Revista

Cadernos de Finanças Públicas

03 | 2025

TESOURO NACIONAL

Modeling the social impact of state public investment in Ceará

Lyanna Araujo

Marcelo Lamas

Paulo Matos

ABSTRACT

This study analyzes the impact of public investments on income redistribution and the reduction of social inequality in Ceará. The state faces socioeconomic challenges, characterized by high inequality and income concentration in the capital and metropolitan region. The methodology is based on a Vector Autoregression (VAR) model to assess the effects of investments on the population's income and the Gini coefficient. The data used covers quarterly series from 2012 to 2023, obtained from the Continuous National Household Sample Survey (PNAD) and the Ceará State Finance Department (SEFAZ). This study found evidence confirming that public investment has a significant social impact on the state through a redistributive income policy. Thus, the rearrangement of public investment contributes to improving the income of the less favored segments of the population.

Keywords: Public investment; Ceará; Income inequality; Social impact.

SUMMARY

1. INTRODUCTION

The relevance of public investment in the economy is widely recognized in everyday practice and in economic literature. Economists such as Adam Smith and David Ricardo stood out in classical theory by arguing that the market is self-regulating, while the state should have a limited role. Furthermore, Say's Law, formulated by Jean-Baptiste Say, argued that supply creates its own demand, in which entrepreneurs play a more important role in economic growth than public spending.

According to the Keynesian approach, John Maynard Keynes and Richard Kahn supported a more active role for the state in the economy. In his work, The General Theory of Employment, Interest, and Money (1936), Keynes defended the role of public investment in times of economic fluctuation, acting to reduce unemployment, generating a higher level of output and, consequently, income. In his 1931 article, Kahn addressed the multiplier effect, relating the impact of each unit of public spending on output in order to expand its effects on the economy.

Subsequently, the importance of public investment was highlighted by Auchauer (1989) when analyzing the role of public spending in the United States, seeking to explain the slowdown in productivity growth in the 1970s. Using US data, he found in his results that a 1% increase in public infrastructure spending increases output by 0.36 to 0.39.

The economic literature highlights the role of public investment on macroeconomic variables. Barro (1990) elucidates the existence of an optimal level of public spending that drives economic growth as well as productive capacity. Evaluating more recent studies, Abiad *et al*. (2016) found evidence that investment increases GDP in the short and long term, reduces unemployment, and attracts private investment, contributing to sustainable growth and a reduction in the debt-to-GDP ratio.

Chatterjee *et al*. (2018) reinforce that public investment, when well planned and managed, stimulates productivity and economic growth. Public debt, provided it is managed cautiously to avoid negative impacts on future indebtedness.

In more specific literature, Matos *et al*. (2024) investigated the importance of public investment at the state and municipal levels for economic growth. That said, the authors found a positive relationship between capital spending and GDP *per capita*, while current spending shows a negative relationship. They concluded that public investment at the municipal level is an important driver of economic growth.

The state of Ceará has stood out in recent years as one of the largest Brazilian investors.

Between 2015 and 2019, it was in evidence as the main investing state, and in 2018 it was in 9th place, with an INV/RCL of 11.5%. However, fluctuations in funding sources led to the state losing this position (FERREIRA *et al*, 2022).

Despite this, Ceará has a high income disparity among its municipalities, with the majority of its wealth concentrated in the hands of a small portion of the population. Ceará's GDP *per capita* in 2023 shows a tendency to vary between 20th and 25th place in the ranking of the 27 Brazilian states. In an international comparison carried out by the International Monetary Fund (IMF), if Ceará were a country, it would occupy 110th place in the international ranking, between El Salvador and Indonesia.

In this context, the search for improvements in social indicators remains constant, both in terms of poverty eradication and the reduction of inequalities, which is one of the main challenges in Ceará's socioeconomic policies. In order to find ways to achieve this, there is a need to assess whether public investment is capable of producing social impacts that meet these demands.

Few studies address the social impact of public investment. One of them is Furceri and Li (2017), who analyzed the economic and social effects of these investments in developing countries. They indicate that a 10% increase in public investment raises GDP by 0.1% in the short term and 0.4% in five years, in addition to increasing employment by 0.15%, encouraging private investment (crowding-in), and reducing the Gini coefficient by 0.2%, promoting growth and reducing inequalities.

The social impact of public investment gained recognition after being debated worldwide in 2013 at the G8 Social Impact Investment Forum in London. Social Impact Investment (SII) is characterized as a financial resource applied with the aim of generating measurable social results—such as poverty reduction and improvement in public health—in addition to financial returns. It gained notoriety due to increasing social challenges and pressure on public resources (OECD, 2015).

Given the above, this study seeks to model the social impacts of public investment in Ceará, using the Vector Autoregression (VAR) model. The analysis uses public investments (construction, equipment, and totals) and their influence on the income of the poorest, the income of the richest, and the Gini Index. Subject to a simulation in RATS® *software* to assess the response of endogenous variables to exogenous shocks. Using a robust methodological approach, this research aims to contribute to the academic debate on the basis of decisions related to public policies, allowing for more informed management and efficient allocation of public resources.

The article is structured in six sections, including this introduction. The second describes the social context of Ceará; the third presents investments in Ceará; the fourth details the methodology used; the fifth presents the empirical exercise; and the sixth section presents the final conclusions of the study.

2. ANALYSIS OF THE SOCIAL CONTEXT OF CEARÁ

Ceará is a region with great territorial diversity and significant socioeconomic contrasts, especially between the capital and the interior. The heterogeneity of the state contributes to significant inequality between municipalities and consequently leads to poor income distribution.

The socioeconomic challenges in Ceará are evident in the economic situation, highlighted by the GDP *per capita* in 2023, with the state tending to vary between 20th and 25th place in the ranking of the 27 Brazilian states. In an international comparison carried out by the International Monetary Fund (IMF), if Ceará were a country, it would occupy the 110th position in the international ranking, between El Salvador and Indonesia, while Brazil is in 76th place, between the Dominican Republic and Saint Vincent and the Grenadines.

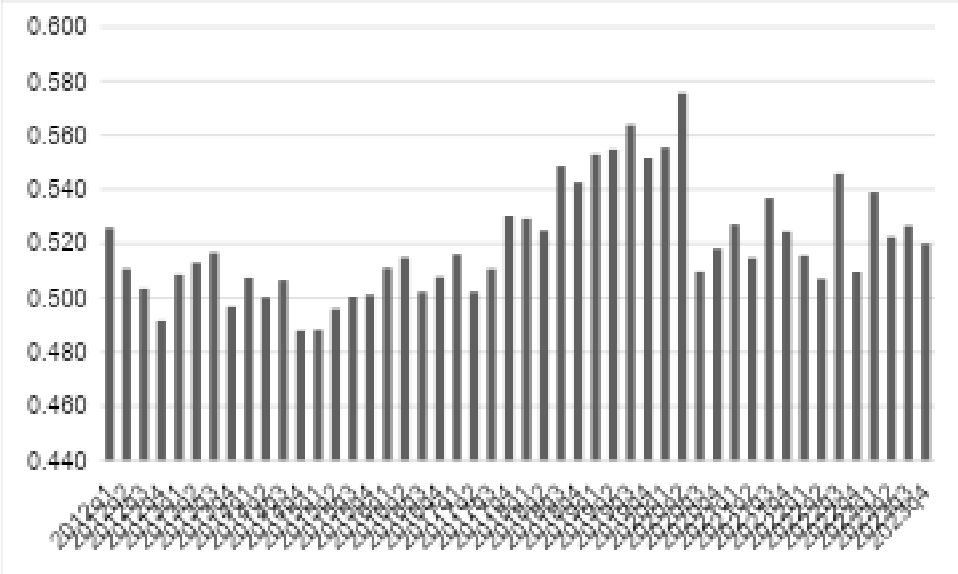
Therefore, it is understood that the state has a large economic gap compared to the country itself and internationally. This existing poverty, although treated in a multidimensional aspect, involving housing, education, health, and consequently quality of life and other dimensions that incorporate it, will be associated with insufficient income in this study.

