.597]	[0.076]	[0.158]	[0.513]	[0.666]	[0.609]	[0.707]	[0.875]
Percentage of the formal workers with higher education	3.055	0.815	2.628	1.430	0.584	-0.731	1.055	-0.418	-1.485
	[0.121]	[0.623]	[0.109]	[0.184]	[0.468]	[0.608]	[0.618]	[0.774]	[0.544]
Social Infrastructure									
FIRJAN Municipal Development Index - Health	0.124	0.412	-1.672	0.747	0.147	0.397	-0.317	0.031	0.621
	[0.757]	[0.396]	[0.148]	[0.133]	[0.347]	[0.248]	[0.704]	[0.935]	[0.285]
Population served by water supply (% of total population)	-0.156	0.074	-0.206	0.032	0.053	-0.294	0.344	-0.213	0.125
	[0.411]	[0.688]	[0.310]	[0.774]	[0.375]	[0.243]	[0.492]	[0.457]	[0.808]
Average per capita water consumption (liter/inhabitant.day) (1st diff.)	0.0003	0.001	-0.002	-0.0002	0.0004	0.001	-0.003	0.00004	0.0001
	[0.743]	[0.687]	[0.292]	[0.783]	[0.223]	[0.423]	[0.536]	[0.955]	[0.975]
Homicide rate (per 100 thousand inhabitants) (1st diff.)	0.002	-0.001	0.002	0.002	0.0005	0.002	0.003	0.00008	0.0002
	[0.225]	[0.587]	[0.331]	[0.179]	[0.600]	[0.271]	[0.103]	[0.926]	[0.889]
Incidence of dengue (per 1thousand inhabitants)(1st diff.)	0.00001	-2.39e-06	0.00001	-0.00004	8.14e-07	6.94e-06	0.00004	9.48e-06	-0.00003
	[0.233]	[0.742]	[0.512]	[0.315]	[0.935]	[0.649]	[0.261]	[0.459]	[0.323]
Business environment									
FIRJAN Municipal Development Index - Employment and income	0.754*	0.147	-0.589	0.548**	0.166	-0.034	0.023	0.216	0.515
	[0.061]	[0.716]	[0.250]	[0.039]	[0.424]	[0.899]	[0.935]	[0.572]	[0.343]
Number of commercial and industrial establishments(per 1000 inhabitants)(1st diff.)	65.384	11.063	376.346***	106.403	1.040	26.711	84.152	32.283	10.715
	[0.409]	[0.714]	[0.002]	[0.103]	[0.944]	[0.428]	[0.162]	[0.242]	[0.865]

Notes:[a]Instruments set: lag of *EMPLO IN, ESTAB PC, HEALTH IN, WATER, WAT CONS, HOMICIDE, RGDP PER (ln), ELEM EDU, HIGH SCH, SECO EDU, DENGUE*.
[c] Respective p-values are reported in the brackets.*** p<0.01, ** p<0.05, * p<0.1. Source**:** author himself, 2021.

As complementary results, we report in Table 9 the results of the sargan-hansen test for the general validity of the instruments, analyzing the sample of the conditions of the moments used in the estimation process. We do not reject the null hypothesis that such restritions are valid for the estimates in 8 of the 9 states. The exception is in the state of Paraíba that doesn't qualify according to the null hypothesis, however the Hansen test is robust to heteroscedasticity and we respect the restriction of the number of instruments to be smaller than the individual units. Furthermore, we apply the Arellano and Bond test (1991), and we do not reject the null hypothesis that there is no automatic correction of the error term for the autoregressive process in the models, except for AR (1) using the cities of the states of Alagoas, Bahia, Ceará, Maranhão, Paraíba, Piauí, Rio Grande do Norte and Sergipe. Despite the suspicion that there are first-order autocorrelation problems, there is no problem in that, as the estimation method used in this thesis corrects this problem. What cannot exist is second-order autocorrelation and, in our results, we do not reject the null hypothesis for an AR(2), thus pointing to the absence of second-order autocorrelation. We also do not reject the null hypothesis of both tests performed on exogeneity instruments in all estimates.

