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Effects of Road Infrastructure Investments on the Local Economic Dynamics of Paraíba

Efeitos de Investimentos em Infraestrutura Rodoviária sobre a Dinâmica Econômica Local da Paraíba

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Abstract
Do public road infrastructure policies have the potential to affect the quality of life and well-being in the regions they target? This study evaluates the impacts of road infrastructure investments on economic activity and labor market indicators in the state of Paraíba, Brazil. The analysis employs a Difference-in-Differences (Diff-in-Diff) methodology with reweighting based on entropy balancing weights, using data from the Paraíba State Department of Highways (DER-PB) for the period 2011 to 2017. Descriptive statistics show that the program invested over R$1.7 billion, improving approximately 3,500 kilometers of roads and benefiting 65% of the municipalities in the state. The econometric results indicate significant effects of the program on net employment, particularly in municipalities previously affected by geographic isolation. Additionally, there was a 13% increase in real GDP and a 16% increase in the gross value added (GVA) of the services sector, both restricted to municipalities that received supplementary infrastructure works.
Keywords: caminhos da paraíba; impact evaluation; difference-in-differences.

Resumo
As políticas públicas de infraestrutura rodoviária possuem potencial de impacto sobre a qualidade de vida e o bem-estar dos locais beneficiados? A pesquisa avalia os impactos de investimentos em infraestrutura rodoviária sobre indicadores de atividade econômica e mercado de trabalho na Paraíba. Emprega-se o método de Diferenças em Diferenças com reponderação pelos pesos do balanceamento por entropia a partir de dados do Departamento de Estradas de Rodagens da Paraíba no período de 2011 a 2017. A descritiva mostrou que o programa já investiu mais de R$1,7 bilhão com cerca de 3,5 mil quilômetros de rodovias melhoradas e 65% dos municípios Paraíbanos beneficiados. Os resultados da análise econométrica indicaram impactos mais expressivos do programa sobre o saldo de emprego, principalmente dos municípios retirados do isolamento. Além disso, verificou-se aumento no PIB real (13%) e no VAB do setor de serviços (16%), ambos restritos aos municípios que receberam obras de suplementação.
Palavras-chave: caminhos da paraíba; avaliação de impacto; diferenças-em-diferenças.

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1. Introduction

The potential impacts of good road infrastructure on individual well-being have driven research in several parts of the world. Studies have been conducted for countries such as the United States (Duranton & Turner, 2012), Spain (Albalate, Fernández & Yarygina, 2013), France (Fritsch & Prud'Homme, 1997), Mexico (Obregón-Biosca, Chávez & Quezada, 2014), India (Ghani, Goswami & Kerr, 2016), Cape Verde (Farinha, 2015), Kenya and South Africa (Lamont & Lee, 2015), among others. Highways are important inputs for several sectors of the global economy. According to Gibbons et al. (2012), freight and passenger road transport dominate the transport structure of most countries.

The quality of road infrastructure is one of the key factors for the economic and social development of any country (Obregón-Biosca, Chávez & Quezada, 2014). Investment in highways can result in several benefits, such as productivity gains in manufacturing and agricultural production, increased safety and reduced travel time, lower traffic intensity, integration of new consumption centers, increased firm profitability, promotion of local economic growth, and improvements in public health (Weitkamp, Martín & Pablo-Marti, 2008; Anantaram, 2010; Albalate & Bel, 2012).

According to Anantaram (2010), investing in road development generates improvements in connectivity and an increase in the supply of economic opportunities. Improvements in road infrastructure reduce transport costs, improve access to markets and employment, promote economic integration, stimulate competition, generate agglomeration economies, among other economic benefits (Gibbons et al., 2019).

Classical contributions within the so-called Location Theories had already emphasized, early on, the importance of minimizing transport costs as a way of explaining the dynamics of economic activity (Christaller, 1933; Dunn, 1954; Lösch, 1954; Isard, 1956). In this context, accessibility and market size emerge as central determinants of firms' locational choices in a market economy (Thünen, 1826; Weber, 1909; Obregón-Biosca, Chávez & Quezada, 2014).

There is also evidence that improvements in transport infrastructure affect employment and firm productivity, increase access to labor markets, lead to changes in trade composition, and improve the organization and efficiency of manufacturing activity (Kelejian & Robinson, 1997; Gibbons et al., 2012; Sanchis-Guarner et al., 2012; Duranton, Morrow & Turner, 2014; Ghani, Goswami & Kerr, 2016). In addition, when implemented in isolated areas, such investments may serve as an important driver of tourism flows, facilitating the movement of people and the creation of new markets.

In order to illustrate how investments in highways can lead to profound changes in local realities, the well-known case of the Gilgit-Baltistan region in Pakistan can be cited. The area was isolated until the construction of a highway that connected it to China. This project enabled the region's connection with the outside world and made it possible for more visitors to choose to visit it, fostering the development of the service sector and greater social inclusion (Hussain, Fisher & Espiner, 2017). Another example occurred in Spain with the construction of the Transversal Axis in the Catalonia region. The project, approximately 154 kilometers in length, influenced territorial organization, population growth, population mobility, and economic development (Obregón-Biosca & Junyent-Comas, 2010).

Turning now to Brazil, Mendes, Teixeira and Salvato (2009), for example, analyzed the effects of this type of investment on total factor productivity (TFP) in agriculture. They observed that infrastructure affects TFP in the early years, with returns occurring within two years. Moreover, investments specifically in road infrastructure showed a greater impact on TFP compared to those made in research, telecommunications, irrigation, and electricity. In the same vein, Cruz, Teixeira and Braga (2010) also indicated a positive impact of improvements in road infrastructure on TFP, thus increasing per capita income. This increase in income ends up influencing development and the creation of a favorable environment for local businesses (Rosa, Melo & Garcia, 2024).