In order to measure income inequality, the Gini Index was used, a metric normally applied to the distribution of income in a given location. The closer to zero, the more perfect the equality, and the closer to one, the greater the inequality.

In Figure 1, throughout the sample from 2012 to 2023, it is possible to identify a trend toward increased income inequality, especially during the COVID-19 crisis, even though the overall effects of the pandemic are difficult to measure. The initial sample is 0.526, with a slight decrease until 2017, which follows a predisposition for growth, reaching a peak in 2020 with the economic shutdown, job losses, and consequently greater income inequality, reaching 0.576.

In the second quarter of 2020, a decrease in inequality is noticeable due to the social income transfer programs adopted by the federal government to subsidize the population most exposed to the effects of the pandemic. The latest sample is 0.52. Even with the reduction in income concentration, the sample remained above 0.5, reflecting a structural concentration of income in the state.

Figure 1. Gini index for Ceará – 2012q1 to 2023q4.



Source: Own elaboration, based on IBGE data, Continuous National Household Sample Survey 2012 to 2023.

With the aim of reducing poverty, in 2015, the United Nations (UN) launched the 17 Sustainable Development Goals (SDGs), establishing as its first goal the eradication of poverty in all its forms and in all places by 2030. Given this commitment, there is a need for member countries to adopt measures to combat poverty (IPECE, 2024).

Brazil, as a member of the UN, implements numerous policies aimed primarily at income distribution to assist the most vulnerable population. However, there is an urgent need to implement political strategies that go beyond the immediate alleviation of financial difficulties.

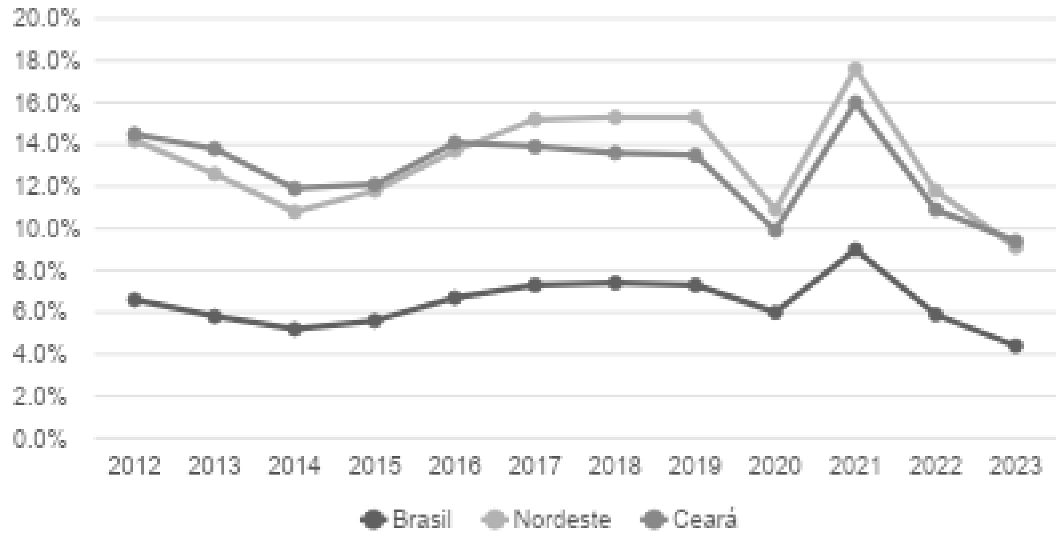
Ceará, as the main focus of this study, presents significant inequality, reflected in the concentration of income in the capital and its metropolitan area. Matos and Gadelha (2022), when analyzing the economic growth of cities in the state between 2009 and 2015 based on Barro's theory (1991), identified a high disparity between municipalities in Ceará. This concentration of wealth had already been highlighted previously by Morais *et al* (2014), who pointed out that *per capita* household income in the state was strongly influenced by the accumulation of wealth in the hands of a small portion of the population.

In this case, reducing the poverty line is one of the global goals, especially in developing countries, where it is essential that national poverty lines be adjusted to the specific reality of each region, based on the cost of a basic basket of essential goods.

The World Bank uses purchasing power parity (PPP) exchange rates to ensure that each basket has the same cost in different countries. Based on the 2017 PPP, the international extreme poverty line is set at US$2.15 per person (IPECE, 2024).

Figure 2 shows that around 14.5% of the population of Ceará, representing more than 1.2 million people, were living in extreme poverty in 2012. In 2023, this proportion decreased to 9.4%, equivalent to 876,000 people. During this period, approximately 388,000 people in Ceará left extreme poverty, reflecting a 30.7% reduction in the number of people in this condition over almost a decade (IPECE, 2024).

Figure 2. Proportion of people with *per capita* household income below the international extreme poverty line – Brazil, Northeast, and Ceará – 2012 to 2023.

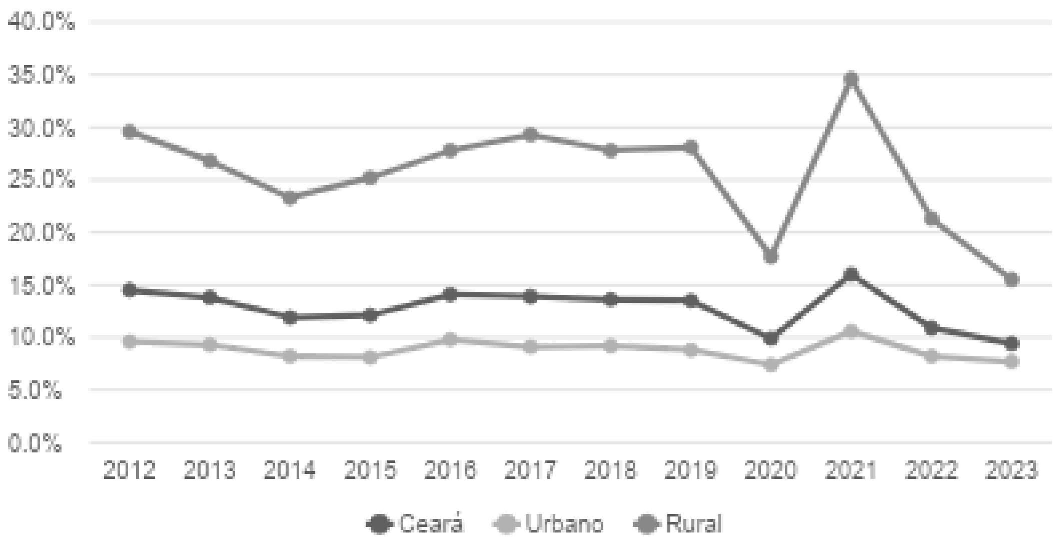


Source: IPECE, based on IBGE data, Continuous National Household Sample Survey 2012 to 2023. **Notes:** Extreme poverty line of US$ 2.15/day PPP 2017. Values in reais: R$ 208.63 for Brazil, R$ 208.81 for the Northeast, and R$ 211.06 for Ceará.