In short, we can compare the results of each state with those of the full sample, which includes all states in the northeast. What can be observed is that the individual convergence of the states was slower than the convergence of the northeast region. While the northeast sample was positive and significant for rural and real estate financing, the latter was positive and significant only for the state of Pernambuco, while the former was not significant for the none state. Already the variables number of bank and savings branches were positive and significant for the states of Alagoas and Maranhão, respectively. These same variables were not significant for the complete sample of the Northeast. With regard to human capital, the sample for the northeast corroborated with the classic results of the literature, while in the states only Alagoas, Ceará and Maranhão showed some significance in human capital, all other states did not reject the null hypothesis. With regard to social infrastructure, the Northeast presented the health FIRJAN index as able to influence regional growth, while this same index did not prove to be relevant for individual states. With respect to the business environment group, the income FIRJAN index proved able to influence Northeast growth, while this same growth index seems to influence the growth only state of Alagoas and Maranhão. Already, the variable number of commercial and industrial establishments per municipality (per 100 thousand inhabitants) did not show any influence, neither over the entire sample nor over most states individually, being able to influence only the growth of the state of Ceará.

Table 9 - Tests and information from the data in table 8

	Alagoas	**Bahia**	**Ceará**	**Maranhão**	**Paraíba**	**Pernambuco**	**Piauí**	**Rio Grande do Norte**	**Sergipe**
Tests and information									
Arellano-Bond test for AR(1) in first differences	[0.021]	[0.014]	[0.002]	[0.002]	[0.002]	[0.322]	[0.022]	[0.028]	[0.014]
Arellano-Bond test for AR(2) in first differences	[0.591]	[0.315]	[0.654]	[0.841]	[0.154]	[0.494]	[0.146]	[0.363]	[0.718]
Sargan test of overidentified restrictions	[0.981]	[0.412]	[0.593]	[0.139]	[0.041]	[0.400]	[0.803]	[0.847]	[0.749]
Hansen test of overidentified restrictions	[0.975]	[0.660]	[0.701]	[0.679]	[0.289]	[0.399]	[0.565]	[0.937]	[0.761]
Difference-in-Hansen test of exogeneity of instruments: excluding group	[0.966]	[0.613]	[0.739]	[0.680]	[0.645]	[0.517]	[0.668]	[0.886]	[0.537]
Difference-in-Hansen test of exogeneity of instruments: difference	[0.831]	[0.536]	[0.494]	[0.508]	[0.140]	[0.290]	[0.378]	[0.787]	[0.752]
Observations	249	1349	536	460	348	590	230	243	229
N. of cities	51	279	112	98	74	123	47	50	46

Source**:** author himself, 2021.

6 CONCLUSION

Researchers in empirical growth literature should study Brazil. It is a country with continental dimensions, which presents robust and persistent heterogeneities and inequalities, whose consolidation of democracy is recent and whose economic stability is constantly threatened by crises and mistaken public policies.

Concerning Brazilian growth path, history shows that the country goes through decades of strong growth that are followed by decades with low growth rates and, finally, lost decades, with almost zero growth. Regarding Brazilian cross-state convergence, it seems to be slower than the reported for the American states, with oscillations in the evolution of inequality over time, and across regions within Brazil. The range and trend of the main growth drivers, when compared to the richest and poorest states, suggest that the convergence between these extremes will be observed. In average terms, the situation is also worrying. According to the IMF, Brazil ranked 76th in 2015 in the GDP per capita ranking, while our sample with 925 cities from the Northeastern region of Brazil if were considered a country, it would be 127th in that ranking, between East Timor and Myanmar.

Regarding our main findings on financial system and development, the results on the significant and positive coefficient of rural and real estate financing are fundamental in conducting public policies aimed at granting credit. Matos and de Jesus Filho (2019) find that non-earmarked and total household credit are insolvent based on negative causality from debt-to-GDP to surplus between amortization and granting of credit as a proportion of GDP, from April 2011 to August 2017. This finding is worrying, since earmarked household credit in Brazil is mainly used for rural credit (1/3) and real estate financing (2/3), while non-earmarked credit is characterized by non-payroll loans, credit cards, overdraft, vehicles and other types of credit that are generally associated with the consumption of non-durable goods, semi-durable goods and services, which although relevant, are negligible and in many cases unnecessary. Non-earmarked credit, whose interest rates are on average six times higher than the interest rate charged on earmarked loans, has a higher delinquency rate and its credit cost index (measured by CBB) is five times the same index for earmarked credit.

Following Matos and de Jesus Filho (2019), we also claim here that this household non-earmarked credit should not be stimulated by the government as a means of increasing social welfare unless accompanied by an improvement in social, economic, labor market and human capital indicators. Otherwise, this might be the next bubble to be blown. The credit that needs to be stimulated, encouraged and facilitated is the earmarked credit, such as rural and real

estate, which are known to add to the production line, as well as microcredit.