Castro (2016) employed a Difference-in-Differences model with control for spatial dependence to evaluate the impacts of the ProAcesso road infrastructure program on the economic growth of municipalities in the state of Minas Gerais, Brazil. The study found that having the main access road paved did not contribute to the economic growth of municipalities in that region. In turn, Amarante (2017) used panel data to test whether there were impacts from the paving of the interstate highways BR-101 and BR-116 on municipal economic growth. In this case, the GDP growth rate of the benefited municipalities was higher than the average compared to non-benefited ones.

As is well known, Brazil has a vast territorial dimension and is the fifth-largest country in the world, behind only Russia, Canada, the United States, and China. The country has 1,435,856 kilometers of road network, of which 94.7% are state and municipal roads, and only 5.3% are federal highways (Lessa, 2017). According to the Statistical Yearbook of Transport 2010–2016 of the Ministry of Transport, Ports, and Civil Aviation, investments totaling 8 billion Brazilian reais were made in road works in 2017 alone, with 61.25% (4.9 billion reais) allocated to maintenance, 22.5% (1.8 billion reais) to capacity expansion, and 16.25% (1.3 billion reais) to construction and paving (Lessa, 2017).

In the wake of this process, the Caminhos da Paraíba program, implemented in the state of Paraíba in 2011, invested approximately 1.7 billion Brazilian reais over six years, improving more than three thousand kilometers of roads. The program benefited 145 municipalities and carried out 178 projects that changed the dynamics of road transportation in the state. Essentially, the program connected all municipalities in Paraíba to the state and/or federal road network, removing 53 cities from isolation by 2017. There were improvements in transport logistics, in addition to providing greater safety for drivers and reducing freight and passenger transport costs.

In view of this, the present research aims to analyze the effects of investments in road infrastructure provided by the Caminhos da Paraíba program on indicators of economic dynamics in the benefited municipalities. Data on the interventions were obtained from the Departamento de Estradas de Rodagem da Paraíba (DER-PB), including information on the municipalities served, the type of work carried out, the start and end periods of the interventions, as well as the amounts invested and the length of the works performed. In addition, the Difference-in-Differences method (Difference-in-Differences – Diff-in-Diff) was used with reweighting by entropy balancing weights. Diff-in-Diff is widely recognized in the economic literature as a robust strategy for identifying causal effects of government programs (Abadie, 2005). Finally, this approach allows for comparing the evolution of indicators between benefited and non-benefited groups, controlling for common time trends and unobserved heterogeneity.

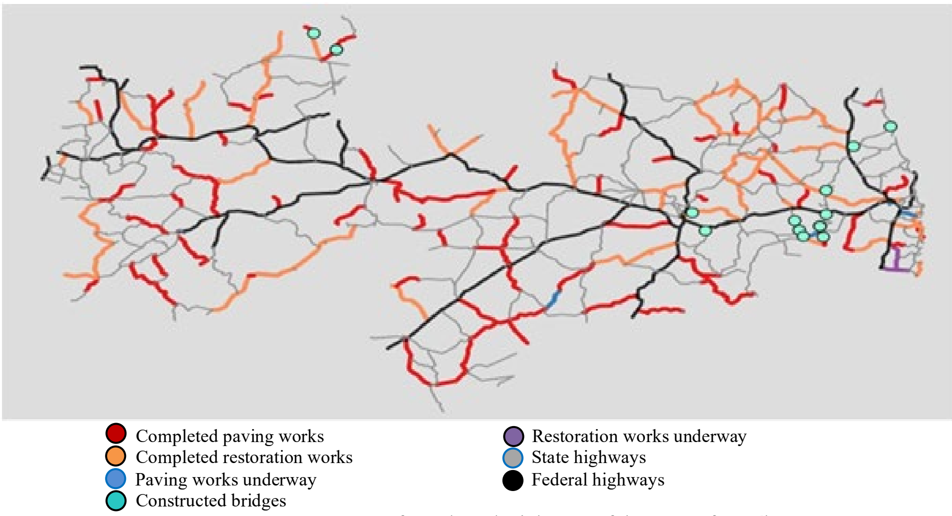
In addition to this introduction, the article is structured into four more sections. Section 2 presents the Caminhos da Paraíba program in detail, explaining its implementation and the volume of invested resources. Section 3 presents the methodological framework of the study. Section 4 presents and discusses the results. Finally, Section 5 discusses the conclusions of the study.

2. The Caminhos da Paraíba Program

The Caminhos da Paraíba program was an initiative of the State Government aimed at reducing deficiencies in Paraíba's road infrastructure. The idea emerged from a diagnostic study conducted in 2011 by DER-PB, the agency responsible for the management of the state highway network. The DER study revealed the very poor conditions of Paraíba's road network. Even in municipalities whose main access road was paved, roads often suffered from natural wear over time, lack of maintenance, inadequate signage, and low accessibility (e.g., absence of duplication, bridges, viaducts, roundabouts). Figure 1 illustrates the distribution of Caminhos da Paraíba projects between 2011 and 2017, divided into three categories: paving works, restoration works, and constructed bridges, indicating whether they were completed or underway.

Figure 1

Distribution of the Works of the Caminhos da Paraíba Program



Source: Department of Roads and Highways of the State of Paraíba.

The program prioritized investments in the implementation, expansion, modernization, restoration, and rehabilitation of road segments, aiming to improve logistics for both passenger and freight transport within the state. The main objective was to enhance traffic quality and flow on state highways and, above all, to remove 54 municipalities from isolation, which until 2011 lacked paved access roads. These localities were previously accessible only via dirt roads, which were highly vulnerable to adverse weather conditions. The program aimed to establish permanent connections between these municipalities and the state or federal highway network, or even with neighboring municipalities. This lack of infrastructure affected more than 300,000 inhabitants, generating losses for users and local economies due to high transport costs, which increased production expenses and commodity prices (DER-PB, 2017). Furthermore, the absence of adequate roads discouraged social actors such as entrepreneurs, healthcare professionals (doctors, nurses, dentists), teachers, and others, negatively impacting local socioeconomic development.