Between 2012 and 2014 in Ceará, extreme poverty decreased, but returned to growth between 2015 and 2016 due to the economic recession of 2014-2016. In 2017, the trajectory of intensified reduction began until 2020, due to the implementation of emergency aid, which contributed significantly to the drop in rates. Despite this, in 2021, with the interruption and reduced value of this program, it resulted in the worst moment of extreme poverty in the 12 years analyzed. Between 2021 and 2023, economic recovery and the strengthening of social programs led to a sharp drop in extreme poverty rates (IPECE, 2024).

Figure 3 shows extreme poverty in urban and rural areas and in Ceará as a whole. In 2012, about 29.6% of the rural population and 9.6% of the urban population lived in extreme poverty. In 2021, the rural area had about 717,000 people in extreme poverty, while in 2023, the number fell to 310,000 people in these conditions. Between 2021 and 2023, around 600,000 people emerged from extreme poverty, 193,000 in urban areas and 407,000 in rural areas, representing a 40.6% drop in extreme poverty in Ceará. In 2023, 15.5% of the rural population and 7.7% of the urban population still lived in extreme poverty, but of the total population of Ceará, around 64.5% in urban areas and 35.4% in rural areas still lived in extreme poverty. Thus, there was a change in the state's profile, in which the urban center began to have a higher concentration of extreme poverty than rural areas.

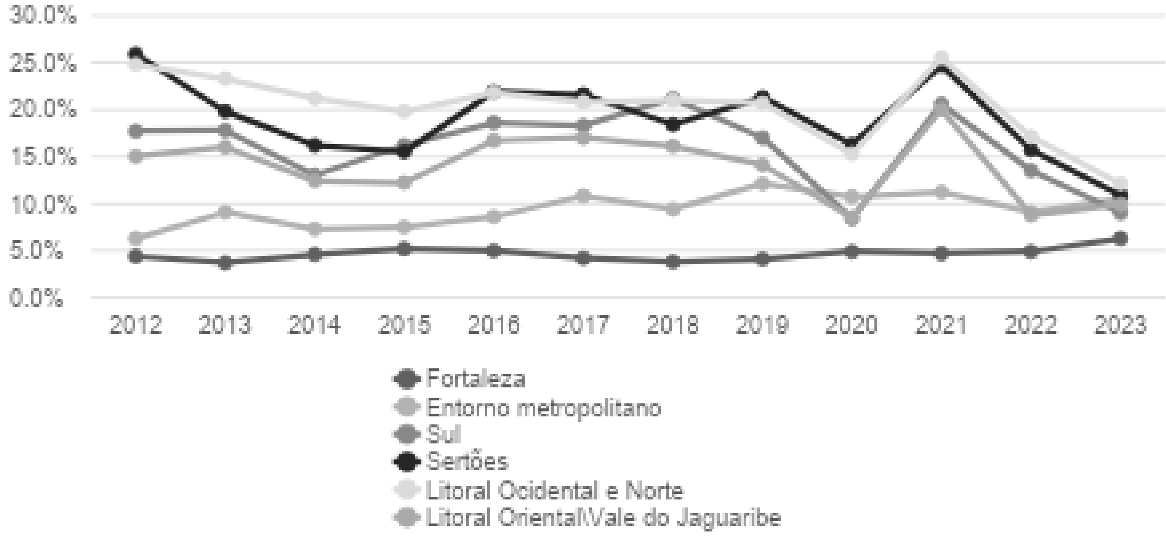
Figure 3. Proportion of people with *per capita* household income below the international extreme poverty line by household situation – Ceará – 2012 to 2023.



Source: IPECE, based on IBGE data, Continuous National Household Sample Survey 2012 to 2023. **Notes:** Extreme poverty line of US$ 2.15/day PPC 2017 (R$ 211.06 in 2023 reais).

In Figure 4, there is a division between the capital municipality, other municipalities in the metropolitan region, and the interior of the state, into four regions: Eastern Coast/Jaguaribe Valley; South; Sertões; and Western Coast and North, according to the continuous PNAD. The highest peak of income inequality can be seen in 2021, followed by the entire sample. In 2023, there is a reduction in most areas, with the exception of the capital, Fortaleza, the metropolitan surrounding area, and the eastern coast. Fortaleza experienced a large increase in extreme poverty when compared to the other regions observed.

Figure 4. Proportion of people with *per capita* household income below the international extreme poverty line by geographic area – Ceará – 2012 to 2023.



Source: IPECE, based on IBGE data, Continuous National Household Sample Survey 2012 to 2023. **Notes:** Extreme poverty line of US$ 2.15/day PPP 2017 (R$ 211.06 in 2023 reais).

Based on this picture, it is clear that income distribution policies and other factors have led to a reduction in extreme poverty in Ceará. However, poverty still persists, along with structural challenges (concentration of income in the capital and metropolitan area, as well as disparities between urban and rural areas).

3. RELATED LITERATURE ON INVESTMENTS IN CEARÁ

3.1. Quality of public investment

The Government of Ceará, through the Secretariat of Planning and Management (SEPLAG), aims to improve the quality of public resources, contributing to improving the quality of life of the state's population, with the implementation of the Public Investment Management (GIP) methodology and the Investment Management System (SEPLAG, 2024).

This methodology aims to deliver a formalized process for planning and analyzing public spending in order to improve the efficiency of resources allocated to investment projects, thereby supporting decision-making by state officials (SEPLAG, 2024).

To this end, investment projects connect the short term to the long term. Investments operate through two channels of economic and social impact, namely aggregate demand and supply, which together can contribute positively to the well-being of the population and improve the indicators of the Sustainable Development Goals (SDGs) (SEPLAG, 2024).

3.2 Public investment in Ceará

Public investment is considered one of the main factors of economic growth, playing a fundamental role in connecting the short and long term in the economy. According to Bredow (2018), this importance stems from the expansion of current demand and the boost in the country's productive capacity.

In this context, Barro (1990), in his endogenous growth model, presents the importance of well-targeted public spending and its impact on economic growth, in addition to contributing to sustainable development over time.

Significant evidence of investment in the state of Ceará can be found in Ferreira *et al*. (2022). This study analyzes the investment policy of the Government of the State of Ceará, a federal (state) entity that has been a national leader since 2016, using the wavelet methodology, analyzing investment under the management of public accounts and evaluations of public policies focused on investments.

In this study, investment is broken down into works and facilities; and equipment and permanent material in order to observe which of these components influence the economy of Ceará. It finds significant impacts of investment in equipment on ICMS tax collection two years ahead, and works influencing a three-year horizon, both IBCR-CE, industrial production, and retail sales volume. Both investments affect job creation, identifying that fiscal balance provides a sustainable investment policy in the state.

In Araújo *et al*. (2014), the relationship between public spending and economic growth in municipalities in Ceará between 2002 and 2009 is explored. The model used the Generalized Method of Moments (GMM) for panel data. The results highlight the importance of strategic investments in infrastructure, health, and education.

Investments in infrastructure are essential to attract private capital (crowding-in) and help reduce logistics costs, while spending on education is crucial for the formation of skilled human capital. The impact of a 1% increase in human capital results in a 0.14% increase in GDP *per capita*.