In this context, it is important to highlight here the role of public banks in Brazil. During the period from 2009 to 2015, and considering the 925 cities in our sample, public banks granted 89% of rural credit, with emphasis on Bank of Brazil, and more than 99% of real estate credit, with emphasis on Caixa Econômica Federal. Even though it was not incorporated into our model, Bank of Northeast is extremely important concerning microcredit concession in the region.

Regarding the human capital, the expected and intuitive relevant role of education suggests that we need to look for good policies that are implementable and replicated to other northeastern cities. The state of Ceará seems to be that benchmark to be followed by the other states. Ceará is the state of the Northeast with the highest percentage of formal workers with a college degree, 21.2%, according to data from our sample. Moreover, according to the IBGE, Ceará remains among the poorest in the country (18th position out of 27). The low economic performance causes the state to challenge the logic of common sense: it is highlighted in the rankings of teaching evaluation. It has the 2nd best Basic Education Development Index (IDEB) for the initial years of elementary school, behind São Paulo. The success of the educational model encouraged the World Bank to organize an unprecedented study that can offer some answers that explain the good performance. The agency's analysis is concentrated between the years 2005 and 2017 and uses IDEB as an indicator of educational performance. According to economists and public policy consultants who prepared the World Bank document, Ceará has a basic education model capable of reducing learning poverty and which can be replicated in other states in the country from some management and efficiency pillars.

The relevance of the FIRJAN employment/income and health indicators suggests that the state has an important role on two fronts. First, it needs to promote an environment good enough to attract investors and allow the market to act. This depends on tax, labor and social security reforms. Second, state governments need to prioritize fiscal austerity, so that they can invest in partnership with the private health sector, even recognizing that public investment in hospitals is associated with an accounting liability in the future.

Another public policy that needs to be strengthened so that the most vulnerable cities can grow is related to the partnership with the private sector in the expansion and maintenance of basic sanitation. In this context, the new Legal Framework for Basic Sanitation is an important step. Its main objective is to universalize and qualify the provision of services in the sector. Theoretically, it seems to be an important advance and this also unlocks the first big wave of investments. According to data from 2020, in the country, 35 million people do not

have access to treated water and more than one hundred million do not have sewage collection services. In relative terms, the scenario is much worse in the Northeast. The goal is to ensure that 99% of the population is served with drinking water and 90%, with sewage treatment and collection, by December 2033.

By expanding our investigation, with the objective of responding to possible criticisms related to the existence of a common convergence pattern between very heterogeneous cities and verifying the behavior of the growth variables between the municipalities of each state in the Brazilian northeast, we corroborate once again with the need for a more accurate look by public policy makers on the neediest cities. The results showed low convergence and little significance in the variables studied. The most prominent variables were human capital, which was significant for 3 of the 9 states, showing that in addition to corroborating with the growth literature, states that invested in education had a better GDP performance.

It is important to highlight that the possible explanation for the lack of significance of the variables in this article comes from the small sample that the states make available for study. Therefore, a suggestion for future works would be to apply the calculations in a model with fewer variables, therefore, we suggest that transform the group the variables infrastructure into a single variable, reduce the variables for education in a single, and so on, in order not to lose degrees of freedom and thus bring the results even closer to reality. As well as expanding the sample to years after 2015.

Our last suggestion applies to future research, such as conducting public policies regarding data collection in Brazilian cities through censuses and household surveys.

A more comprehensive and complete understanding of cross-city variation, whether in the Northeast, in the North of the country or in other regions, involves the expansion of growth drivers in the model. Certainly, the impact of the industrial sector (not captured by the FIRJAN employment/income index), or programs and initiatives geared to technology, must be significant and positive. Despite the low market share, the insertion of microcredit data for informal, small business owners and more underserved families, can bring insights not measured in this article. The simple use of disaggregated credit data between households and companies at the municipal level would already be a promising extension. Moreover, since the country has not been able to solve the basics, which is basic sanitation, already solved in civilization for decades or centuries, at least researchers could access complete data from all over 5570 Brazilian cities of water, sewage and garbage collection. It is very difficult to promote growth when the following numbers persist for decades: more than 40% of the population below

the poverty line, according to the IMF, about 43% of the population with access to sewage service and most cities consume water in quantity below that established by WHO.

Our final words are aligned to Leach, MacGregor and Wilkinson (2021) on the insights of the relevance of the pandemic crisis due to COVID-19, as milestone able to propose transformations and to rethink development more broadly. Possibly, the most relevant key change is how scientific advice and evidence are used in policy, when conditions are rigidly ‘locked in’ to established power relations and yet so uncertain. These authors also claim that the COVID-19 crisis revealed the limits of a conventional model of economic growth.

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