The program invested more than R$ 1.7 billion between 2011 and 2017, improving approximately 3,433 km of highways. By 2017, a total of 145 municipalities had benefited, representing 65% of the state's municipalities. The program's projects are divided into three main categories, hereinafter referred to as types of treatment: I – paving works[1]; II – restoration works[2]; and III – supplementation works[3].

The Caminhos da Paraíba program features these different types of treatment (Types I, II, and III), and in some cases, the same municipality received more than one type of intervention. In this context, 178 projects were completed by 2017, including 53 paving works, 71 restoration works, and 54 supplementation works. Table 1 presents information on the length of the projects and the amount of investment by type of treatment.

The 43 municipalities treated under Type I account for almost 30% of the beneficiaries. Meanwhile, Type II (48 municipalities) and Type III (21 municipalities) treatments represent approximately 33% and 14.5%, respectively. In addition, 33 municipalities received more than one type of treatment: 10 municipalities were treated under Types I and III, and 23 municipalities under Types II and III, representing 6.9% and 15.86% of the municipalities treated during the period, respectively.

Table 1

Overall Data of the Caminhos da Paraíba Program

	Treatment		**Extension**		**Investment**		**Cost/km**
	Absolute Frequency	**%**	**Km**	**%**	**Million R$**	**%**	**R$ million/km**
Type I	43	29.66	905.30	26.37	692.69	40.43	0.765
Type II	48	33.10	1,798.40	52.38	410.92	23.87	0.228
Type III	21	14.48	287.60	8.38	187.50	10.89	0.652
Type I e II	0	0.00	0.00	0.00	0.00	0.00	0.000
Type I e III	10	6.90	113.09	3.29	101.78	5.91	0.900
Type II e III	23	15.86	328.76	9.58	328.76	19.10	1.000
Type I, II e III	0	0.00	0.00	0.00	0.00	0.00	0.000
Treated	145	65.02	-	-	-	-	-
Not treated	78	34.98	-	-	-	-	-
Total	223	100	3,433.15	100	1,721.64	100	-

Source: Authors' own elaboration based on DER-PB data.

Table 2 shows the descriptive statistics, with restoration works (Type II) presenting the highest average length (37.47 km), followed by paving works (Type I). In turn, supplementation works (Types I and III; Types II and III) show average lengths of 11.31 km and 14.29 km of highways, respectively. The average cost per kilometer was higher for paving works, as these projects generally start from scratch[4], whereas restoration projects build upon existing infrastructure, reducing costs. Supplementation works resemble paving projects in that many also start from scratch, such as viaducts or bridges.

1 Type I - Municipality that did not yet have its main access road paved.
2 Type II - Municipality whose main access road was paved but in poor condition (requiring resurfacing works).
3 Type III - Municipality whose main access road was paved and in good condition, but was benefited by duplication, rehabilitation, signage, viaducts, low-water crossings, interchanges, among other improvements.
4 Average expenditure per kilometer (R$ million/km): Type I – 0.765; Type II – 0.228; Type III – 0.652.

Table 2

Caminhos da Paraíba Program: Descriptive Statistics by Type of Treatment

	Length of the road project (km)				**Investment (R$ million)**			
	Mean	**SD**	**Min.**	**Max.**	**Mean**	**SD**	**Min.**	**Max.**
Type I	21.05	17.30	2.00	69.70	16.11	17.19	1.25	66.05
Type II	37.47	27.25	1.50	116.10	8.50	8.28	0.43	37.38
Type III	13.69	10.77	0.10	35.90	8.93	8.04	0.35	33.62
Type I and III	11.31	9.47	3.20	32.26	11.31	9.32	3.24	32.26
Type II and III	14.29	13.95	1.24	66.05	14.29	13.93	1.24	66.05
Total	23.70	22.00	0.10	116.10	11.95	12.01	0.35	66.05

Source: Authors' own elaboration based on DER-PB data.
Note: Type I – Removed from isolation; Type II – Restoration; Type III – Supplementation.

Finally, an important point is that municipalities' participation in the program occurs heterogeneously, with units becoming treated at different points in time[5]. In this article, a municipality is considered treated only from the completion of the project onward, since during the execution of the works the municipality still faces traffic problems similar to those observed in the pre-intervention period[6].

3. Methodological Aspects

This section describes the methodological aspects of the study, detailing the procedures employed to identify the effects of the Caminhos da Paraíba program on income and employment indicators (outcomes) in the treated municipalities.

3.1 Data Sources and Description of Variables

The study's database consists of a panel of the 223 municipalities in the state of Paraíba observed between 2007 and 2017, totaling 2,453 observations. Information on the Caminhos da Paraíba program was obtained from DER-PB. The data indicate which municipalities were benefited and the type of work carried out, in addition to detailing the start and end dates of each project, as well as the amount invested and the length of the project.

In order to assess the impact of the program, municipal indicators of economic activity and labor market conditions were used (Table 3). As previously discussed, reductions in transport costs, productivity gains, and greater employment dynamics are associated with improvements in road infrastructure (Obregón-Biosca, Chávez & Quezada, 2014; Gibbons et al., 2019).

[5] Municipalities treated under the Caminhos da Paraíba program between 2011 and 2017 were distributed as follows: 2011 (4.14%), 2012 (19.31%), 2013 (15.17%), 2014 (15.86%), 2015 (22.07%), 2016 (8.97%), and 2017 (14.48%).

[6] Roads under construction still exhibit low traffic speeds, high freight and vehicle maintenance costs, detours, stops, operating machinery, and related disruptions.

Table 3

Outcome Indicators

Code	Description	Source
Real GDP	Logarithm of real Gross Domestic Product	IBGE
Industrial GVA	Logarithm of real Gross Value Added of the industrial sector	IBGE
Services GVA	Logarithm of real Gross Value Added of the services sector	IBGE
Employment Balance	Net job flows in the labor market	CAGED
Wage Bill	Logarithm of the real wage bill of workers	CAGED

Source: Authors' own elaboration.
Note: IBGE – Brazilian Institute of Geography and Statistics; CAGED – Cadastro Geral de Empregados e Desempregados.