In Matos *et al*. (2022), the fiscal dynamics of Brazilian state governments were analyzed to identify the relationship between public investment, primary results, social security deficits, debt, and cash flow. Using three empirical exercises to model and measure this relationship, considering different hypotheses, equations, and econometric techniques, they found a significant relationship between investment and primary results, gross debt, and cash.

Ceará's investment policy stood out between 2015 and 2019, leading the annual ranking of the ratio between investments paid and Net Current Revenue (NCR). In 2020, it remained the second largest investor, and in 2021, it ranked 4th among the 27 Brazilian states. In 2022, it ranked 9th and reached a margin of 11.5% INV/NRCR. Despite this positive track record, the state's position fluctuated due to changes and challenges faced in financing investments. Between 2021 and 2022, Ceará experienced a negative variation of 10.2% in its cash flow, due to a trend of financing a smaller portion of its investments with third-party resources, starting to use its own resources instead. This has created a need to strike a balance between the use of own resources and credit operations that ensure the long-term sustainability of investments (MATOS *et al*., 2022).

The year 2022 was characterized by a change in the historical behavior of the Ceará state government, where public investment was financed mainly by its own resources, so that for every R$ 1.00 invested, approximately R$ 0.80 of equity capital was used. However, in 2023, the Ceará government returned to its standard practice, using approximately R$0.59 of third--party resources for every R$1.00 invested (IPECE, 2024).

Matos *et al*. (2022) emphasize the importance of diversifying long-term financing sources, in line with state investment policies. Efficient use of debt should be made to strengthen own revenue collection and seek public and private partnerships, in order to vary the sources for new projects. In this regard, the study shows that, although public investment is less sensitive to the social security deficit than to the primary result, there is a growing need to monitor this relationship to avoid long-term negative impacts.

Matos *et al*. (2024) found a long-term negative relationship between investments and debt increase and a positive relationship between investments and cash flow. In this sense, Ferreira *et al* (2022) reinforce the importance of well-structured fiscal planning, going beyond the reduction of economic vulnerabilities and ensuring the security of investments in times of crisis.

Matos and Viana (2024) investigated the movements between public investment cycles, primary results, and short-term growth cycles in the state of Ceará through wavelet analysis. They concluded that the fiscal efforts and investments made during Brazil's worst financial crisis in recent decades were responsible for anticipating and leading short- and medium-term growth cycles in the same direction, which helps to strengthen the important role of fiscal soundness during such economic times.

4. METHODOLOGY

This section presents the methodological strategies used to examine the effects of the investment shock on the population's income distribution and the Gini coefficient, in order to analyze the social impact of public investment. The purpose is to report the steps that were necessary for the econometric simulation applied to obtain and interpret the results found.

4.1. Basic VAR and presentation of the models to be estimated

This study used the Vector Autoregression (VAR) model developed by Christopher Sims (1980), in which the variables are jointly determined, i.e., they consider their values lagged in time. The equation can be written as:

$$Y_t = \mu + A_1 Y_{t-1} + \ldots + A_k Y_{t-k} + u_t \tag{1}$$

Where μ is a vector that depicts the constant terms, Ai are the coefficient matrix, and u_t is the error term, in which $u_t \sim N(0,\Sigma)$. The model helps to elucidate the dynamics between the variables, capturing the interrelationship between endogenous variables and assessing the effects of shocks.

In this study, we analyze the reactions of income variables (lagged) in response to quarterly investment shocks (lagged) in the economy. The data were estimated from the first quarter of 2012 to the last quarter of 2023, considering 12 years of samples, accounting for 48 quarterly observations. Over time, it is possible that the variables undergo changes. In order to capture this variation, we use the following equation:

$$Y_t = \beta 0 + \alpha Y_{t-1} + \beta_i X_{t-1} + \gamma Z_{t-1} + u_t \tag{2}$$

In the model, the vector of endogenous variables is represented by $Y_{t-1}=(y_{1,t-1}, y_{2,t-1}, y_{3,t-1})$, where y_1 is the income of the 20th quintile, y_2 is the income of the 80th quintile, and y_3 is the Gini index. These variables were lagged by up to two periods in time, for example, $y_{1,\, t-1}$ and $y_{1,}$

$_{t-2}$. Thus, the parameter β0 is the intercept of the model, so that βi is the coefficient of variation ofX_{t-1}, where X_{t-1} represents the vector of the exogenous variable of the model, where x_1, x_2,x_3 are total investment, investment in construction, and investment in equipment. Meanwhile z_t corresponds to the control variable of the model given by the Regional Economic Activity Index – Ceará - IBCR-CE and $u_t \sim N(0,\Sigma)$.

4.2. Alternative impulse response model

Based on the study by Otero (2020), it is possible to analyze the impact of a shock from an exogenous variable directly on the endogenous variable using a VAR in its reduced form, through the econometric *software* RATS® to generate impulse-response functions via Monte Carlo simulations. Considering the following model:

$$X_t = F(L)X_{t-1} + G(L)Z_{t-1} + \xi_t \tag{3}$$

Where X_t represents an endogenous variable vector, F(L) is a polynomial of order $n \times n$, $G(L)$ is a polynomial vector n ×1, L is a lag operator, Z_t is a vector of exogenous variables, and ξ is a vector of classical errors such that $\xi_t \sim (0, \Sigma)$, where Σ is a covariance matrix. Two versions of this model were created. The first version, with respective vectors of endogenous and exogenous variables, is given by:

$$X_t = [X_{1,t}\ X_{2,t}\ X_{3,t}] \tag{4}$$

$$Z_{it} = [z_{1t}\ z_{4t}] \tag{5}$$

where $X_{1,t}$ is the income of the 20th quintile, $X_{2,t}$ is the income of the 80th quintile, $X_{3,t}$ is the Gini coefficient variable, Z_{it} is the total investment, and Z_{4t} is the IBCRCE. The second version of the VAR model uses disaggregated investment in construction and equipment, as in the following model:

$$X_t = [X_{1,t}\ X_{2,t}\ X_{3,t}] \tag{6}$$

$$Z_{it} = [z_{1t}\, z_{2t}\, z_{3t}\, z_{4t}] \tag{7}$$

The endogenous variables remain the same, while z_{2t} is investment in construction, z_{3t} is investment in equipment, and z_{4t} refers to the IBCRCE. In the inference process, a simulation was constructed in which an isolated unit shock was simulated in an exogenous variable, while the other variables remained constant. This approach helps to create a placeholder useful for Monte Carlo simulations and for calculating impulse response functions. The effect of exogenous variables on endogenous variables is given by the unit shock in the exogenous variable, which is then disseminated in the endogenous variables that are recorded in the impulse response functions. For each endogenous variable in the model (rendaq20, rendaq80, and gini), a VAR model was estimated with the respective exogenous variables (construction, equipment, and total investment). This results in 3 x 3 = 9 models.