To measure the impacts of the policy on economic performance, Gross Domestic Product (GDP) and Gross Value Added (GVA) in the services and industrial sectors were selected. In addition, to capture the effects on the labor market, net employment flows and the wage bill were used. GDP and GVA data for the industrial and services sectors were deflated using the IGP-DI, while the wage bill was deflated using the INPC, with 2017 as the base year.

To control for municipal heterogeneity and obtain a more homogeneous sample in terms of observable characteristics, a balancing procedure was carried out using the variables described in Table 4. The covariates related to political alignment and the share of votes received by the elected governor are intended to control for political factors that may be associated with the selection of municipalities into the program. Municipalities where the mayor is politically aligned with the governor, as well as those in which the governor received a substantial vote margin, have a higher probability of receiving the treatment. The remaining variables are included to control for municipal population size, urban well-being characteristics, and regional specificities.

Table 4

Control Variables for Balancing

Code	Description	Source
Political alignment	Dummy variable equal to 1 if the mayor belongs to the governor's political coalition; 0 otherwise	TSE
Share of votes for elected governor	Proportion of votes received by the elected governor	TSE
Population	Logarithm of population	IBGE
Water supply and sanitation	Proportion of individuals with inadequate water supply and sanitation services	IBGE
Extreme poverty	Proportion of individuals living in extreme poverty	IBGE
Meso-region	Meso-region dummy variables	IBGE

Source: Authors' own elaboration.
Note: TSE – Tribunal Superior Eleitoral (Superior Electoral Court).

3.2 Difference-in-Differences with Entropy Balancing

The Difference-in-Differences (Diff-in-Diff) method is widely used in studies evaluating the impact of public policies and social programs (Abadie, 2005). The method is appropriate for evaluating natural experiments or quasi-experiments, in which an exogenous change occurs in the decision-making environment of individuals, households, firms, and other agents (Wooldridge, 2010).

The application of the Diff-in-Diff approach requires the availability of information for at least one period before and one period after the implementation of the program, for both treated and control groups. The main assumption of the method is that the time path of the outcome variable for the control group represents the counterfactual of what would have happened to the treatment group in the absence of the program. Therefore, in the absence of treatment, both groups would have evolved in parallel, so that deviations from parallel trends indicate the impact of the program (Athey & Imbens, 2006; Cameron & Trivedi, 2005). Estimation is performed using a fixed effects model, according to the following specification:

$$y_{it,k} = \sum_j \beta_{j,k} Program_{j,it} + \alpha_i + \lambda_t + \epsilon_{it,k} \qquad (1)$$

Where: $y_{it,k}$ corresponds to outcome indicator k for municipality i at time t; Program is a dummy variable equal to 1 if municipality i at time t received treatment type j; α_i is the municipality fixed effect; λ_t represents time dummies; and $\epsilon_{it,k}$ is the random error term. The estimated parameters $\widehat{\beta}_{j,k}$ provide the average effects (ATTs) of the five treatment types of the Caminhos da Paraíba program on the outcomes of interest.

Abadie (2005) emphasizes that the parallel trends assumption is difficult to satisfy in practice, especially due to the heterogeneity between treatment and control groups with respect to pre-treatment characteristics associated with the dynamics of the outcome of interest. In order to minimize this problem, the literature has commonly combined *Diff-in-Diff* with some matching method (Heckman, Ichimura & Todd, 1998; Hirano, Imbens & Ridder, 2003). Hainmueller (2012), for example, proposed multivariate reweighting, called entropy balancing. The procedure consists of reweighting the units in the control group so that they match, as closely as possible, the moments of the covariates of the treated units. In this way, a dataset balanced in observable characteristics is obtained. As a result, the sample becomes more balanced, with the potential effect of reducing bias in the estimation of the treatment impact. To understand the method more formally, following Hainmueller and Xu (2013), consider the estimated counterfactual mean given by:

$$E[\widehat{Y(0)|D} = 1] = \frac{\sum_{\{i|D=0\}} Y_i d_i}{\sum_{\{i|D=0\}} d_i} \qquad (2)$$

A fairly common procedure is to assign to each unit in the control group a weight given by $d_i = \frac{\hat{p}(x_i)}{1-\hat{p}(x_i)}$, where $\hat{p}(x_i)$ is the propensity score estimated parametrically (for example, through a logit or probit model).

However, if there is misspecification in the estimation of the propensity score, the covariates will not be adequately balanced between the groups, which may lead to bias in the estimation of the treatment effect. Entropy balancing seeks to address this problem by generalizing the propensity score approach through the direct estimation of weights and by considering a set of balancing constraints on moment conditions (Hainmueller & Xu, 2013). Thus, the estimated counterfactual mean becomes:

$$E[\widehat{Y(0)|D} = 1] = \frac{\sum_{\{i|D=0\}} Y_i w_i}{\sum_{\{i|D=0\}} w_i} \qquad (3)$$

where W_i is the entropy balancing weight for each unit in the control group. The weights are defined through a reweighting scheme that minimizes the entropy distance metric:

$$\min_{w_i} H(w) = \sum_{\{i|D=0\}} w_i log\, w_i/q_i \quad (4)$$

Subject to the following constraints:

$$\sum_{\{i|D=0\}} w_i C_{ri}(X_i) = mr, \qquad com\, r\ \in 1, \dots, R \quad (5)$$

$$\sum_{\{i|D=0\}} w_i = 1 \quad (6)$$

$$wi \geq 0\ \forall\ i \text{ such that } D = 0 \quad (7)$$

Where: $q_i = 1/n_0$ is the base weight, and c_{ri} (X_i) describes the set of R balancing constraints imposed on the moments of the covariates in the control group (Hainmueller & Xu, 2013).

The first step in implementing entropy balancing is the selection of the covariates to be included in the reweighting scheme. Next, for each covariate, the researcher specifies a set of balancing constraints, as shown in equation (5), in order to match the moments of the distributions of these variables between the treatment group and the reweighted control group. The available moment constraints are the mean, variance, and skewness.

Entropy balancing seeks a given set of weights $W = [w_i, \dots, w_{n0}]^T$ that minimizes equation (4), that is, the entropy distance between W and the base weight vector $Q = [q_i, \dots, q_{n0}]^T$, subject to the balancing constraint in equation (5), the normalization constraint in equation (6), and the non-negativity constraint in equation (7). Finally, the treatment effect is estimated (for example, through a regression model) using the obtained weights as a data reweighting factor. Treated units receive weight 1, whereas control group units receive weights $w_i, \dots, w_{n0}$.

4. Results

This section presents and discusses the results of the descriptive and impact evaluations, based respectively on the naïve assessment and on the estimates obtained from the econometric models.

4.1 Homogeneous Treatment Effects

Table 5 presents the mean differences for the indicators of interest between municipalities that received projects under the Caminhos da Paraíba program (treated) and those that did not (control). The descriptive results indicate positive and statistically significant difference in favor of the treated units for most outcomes.

Despite the restrictions and limitations inherent in this type of analysis, there is preliminary evidence that the program improved some indicators of economic activity and labor market performance in the treated municipalities. However, it is also important to examine whether these effects change over time and whether they differ across the various regions of the state. Thus, this initial overview of the program helps to better understand the dynamics of the program's homogeneous effects over time and across space.

Table 5

Mean Differences Between Treated and Control Municipalities: Caminhos da Paraíba Program

Indicador	A	B	(A-B)
Real GDP	11.284	11.178	0.106*
Industrial GVA	8.354	8.177	0.177**
Services GVA	9.802	9.677	0.125*
Employment Balance	14.472	1.419	13.052
Wage Bill	11.030	10.819	0.211*

Source: Authors' own elaboration based on data from DER-PB, IBGE, and CAGED.
Note[1]: A = Treated; B = Control. *Note*[2]: ***p <0.01; **p <0.05; *p <0.1.

Table 6 advances the analysis by capturing the mean differences between treated and control municipalities across different time horizons. This is important because it helps to better understand the effects of investment maturation over time. The gradual incorporation of additional time periods reveals three findings: (i) the mean difference between treated and control groups increases over time; (ii) a larger number of outcome variables become statistically significant over time; and (iii) the analysis based on homogeneous effects shows that there is no significant difference in employment balance over longer periods.

Paraíba has 223 municipalities distributed across 23 microregions [7] and four mesoregions[8]. Differences in the program's effects were also analyzed by mesoregion, since these regions exhibit substantial heterogeneity in aspects such as climate, population, income, labor market conditions, and production.

The Zona da Mata mesoregion presents characteristics that are more favorable to the business environment. The greater João Pessoa region, for example, is composed of the municipalities of Bayeux, Cabedelo, João Pessoa, and Santa Rita. It is an area with infrastructure favorable to the circulation of goods and services, an important consumer market within the state, and the presence of a port, an airport, important industrial districts, service-sector firms, and distribution centers. The region exhibits the highest levels of economic, human, and social development within the state, with greater urbanization, income, and employment, while concentrating a significant number of hospitals, schools, universities, and other institutions.

Table 7 presents the results of the mean difference tests by mesoregion. In other words, the objective is to assess how differences in local characteristics shaped the impacts of the Caminhos da Paraíba program across regions. The results indicate that the program does not affect all regions in the same way. In particular, no statistically significant effects were found on economic activity or labor market indicators in the Agreste mesoregion.

7 Microregions of Paraíba in alphabetical order: Brejo Paraíbano, Cajazeiras, Campina Grande, Cariri Ocidental, Cariri Oriental, Catolé do Rocha, Curimataú Ocidental, Curimataú Oriental, Esperança, Umbuzeiro, Guarabira, Itabaiana, Itaporanga, João Pessoa, Litoral Norte, Litoral Sul, Sapé, Patos, Piancó, Seridó Ocidental, Seridó Oriental, Serra do Teixeira, and Sousa.
8 Mesoregions of Paraíba in alphabetical order: Agreste, Borborema, Sertão, and Zona da Mata.

In the Borborema and Sertão mesoregions, the program negatively affected economic activity. By contrast, in the Zona da Mata mesoregion, the results are positive and statistically significant for both economic activity indicators and the wage bill, although no statistically significant effect was observed for employment balance.

The observed mesoregional differences may reflect pre-existing infrastructure in these areas, since it can positively influence firm location, job creation, production, and municipal income over time. Thus, investment in road infrastructure in a region where the business environment is already better organized may generate stronger effects compared with other regions, particularly in terms of economic activity and labor market outcomes.

In addition, this mesoregional division highlights other important local factors that may also influence production and labor relations, such as rainfall patterns, temperature, pollution, and culture. However, in order to obtain more robust evidence regarding the impacts of this intervention, it is necessary to rely on methods that allow better identification of the effects of the program's actions on the outcome indicators.

Table 6

Mean Difference Test by Period (Caminhos da Paraíba Program)

	2011-2013			2011-2015			2011-2017		
	A	**B**	**(A-B)**	**A**	**B**	**(A-B)**	**A**	**B**	**(A-B)**
Real GDP	11.214	11.114	0.100	11.262	11.159	0.103	11.284	11.178	0.106*
Industrial GVA	8.305	8.141	0.164	8.348	8.182	0.165*	8.354	8.177	0.177**
Services GVA	9.662	9.547	0.115	9.750	9.628	0.122	9.802	9.677	0.125*
Employment Balance	81.232	9.795	71.437**	41.323	5.923	35.399	14.472	1.419	13.052
Wage Bill	10.986	10.784	0.202	11.055	10.817	0.238*	11.030	10.819	0.211*

Source: Authors' own elaboration based on data from DER-PB.
Note[1]: A = Treated; B = Control. *Note*[2]: ***p <0.01; **p <0.05; *p <0.1.