After estimation, the impulse response functions were generated considering a period of nine quarters, accounting for two years and one quarter. Ten thousand results from the estimation of the coefficient vectors were obtained by Monte Carlo simulations. To quantify the uncertainty, in the odd-order Monte Carlo simulations, the covariance matrix was obtained via the inverse Wishart distribution given by:

$$\Sigma \sim IW(\Sigma_S, T - k) \tag{8}$$

Where Σ_S is the true covariance matrix, T is the number of time observations, k is the number of lags of the endogenous variables included in the model (the order of the VAR), and $T - k$ is the number of degrees of freedom. The inverse Wishart distribution applied to the covariance matrix emerges as the distribution resulting from the adoption of *Jeffrey's prior*, a neutral (non-informative) distribution in relation to a set of parameters, whose density function is consistent with the square root of the determinant of the Fisher information matrix (SUN; NI, 2004). Therefore, the function:

$$\pi(S) \propto |\Sigma|^{-\frac{n+1}{2}} \tag{9}$$

Where n, and the number of equations in the VAR. This distribution is applied when one wishes to avoid incorporating prior assumptions about the model parameters. After drawing the matrix Σ, the odd coefficients of the Monte Carlo simulations are chosen using the multivariate normal distribution in order to estimate the parameter Ø via OLS and added to the white noise, u_d.

$$\emptyset_d = \hat{\emptyset} + u_d \tag{10}$$

Where $u_d \sim N(0, \Sigma_S)$ and $\hat{\emptyset}$ is the OLS estimate. The estimators will be drawn from a multivariate normal distribution given by $\emptyset_d | \Sigma \sim N(\hat{\emptyset}, \Sigma \otimes (X'X)^{-1})$. For even values of the Monte Carlo simulations, the matrix Σ is kept at its original value, and the values of the model parameter estimates are equal to:

$$\emptyset_d = \hat{\emptyset} - u_d \tag{11}$$

And thus, the coefficients $\emptyset_d$ are adjusted around the OLS estimate, following a unit shock applied *to the placeholder*, the VAR model is estimated and incorporated into this new result. The shock of the exogenous variable propagates and affects the endogenous variable, with an effect recorded in the IRF. According to Bueno (2011), to obtain this function, it is necessary to represent in a graph the impact multipliers of one variable of the model on the other, in relation to t. To achieve this result, it is important to transform the VAR of order n into a finite moving average vector (VMA), which is possible through a stable VAR or when the eigenvalues of the polynomial are outside the unit circle $\left(I - \sum_{i=1}^{p} \Phi_i L^i\right)$. To achieve the VMA, it is necessary t $\frac{1}{n}(n^2 - n)$ ly impose limitations on the matrix, which present the simultaneous interactions between the endogenous variables, enabling the identification of the model. Through Cholesky decomposition, which allows the covariance matrix to be decomposed by the following structure:

$$W_t = B_0 + \sum_{i=1}^{n} B_i W_{t-i} + \rho_t \tag{12}$$

Where ρ_t is a column vector whose elements are equal to $\sigma_j \varepsilon x_{j-i}$, where εx_{j-i} is a shock (referring to the endogenous variable X_j) with variance σ_j. Converting to a VMA(∞), we have the following:

$$W_t = \overline{W} + \sum_{i=0}^{\infty} \Phi^i \rho_{t-i} \tag{13}$$

Where $\underline{W}$ is the vector of long-term means. Writing (13) in terms of the shocks ε_t, we have:

$$W_t = \mu + \sum_{i=0}^{\infty} \Psi_i \varepsilon_{t-i} = \tag{14}$$

$$= [W_{1t}\, W_{2t} \,\vdots\, W_{3t}] = [\overline{W}_1\, \overline{W}_2 \,\vdots\, \overline{W}] + \sum_{i=0}^{\infty} [\Psi_{11}(i)\, \Psi_{21}(i)\, \Psi_{12}(i)\, \Psi_{22}(i) \;\cdots\; \Psi_{1n}(i)\, \Psi_{2n}(i) \,\vdots\, \Psi_{n1}(i) \,\vdots\, \Psi_{2n}(i) \ddots \cdots \vdots\, \Psi_{nn}(i)]\,[\varepsilon w_{1t-i}\, \varepsilon w_{2t-i} \,\vdots\, \varepsilon w_{nt-i}]$$

Where ψ_{ij} are the multipliers of the impact of the shock of the exogenous variable on the endogenous variable of the model. Allowing the effect of investment shocks on the main incomes explored and on the Gini Index to be detected.

5. EMPIRICAL EXERCISE

5.1. Data

In the proposed empirical exercise, the data series has a quarterly frequency for the period from 2012q1 to 2023q2. The limitation that defines this frequency and time interval is the availability of income data by quintile and Gini, whose source is the Continuous National Household Sample Survey (PNAD). Investment was broken down into works and facilities; and equipment and permanent materials, considering the predominance of categories that together accounted for between 60% and 90% of total investments, in which their monthly series of committed expenditure available at the Ceará State Finance Department (SEFAZ) were aggregated each quarter. All income and investment series are real, in R$ values from December 2023, using the Broad Consumer Price Index (IPCA). The IBCR-CE, a monthly economic activity index used as an instrument, is available from the Central Bank.

Looking at the annualized real investment data over the period, such spending usually fluctuates between R$ 2.5 and R$ 4.0 billion, with the exception of 2022 (R$ 4.6 billion) and 2013 (R$ 11.8 billion). The element of works and facilities is the most relevant, with 50.5% in these 12 years, followed by equipment and permanent material, which represents 15.8% of the total investment. Looking at the income data for the last quintile, this variable ranges from R$ 1,900.00 to R$ 2,700.00, closing the year 2023 at a level above R$ 2,500.00. The income of the first quintile fluctuates less, ranging between R$ 500.00 and almost R$ 700.00 during this period, ending the interval at R$ 600.00. It is interesting to note the steady decline between the end of 2014 and the second half of 2019, when this income reached its lowest level. The Gini inequality coefficient remained between 0.49 and 0.58, evolving between 2015 and the second quarter of 2020, when it peaked. During the pandemic, more precisely in 2020q3, inequality recorded its largest reduction, falling from 0.58 to 0.51. This social indicator closed 2023 at 0.52.

Figure 4 reports the dispersion associating each of the investment variables (total, in construction, and in equipment) with the income of the first and last quintiles, as well as with the Gini inequality. This is a simple and unconditional analysis, since it does not use instruments to measure the linear relationship between the type of investment and the social variable in question. Even so, this preliminary exercise suggests that all three types of investment seem to perform the same social functions, as they are positively correlated with q20 income, negatively correlated with q80 income, and consequently also negatively correlated with Gini inequality, since they favor the income of the most disadvantaged and disadvantage the income of the most advantaged.

There is also a common pattern among the three socioeconomic indicators, since actual spending on investments in equipment and permanent materials is the capital expenditure with the greatest potential to influence the incomes analyzed and the Gini, based on the parameter that measures this linear relationship.

In addition to being unconditional, this analysis has another limitation, since income variables exhibit non-stationary behavior, just as investment variables exhibit non-seasonal behavior. Thus, in the main analysis of this article, all variables will be treated as percentage differences, with the exception of the Gini coefficient, which will be used in first difference, as it is already a variable normalized between 0 and 1. The investment variables also underwent a process of deseasonalization.