Table 7

Mean Difference Test by Mesoregion (Caminhos da Paraíba Program)

	Agreste			Borborema			Sertão			Zona da Mata		
	A	**B**	**(A-B)**	**A**	**B**	**(A-B)**	**A**	**B**	**(A-B)**	**A**	**B**	**(A-B)**
Real GDP	11.508	11.394	0.1137	10.658	11.042	-0.386***	10.898	11.085	-0.187**	12.924	11.106	1.818***
Industrial GVA	8.572	8.411	0.1602	7.598	8.185	-0.587***	7.784	8.026	-0.242**	10.726	8.112	2.614***
Services GVA	9.999	9.880	0.119	9.117	9.591	-0.473***	9.404	9.635	-0.231**	11.637	9.439	2.197***
Employment Balance	21.551	-1.970	23.521	1.895	1.143	0.752	14.366	2.177	12.188	21.609	6.792	14.817
Wage Bill	11.383	11.281	0.102	9.948	10.812	-0.862***	10.240	10.352	-0.112	14.073	11.180	2.893***

Source: Authors' own elaboration based on data from DER-PB, IBGE, and CAGED.
Note[1]: A = Treated; B = Control. *Note*[2]: ***p <0.01; **p <0.05; *p <0.1.

4.2 Entropy Balancing

Table 8 presents the entropy balancing results for the selected covariates. As can be observed, the method was successful in adjusting both the mean and the variance for all variables, with values becoming very similar between the treatment and control groups. Therefore, the weights obtained through this procedure provide a balanced sample in terms of observable factors for estimating the program's effects.

The homogeneous impacts of the Caminhos da Paraíba program on economic activity and labor market indicators (Table 9) are presented in two models: type (1), corresponding to the standard Diff-in-Diff approach, and type (2), which incorporates reweighting using entropy balancing weights. However, in the estimated models, the outcomes are not statistically significant.

The homogeneous effects strategy neglects the existence of multiple treatments within the Caminhos da Paraíba program. In this case, only treated and control groups are considered, regardless of the type of treatment received. However, as previously shown, this strategy does not appear capable of capturing the true impacts of the intervention. Thus, the results presented so far indicate the need to rely on statistically more appropriate strategies, particularly those capable of incorporating the existence of multiple treatments.

Table 8

Entropy Balancing Results

	Treatment Group		**Control Group**	
Variable	**Mean**	**Variance**	**Mean**	**Variance**
Political coalition	0.807	0.157	0.808	0.157
Vote share for the elected governor	50.600	118.400	50.630	118.500
Population	9.023	1.141	9.028	1.142
Water supply and sanitation	18.900	187.200	18.910	187.300
Extreme poverty	19.470	51.190	19.480	51.230
Mesoregion (Sertão)	0.345	0.224	0.345	0.229
Mesoregion (Borborema)	0.234	0.181	0.234	0.182
Mesoregion (Agreste)	0.290	0.207	0.289	0.208
Number of observations	145		78	

Source: Authors' own elaboration based on data from DER-PB, IBGE and TSE.

Table 9

Effects of the Caminhos da Paraíba Program on Economic Activity and Labor Market Indicators

	Real GDP		**Industrial GVA**		**Services GVA**		**Employment Balance**		**Wage Bill**	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Program	0.0128	0.0049	0.0166	-0.0036	0.0204	0.0176	-63.2688	-36.6799	-0.0541	-0.0418
Municipality fixed effects	x	x	x	x	x	x	x	x	x	x
Time fixed effects	x	x	x	x	x	x	x	x	x	x
Entropy balancing	-	x	-	x	-	x	-	x	-	x

Source: Authors' own elaboration based on data from DER-PB, IBGE, and CAGED.
Note: ***p <0.01; **p <0.05; *p <0.1.

4.3 Heterogeneous Treatment Effects

Table 10 reports the estimated impacts of the Caminhos da Paraíba program on economic activity and labor market indicators. Model (1), corresponding to the standard Diff-in-Diff specification, whereas type (2) models incorporate reweighting using balancing weights. It is important to emphasize that the effects were estimated by separately incorporating the different treatment types of the program, in order to identify which types of interventions may be considered more effective.

The results with and without balancing differ for most outcomes, indicating, as expected, that the parallel trends assumption cannot be considered satisfied. In this case, the analysis should prioritize type (2) models, since entropy balancing allows for more reliable comparisons between groups, given that it satisfactorily adjusted the means and variances of the covariates.

With this in mind, the results indicate an average increase of approximately 13% in the real GDP of municipalities that received type III treatment (supplementation works). It is worth noting that these municipalities started from a more favorable initial condition, as they already had a fully functioning road system, facing only bottlenecks that emerge over time and that can be mitigated through specific works (duplication, overpasses, access roads, and junctions). Thus, it is understandable that removing these constraints leads municipalities to experience significant income gains. For the other treatment types, however, a longer maturation period is required before municipalities begin to experience the benefits of the interventions. Regarding the maturation period of transport infrastructure investment, Ferreira (1998) points to a positive relationship between transport infrastructure and output only in the long run.

Castro (2016) observed that, for municipalities in Minas Gerais, having their main access road paved – which in the Caminhos da Paraíba program corresponds to type I treatment (paving works) – did not appear to contribute to economic growth. It is likely that more time is needed before changes in the local economic dynamics occur, including the attraction of new industries and the expansion of trade and other service sector activities, so that any impact can eventually be observed.

Furthermore, much of the impact of road improvements may be redistributive in nature. In this sense, a road investment connecting a peripheral (less-developed) region to a central (more-developed) region may lead to the migration of economic activity from the periphery to the center, rather than the intended effect of promoting the migration of activity from the center to the periphery (Holvad & Preston, 2005). Positive and negative effects arising from these externalities may offset each other, ultimately neutralizing the impact of transport infrastructure investments on the local economic growth rate (Holvad & Preston, 2005; Castro, 2016).

No significant impact of the program was found for the industrial sector. In this case, such results may arise because other factors are equally or more relevant to industrial expansion than road infrastructure. Issues such as access to raw materials, availability of skilled labor, the local consumer market, tax incentives, and urban infrastructure are crucial for attracting new industries or encouraging expansion decisions.