5.2. Basic VAR results

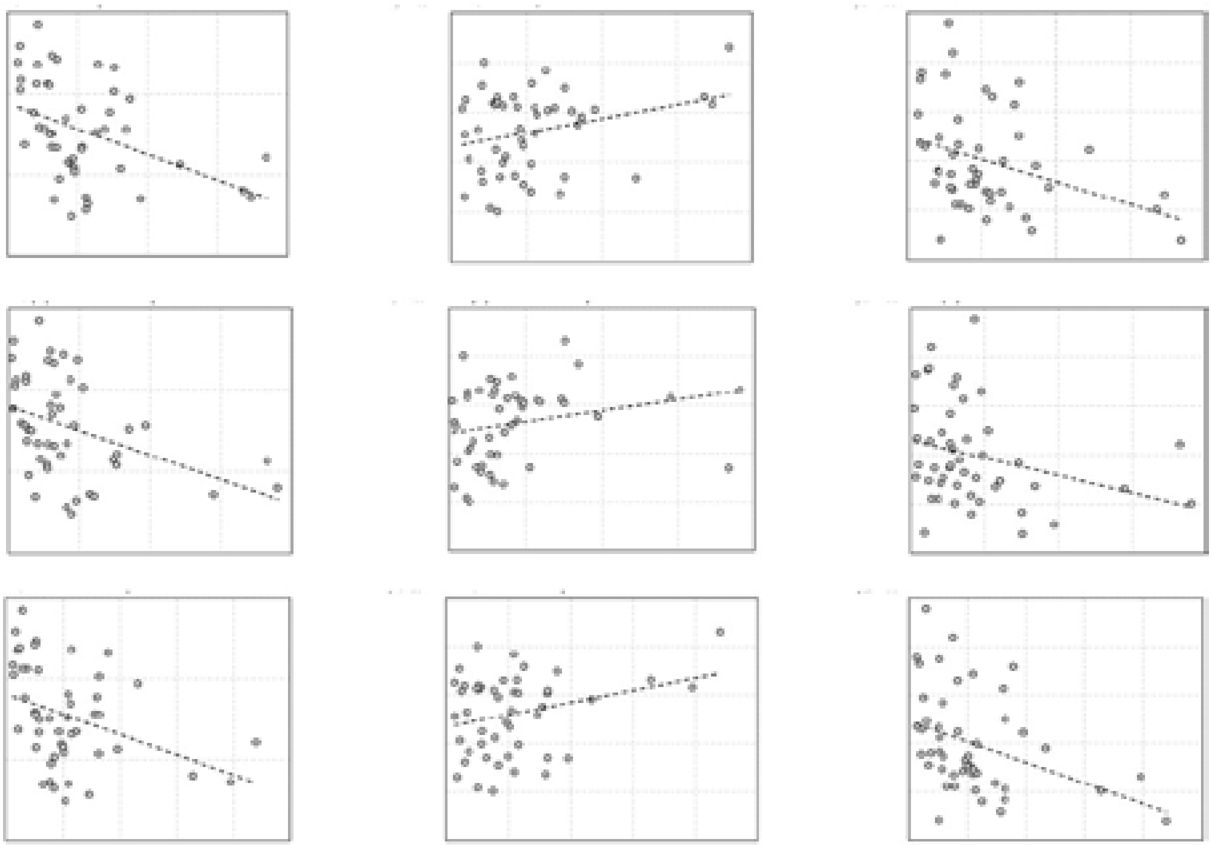
Table 1 reports the results of the Vector Autoregression (VAR) estimation, which has the incomes of the first and last quintiles and the Gini index as endogenous variables, and investment as an exogenous variable. With regard to the timing of the empirical exercise, all variables are used with up to two quarterly lags, both for reasons of parsimony, given the limited number of observations, and in order to obtain short-term reactions. The results are tested considering up to four lags, i.e., one year of investment effect; however, associated with a lower degree of freedom, there is a loss of significance for most variables.

The first two models show the results considering total investment, while models 3 and 4 show the results of investment broken down into construction and equipment. The paired models (2 and 4) use economic activity (IBCR-CE) as an instrument to measure effects capable of explaining income variation in a parsimonious approach. These two frameworks are the main ones in the formulation of analyses and conclusions, both for the use of the instrument and based on Akaike's information criterion.

Based on both specifications, the income of the most favored quintile (q80) and Gini inequality show a reversion to the mean in the very short term, based on the respective significant negative parameters.

The significance of the positive impacts (with one and two lags) on the Gini, in addition to the higher explanatory power in the equation of this social variable, allows us to infer that economic growth (seasonally adjusted quarterly variation of the IBCR-CE) in the state of Ceará has been characterized by behavior that favors inequality, that is, it is not pro-poor growth, which is desirable in unequal and poor societies.

Figure 4. Dispersion between types of investment spending and social indicators



Notes: Time series: 2012q1 – 2023q4, 48 quarterly observations. Investment (millions of R$ in Dec/23 values). Income q80 and q20 (R$ in Dec/23 values).

On the other hand, total public investment by the state government has mitigated some of this unfavorable evidence by positively influencing the variation in q20 income one quarter ahead and reducing q80 income two quarters ahead, thereby influencing the reduction in the Gini coefficient one semester ahead.

This conclusion is corroborated by the results of model 1, without using the IBCR-CE as an instrument. This evidence can be better understood by observing the results of disaggregated investments (models 3 and 4), according to which investments in works and facilities are capable of positively influencing q20 income and negatively influencing q80 income in the very short term, with investment in equipment playing the role of reducing income inequality via the Gini Index.

5.3. Impulse response results

The results of the impulse-response functions were obtained through simulations in Rats® *software* by estimating the Vector Autoregressive (VAR) model and are represented in Figure 5. Each illustration clearly and elucidatively depicts the effect of shocks in public investments (total and disaggregated) on endogenous variables, emphasizing their impacts over nine quarters (corresponding to two years and one quarter) after the shocks occurred. The impulse-response analysis was composed of three distinct shock configurations: the first considers the impact of total investment; the second, investment in equipment; and the third, investment in construction. In each of these models, the IBCRCE variable was used as a control, ensuring greater accuracy and robustness of the estimates.

The impact of total public investment on the income of the most vulnerable community is initially positive, promoting temporary gains and confirming the results obtained in the previous section.

For higher-income individuals, a positive result is observed in the first period, followed by a more pronounced negative impact, indicating a downward trend in the income of the wealthiest, but with low statistical significance over the period. As for the Gini coefficient, there was an initial negative impact, reinforcing the hypothesis of reduced inequality. This indicates that public investment contributed to a better distribution of income in the short term. The impact of the equipment and construction shocks has similar effects to the observations presented. In the first equipment shock, it is possible to see a more pronounced impact on income.

Table 1. VAR Results

	Modelo 01			Modelo 02		
	Renda Q20	Renda Q80	Gini	Renda Q20	Renda Q80	Gini
Renda Q20 (-1)	-0,170 [-1,022]	-0,100 [-0,369]	-0,012 [-0,264]	-0,160 [-0,858]	-0,204 [-0,730]	-0,019 [-0,432]
Renda Q20 (-2)	0,163 [0,956]	0,105 [0,374]	0,095** [2,022]	0,177 [1,013]	0,099 [0,361]	0,107*** [2,443]
Renda Q80 (-1)	-0,085 [-0,786]	-0,312** [-1,778]	-0,016 [-0,540]	-0,078 [-0,665]	-0,249* [-1,334]	0,000 [0,007]
Renda Q80 (-2)	-0,289*** [-2,636]	-0,301** [-1,768]	0,030 [1,475]	-0,289*** [-2,764]	-0,318** [-1,876]	0,027 [1,546]
Gini (-1)	0,181 [0,218]	-0,779 [-0,633]	-0,530*** [-3,464]	0,422 [0,503]	-1,668* [-1,416]	-0,473*** [-3,098]
Gini (-2)	1,050** [1,862]	0,038 [0,056]	-0,201* [-1,326]	1,280** [1,954]	0,677 [0,626]	0,056 [0,396]
Constante	-0,014 [-1,150]	0,018 [0,880]	0,004 [1,160]	-0,014 [-1,068]	0,023 [1,062]	0,005 [1,596]
Investimento Total (-1)	0,030** [2,078]	0,029 [0,966]	-0,002 [-0,663]	0,027** [1,858]	0,017 [0,673]	-0,005* [-1,464]
Investimento Total (-2)	0,009 [0,566]	-0,036* [-1,498]	-0,006* [-1,434]	0,008 [0,563]	-0,040* [-1,632]	-0,007** [-1,753]
IBCR-CE (-1)				0,222 [0,708]	-0,352 [-0,603]	0,137** [1,863]
IBCR-CE (-2)				0,108 [0,348]	1,457 [1,866]	0,179** [2,350]
R2 ajustado	0,135	0,119	0,370	0,098	0,113	0,451
C. de inf. de Akaike		-10,514			-10,699	