Regarding the services sector, supplementation works again showed significant effects. Specifically, type III investments led to a 16% increase in the gross value added (GVA) of this sector. This result likely drove the GDP growth observed in the treated municipalities. As previously discussed, road quality is associated with productivity gains, increased firm profitability, and changes in trade composition.

Labor market indicators show a substantial improvement in the employment balance of the treated units. Municipalities benefiting from type I, type II, and combined type I and III works registered significant increases in employment levels compared with untreated municipalities. Units that received type I treatment (those previously isolated) gained approximately 87 new jobs—a particularly important result for small municipalities with low economic dynamism. Therefore, this provides evidence that infrastructure improvements can stimulate local employment and promote some reorganization of production within existing firms (Gibbons et al., 2019), enhancing connectivity and expanding economic opportunities (Anantaram, 2010).

According to Weitkamp, Martín, and Pablo-Marti (2008), the most significant social benefit of transport infrastructure investment projects is travel-time savings. Improvements in a region's road infrastructure reduce the opportunity costs of accessing new job opportunities through two mechanisms: (i) workers can leave their municipality to access other labor markets; and (ii) workers from other regions can also access the local labor market at relatively lower costs. Consequently, reductions in travel time between regions have direct effects on the effective size of the labor market (Sanchis-Guarner et al., 2012) and on municipal employment levels (Duranton & Turner, 2012).

Table 10

Effects of the Caminhos da Paraíba Program on Economic Activity and Labor Market Indicators by Type of Treatment

	Real GDP		**Industrial GVA**		**Services GVA**		**Employment Balance**		**Wage Bill**	
	(1)	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**	**(1)**	**(2)**
Type I	-0.013	-0.008	0.455	0.032	0.028*	0.041	61.744*	86.469**	-0.056	0.045
Type II	0.023	0.023	0.047	0.036	0.020	0.026	59.715*	82.104**	0.026	0.046
Type III	0.045	0.128**	0.007	0.079	0.044	0.160*	-26.637	10.875	-0.273*	-0.276
Type I and III	0.009	0.015	0.099	0.122	-0.005	0.013	61.702*	85.151**	-0.171	-0.108
Type II and III	0.026**	0.028	-0.023	-0.036	0.037	0.047	-470.139	-448.167	0.084	0.086
Municipality fixed effects	x	x	x	x	x	x	x	x	x	x
Time dummies	x	x	x	x	x	x	x	x	x	x
Entropy balancing	-	x	-	x	-	x	-	x	-	x
Number of observations	2,453	2,453	2,453	2,453	2,453	2,453	2,453	2,453	2,453	2,453

Source: Authors' own elaboration based on data from DER-PB, IBGE, and CAGED.
Note: ***p <0.01; **p <0.05; *p <0.1.

5 Conclusions

Road infrastructure investment programs focused on state highway networks are rare in Brazil. In the state of Paraíba, a program for the construction and improvement of highways, Caminhos da Paraíba, was launched in 2011. The initiative aimed to improve the quality of life of Paraíba's population and provide paved road access to 54 isolated municipalities across different regions of the state.

This study sought to evaluate the impacts of the program on economic activity and labor market indicators in the municipalities targeted by the intervention. The identification strategy employed the Diff-in-Diff method with reweighting using entropy balancing weights. Data were obtained from the Department of Roads (DER) of Paraíba, covering the period from 2011 to 2017.

The Caminhos da Paraíba program invested more than BRL 1.7 billion between 2011 and 2017, improving approximately 3,500 kilometers of highways. By 2017, 145 municipalities had benefited, representing 65% of Paraíba's municipalities, with 178 projects completed: 53 paving works, 71 restoration works, and 54 supplementation works.

The results indicate that the hypothesis of a positive relationship between road infrastructure investment and economic growth cannot be rejected. However, the most significant impacts were observed on employment in the treated municipalities, particularly in those that received paving works and were removed from isolation, resulting in approximately 87 new formal jobs. Municipalities benefiting from restoration works (Type II) and combined paving plus supplementation works (Type I and III) showed employment gains of approximately 82 and 85 new jobs, respectively.

Moreover, increases were also observed in real GDP (13%) and the services sector GVA (16%), with both results restricted to municipalities that received supplementation works (such as road duplication, overpasses, access ramps, junction improvements, and bypasses). It is worth noting that these municipalities already had more favorable conditions for the business environment, even before the program's intervention.

Nevertheless, it is important to interpret these findings with caution, primarily because of potential selection bias that may persist despite the methodological strategy adopted. In addition, the estimated effects refer to short-term changes and derive from a partial equilibrium analysis. As such, there may be general equilibrium effects, or even spatial spillovers, that could not be controlled for and should be addressed in future research.

The findings provide important insights for the design and redesign of public policies related to road infrastructure. It was observed that the impacts of such interventions tend not to be homogeneous across beneficiaries; that is, the effects may vary depending on the pre-existing infrastructure in the treated municipalities.

Finally, although the results are not uniformly robust, they should serve as motivation for further research, particularly to explore additional outcomes in this important field. Future studies could also examine the effects of these investments on education, health, crime, traffic accidents, and wildlife in the treated regions.

References

Abadie, A. (2005). Semiparametric difference-in-differences estimators. *The Review of Economic Studies, 72*(1), 1–19.

Albalate, D. & Bel, G. (2012). Motorways, tolls and road safety: evidence from Europe. *SERIEs, 3*(4), 457–473.

Albalate, D., Fernández, L. & Yarygina, A. (2013). The road against fatalities: Infrastructure spending vs. regulation? *Accident Analysis & Prevention, 59*, 227–239.

Amarante, A. de. (2017). Infraestrutura e crescimento econômico regional: o efeito da pavimentação de rodovias interestaduais sobre a atividade econômica municipal na região sul do brasil. *Revista Catarinense de Economia, 1*(1).

Anantaram, R. (2010). Developing India's surface transport capability: The case of road infrastructure. *Elcano Newsletter, 65*, 7.

Athey, S. & Imbens, G. W. (2006). Identification and inference in nonlinear difference-in-differences models. *Econometrica, 74*(2), 431–497.