	Modelo 03			Modelo 04		
	Renda Q20	Renda Q80	Gini	Renda Q20	Renda Q80	Gini
Renda Q20 (-1)	-0,104 [-0,654]	-0,063 [-0,216]	-0,023 [-0,478]	-0,111 [-0,606]	-0,187 [-0,638]	-0,030 [-0,456]
Renda Q20 (-2)	0,212 [1,193]	0,080 [0,304]	0,074* [1,536]	0,234 [1,276]	0,096 [0,326]	0,090** [1,958]
Renda Q80 (-1)	-0,046 [-0,498]	-0,313** [-1,778]	-0,016 [-0,529]	-0,033 [-0,287]	-0,229 [-1,248]	-0,005 [-0,164]
Renda Q80 (-2)	-0,300*** [-2,678]	-0,359** [-1,965]	0,041* [1,398]	-0,308*** [-2,448]	-0,389** [-2,086]	0,035 [1,171]
Gini (-1)	0,392 [0,665]	-0,613 [-0,550]	-0,449*** [-3,442]	0,579 [0,647]	-1,609 [-1,254]	-0,385** [-1,999]
Gini (-2)	1,229** [1,853]	0,622 [0,557]	-0,097 [-0,539]	1,900 [2,039]	0,678 [0,759]	0,092 [0,460]
Constante	-0,011 [-0,768]	0,025 [1,056]	0,002 [0,443]	-0,008 [-0,558]	0,032* [1,443]	0,003 [0,828]
Inv. em Obras (-1)	0,019* [1,354]	0,008 [0,308]	0,003 [0,763]	0,015 [1,030]	0,006 [0,263]	0,000 [0,118]
Inv. em Obras (-2)	-0,006 [-0,427]	-0,029* [-1,470]	-0,001 [-0,383]	-0,009 [-0,799]	-0,037** [1,803]	-0,003 [-1,105]
Inv. em Equipam. (-1)	0,005 [1,208]	0,004 [0,461]	-0,002* [-1,347]	0,006 [1,081]	0,002 [0,243]	-0,002* [-1,676]
Inv. em Equipam. (-2)	0,001 [0,298]	-0,005 [-0,667]	-0,001 [-0,579]	0,002 [0,409]	-0,006 [-0,623]	0,000 [-0,282]
IBCR-CE (-1)				0,212 [0,672]	-0,398 [-0,768]	0,134* [1,672]
IBCR-CE (-2)				0,241 [0,792]	0,692* [1,315]	0,177** [2,135]
R2 ajustado	0,091	0,067	0,342	0,055	0,099	0,412
C. de inf. de Akaike		-10,389			-10,490	

Notes: Time series: 2013q2 – 2023q4, 43 quarterly observations. T-statistic in brackets. * 10% significance, ** 5% significance, *** 1% significance.

of the most vulnerable strata, while negatively impacting the Gini Index in its third shock.

In this regard, the impact of the construction shock on the income of the poorest has a slightly positive result, suggesting potential benefits in job creation and increased demand for labor. The shock to the income of the most advantaged shows a more significant drop, visible in all simulations of this variable. However, there is a partial recovery that causes the value to oscillate on a long-term scale to zero.

Many of the results of the impulse-response functions corroborate the results obtained previously, showing that total investment had a positive influence on the income of the most vulnerable. Although these investments may have momentary redistributive impacts, they do not promote structural changes in income inequality without additional complementary policies in the long term.

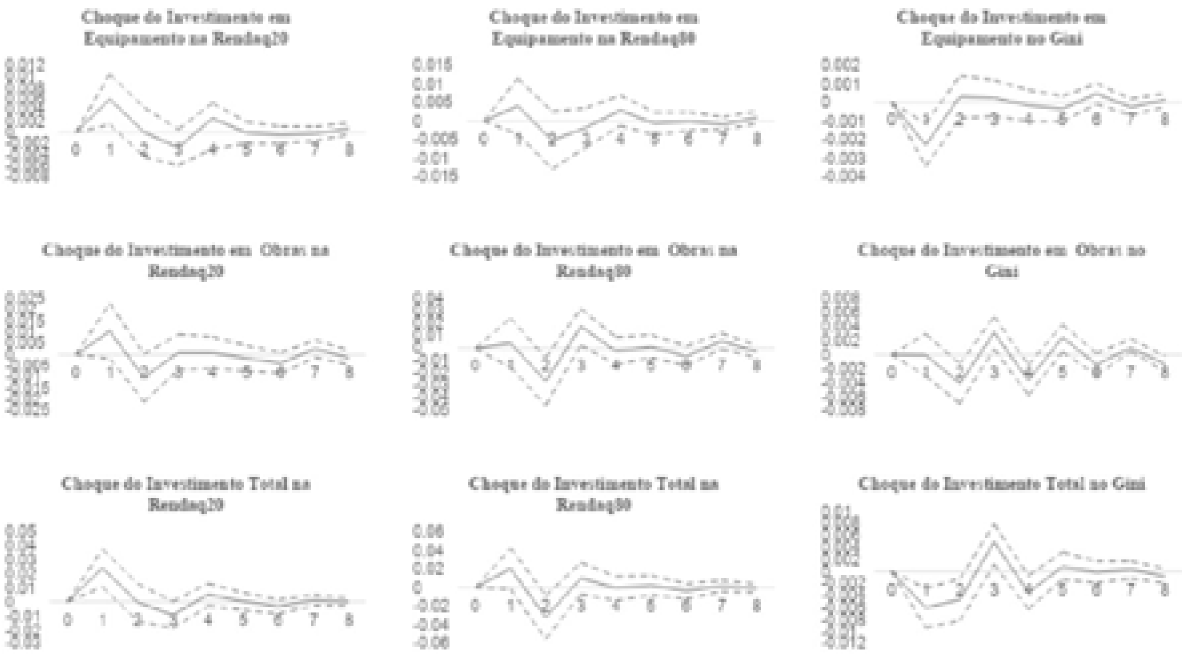
6. CONCLUSION

The results obtained in this study show the fundamental role of public investment in the dynamics of income redistribution. The VAR analysis showed that total investment in Ceará was able to positively influence the income of the most disadvantaged, as well as reduce the Gini index, which measures income inequality in the population, in the short term.

The breakdown of investments in works and facilities, equipment, and permanent materials seen in models 3 and 4 made it possible to identify which types of investment affect social variables. Investments in construction are capable of positively influencing the income of the poorest in the very short term and, conversely, the income of the richest, while investment in equipment reduces income inequality, as measured by the Gini index. Thus, impulse-response functions validate these results through the similar effects of investment shocks.

This same breakdown of public investment in construction and equipment was seen in Ferreira *et al* (2022). The study pointed out that investment in equipment influences tax collection, via ICMS, two years ahead, while investment in construction influences economic activity in Ceará (IBCR-CE), industrial activity, as well as retail sales volume in three years. Furthermore, these investments have the power to influence job creation in the short and medium term.

Figure 5. Impulse Response Functions



Source: Own elaboration.

Meanwhile, the study by Ferreira *et al* (2022) found that public investment affects the social sphere of the state, enabling an increase in average income. In this study, evidence was found confirming that public investment has a significant social impact on the state through a redistributive income policy. Thus, the rearrangement of public investment contributes to improving the income of the less favored segments of the population.

Given these results, public investment policies must be planned in such a way as to maximize their efficiency and achieve the expected social return. To this end, it is necessary that: (i) investments be made in sectors with a high multiplier effect on the economy; (ii) preference be given to sectors that increase capital productivity in order to boost economic growth and stimulate the income of the poorest; and (iii) the private sector be stimulated through the crowding-in effect. In this way, such policies can lift the population out of (extreme) poverty.

For future research, we suggest including the variable of extreme poverty as endogenous in the model in order to conduct a more in-depth analysis of this population group. In addition, we propose the incorporation of new control variables, such as the Monthly Industrial Survey (PIM) on industrial production in Ceará, as well as the employment balance.

BIBLIOGRAPHIC REFERENCES

ABIAD, Abdul; FURCERI, Davide; TOPALOVA, Petia. The macroeconomic effects of public investment: Evidence from advanced economies. Journal of Macroeconomics, 2016. DOI: https://doi.org/10.1016/j.jmacro.2016.07.005

ASCHAUER, D. Is public expenditure productive? **Journal of monetary economics,** Chigaco, v. 23, p.177-200, abr, 1989.

BANCO CENTRAL DO BRASIL. Sistema Gerenciador de Séries Temporais. Disponível em: https://www3.bcb.gov.br/sgspub/localizarseries/localizarSeries.do?method=prepararTelaLocalizarSeries.

BARRO, R. J. Government spending in a simple model of endogenous growth. Journal of Political Economy, v. 98, n. 5, p. 103-125, 1990.

BREDOW, Sabrina Monique Schenato; CUNHA, André Moreira; LÉLIS, Marcos Tadeu Caputi. Investimentos públicos e privados no Brasil entre 1996 e 2018. Revista de Economia Política, v. 42, n. 4, p. 957-976, 2022. DOI: https://doi.org/10.1590/0101-31572022-3273

BUENO, Rodrigo De Losso da Silveira. Econometria de Séries Temporais. São Paulo: Cengage Learning, 2022.

CHATTERJEE, Satyajit; GIBSON, John; RIOJA, Felix. Public investment, debt, and welfare: A quantitative analysis. Journal of Macroeconomics, 2018. DOI: https://doi.org/10.1016/j.jmacro.2018.01.007.

Filho, RH, Matos, P., Cardoso, S., de Jesus Filho, J., Lima, SM, de Almeida Filho, M., & Junior, JA (2022). O trade-off entre investimentos públicos e déficit previdenciário: o caso do governo do Estado do Ceará.

Furceri, Davide e Li, Bin (Grace), The Macroeconomic (and Distributional) Effects of Public Investment in Developing Economies (outubro de 2017). Documento de Trabalho do FMI n.º

17/217, disponível em SSRN: https://ssrn.com/abstract=3067269.

GOVERNO DO CEARÁ. Caderno de Finanças Públicas: Análise da sustentabilidade e dos impactos macroeconômicos da política de investimentos do Governo do Estado do Ceará. Fortaleza: SEFAZ, 2022. DOI: https://doi.org/10.55532/1806-8944.2022.205

HOLANDA FILHO, Raimir; MATOS, Paulo; CARDOSO, Sérgio; *et al***.** The Trade-Off Between Public Investments And Pension Deficit: The Case Of Ceará State Government. IOSR Journal of Business and Management, v. 25, n. 11, p. 43-50, 2023.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Índice Nacional de Preços ao Consumidor Amplo (IPCA). Disponível em: https://www.ibge.gov.br/estatisticas/economicas/precos-e-custos/9256-indice-nacional-de-precos-ao-consumidor-amplo.html.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). Pesquisa Nacional por Amostra de Domicílios Contínua (PNAD Contínua). Disponível em: https://www.ibge.gov.br/estatisticas/sociais/trabalho/17270-pnad-continua.html.

IPECE - Instituto de Pesquisa e Estratégia Econômica do Ceará. IPECE Informe nº 250: A dinâmica da extrema pobreza nos estratos geográficos do Ceará no período de 2012 a 2023. Fortaleza: IPECE, 2024. ISSN: 2594-8717.

IPECE - Instituto de Pesquisa e Estratégia Econômica do Ceará. IPECE *Informe nº 251: Situação Fiscal do Estado do Ceará no ano de 2023*. Fortaleza: IPECE, 2024. ISSN: 2594-8717.

KAHN, Richard F. The relation of home investment to unemployment. *The Economic Journal,* v. 41, n. 161, p. 173-198, 1931.

KEYNES, John Maynard. *A teoria geral do emprego, do juro e da moeda.* Londres: Macmillan, 1936.

MATOS, Paulo; GADELHA, Fabiano Pinto. Determinantes do crescimento econômico das cidades do Estado do Ceará. Fortaleza: Universidade Federal do Ceará, 2021.

MATOS, Paulo; ***et al*****.** Ciclos fiscais e econômicos do estado do Ceará. Revista Brasileira de Economia, 2024.

MORAIS, Gaspar. Investimentos e Crescimento Econômico: uma Análise Empírica. Brasília: Revista de Finanças Públicas, 2014.

MORAIS, Gabriel Alves de Sampaio; ARAÚJO, Jair Andrade; SANTANA, Denise Moreira Araújo de. Análise da decomposição da desigualdade de renda no Estado do Ceará. Revista Ciências Administrativas, Fortaleza, v. 20, n. 2, p. 692-723, jul./dez. 2014.

OCDE (2015), Investimento de Impacto Social: Construindo a Base de Evidências , OECD Publishing, Paris. DOI: https://doi.org/10.1787/9789264233430-en .

OTERO, Jorge David Quintero. Not all sectors are alike: Differential impacts of shocks in oil prices on the sectors of the Colombian economy. Energy Economics, v. 86, 2020. DOI: 10.1016/j.eneco.2020.104691

RICARDO, David. *Princípios de economia política e tributação.* 1817.

SAY, Jean-Baptiste. *Traité d'économie politique*. 1803.

Sun, Dongchu & Ni, Shawn. (2004). Bayesian analysis of vector-autoregressive models with noninformative priors. Journal of Statistical Planning and Inference - J STATIST PLAN INFER. 121. 291-309. 10.1016/S0378-3758(03)00116-2.

Sims, C. A. (1980). Macroeconomics and Reality. Econometrica, 48, 1–48.

SMITH, Adam. *A riqueza das nações*. 1776.

Viana, Mateus & Matos, Paulo. (2024). Ciclos fiscais e econômicos do estado do CearáFiscal and economic cycles in the state of Ceará. Revista Controle - Doutrina e Artigos. 23. 289-316. 10.32586/rcda.v23i1.952.