Cameron, A. C. & Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge University Press.

Castro, L. (2016). *Crescimento econômico e infraestrutura: o impacto do PROACESSO em Minas Gerais* [Doctoral dissertation, Universidade Federal de Viçosa].

Christaller, W. (1933). *Die Zentralen Orte In Süddeutschland. Eine ökonomisch-geographische Untersuchung über die Gesetzmässigkeit der Vorbreitung und Entwicklung der Siedlungen mit städtischen Funktionen*. Gustav Fischer Verlag.

Cruz, A. C., Teixeira, E. C. & Braga, M. J. (2010). Os efeitos dos gastos públicos em infraestrutura e em capital humano no crescimento econômico e na redução da pobreza no brasil. *Revista Economia, 11*(4), 163–185.

DER-PB. (2017). *Caminhos da Paraíba, isolamento nunca mais*.

Dunn, E. S. (1954). *The location of agricultural production*.

Duranton, G., Morrow, P. M. & Turner, M. A. (2014). Roads and trade: Evidence from the US. *Review of Economic Studies, 81*(2), 681–724.

Duranton, G. & Turner, M. A. (2012). Urban growth and transportation. *Review of Economic Studies, 79*(4), 1407–1440.

Farinha, L. M. P. (2015). O plano rodoviário de cabo verde de 1962: Génese e evolução. *Revista Portuguesa de História, 46*, 327–346.

Ferreira, P. C. & Malliagros, T. G. (1998). Impactos produtivos da infraestrutura no Brasil – 1950/95. *Pesquisa e Planejamento Econômico, 28*(2), 315–338.

Fritsch, B. & Prud'homme, R. (1997). Measuring the contribution of road infrastructure to economic development in France. In *The econometrics of major transport infrastructures* (pp. 45–67). Springer.

Gertler, P. J., Martinez, S., Premand, P., Rawlings, L. B. & Vermeersch, C. M. J. (2015). *Avaliação de impacto na prática*. World Bank Publications.

Ghani, E., Goswami, A. G. & Kerr, W. R. (2016). Highway to success: The impact of the golden quadrilateral project for the location and performance of Indian manufacturing. *The Economic Journal, 126*(591), 317–357.

Gibbons, S., Lyytikäinen, T., Overman, H. & Sanchis-Guarner, R. (2012). *New road infrastructure: the effects on firms* (SERC Discussion Paper No. 1170). Spatial Economics Research Centre, LSE.

Gibbons, S., Lyytikäinen, T., Overman, H. & Sanchis-Guarner, R. (2019). New road infrastructure: the effects on firms. *Journal of Urban Economics, 110*, 35–50.

Hainmueller, J. (2012). Entropy balancing for causal effects: A multivariate reweighting method to produce balanced samples in observational studies. *Political Analysis, 20*(1), 25–46.

Hainmueller, J. & Xu, Y. (2013). ebalance: A Stata package for entropy balancing. *Journal of Statistical Software, 54*(7).

Heckman, J. J., Ichimura, H. & Todd, P. (1998). Matching as an econometric evaluation estimator. *The Review of Economic Studies, 65*(2), 261–294.

Hirano, K., Imbens, G. W. & Ridder, G. (2003). Efficient estimation of average treatment effects using the estimated propensity score. *Econometrica, 71*(4), 1161–1189.

Holvad, T. & Preston, J. (2005). *Road transport investment projects and additional economic benefits*. European Regional Science Association (ERSA).

Hussain, A., Fisher, D. & Espiner, S. (2017). Transport infrastructure and social inclusion: A case study of tourism in the region of Gilgit-Baltistan. *Social Inclusion, 5*(4), 196–208.

Isard, W. (1956). *Location and space-economy*.

Kelejian, H. H. & Robinson, D. P. (1997). Infrastructure productivity estimation and its underlying econometric specifications: a sensitivity analysis. *Papers in Regional Science, 76*(1), 115–131.

Lamont, M. & Lee, R. (2015). Arrive alive: road safety in Kenya and South Africa. *Technology and Culture, 56*(2), 464–488.

Lessa, M. Q. M. (2017). *Anuário Estatístico de Transportes 2010–2016*. Ministério dos Transportes, Portos e Aviação Civil.

Lösch, A. (1954). *The economics of location*. Yale University Press.

Mendes, S. M., Teixeira, E. C. & Salvato, M. A. (2009). Investimentos em infraestrutura e produtividade total dos fatores na agricultura brasileira: 1985–2004. *Revista Brasileira de Economia, 63*(2), 91–102.

Obregón-Biosca, S. & Junyent-Comas, R. (2010). Socioeconomic impact of the roads: case study of the "Eix transversal" in Catalonia, Spain. *Journal of Urban Planning and Development, 137*(2), 159–170.

Obregón-Biosca, S. A., Chávez, M. & Quezada, E. B. (2014). Road transport infrastructure and manufacturing location: an empirical evidence and comparative study between Tijuana and Nuevo Laredo, Mexico. *Frontera Norte, 26*(52), 10.

Rosa, C., Melo, P. L. R. & Garcia, D. B. (2024). Ambiente institucional e o desenvolvimento das redes de franquias na região norte do Brasil. *Gestão & Regionalidade, 40*, e20248428. https://doi.org/10.13037/gr.vol40.e20248428

Sanchis-Guarner, R., Moreira, J. M. F., Teixeira, A. C. & Overman, H. (2012). *Driving up wages: The effects of road construction in Great Britain* (SERC Discussion Paper No. 120). Spatial Economics Research Centre, LSE.

Von Thünen, J. (1826). *Der Isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie*. Perthes. (English translation by C. M. Wartenberg, Oxford: Pergamon Press, 1966).

Weber, A. (1909). *Ueber den Standort der Industrien* (Vol. 1).

Weitkamp, C. D., Martín, M. & Pablo-Marti, F. (2008). *Economic effects of road accessibility in the Pyrenees: user perspective*. XREAP.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT Press.