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## Article

# Public investment, infrastructure and private investment in Brazil: is there a crowding-in effect?

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# Public investment, infrastructure and private investment in Brazil: is there a crowding-in effect?

Public and  
private  
investment in  
Brazil

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## Abstract

**Purpose** – Our study aims to evaluate the impact of infrastructure and public investment on private investment in machinery and equipment in Brazil from 1947 to 2017. The contribution of our article to the existing literature lies in providing a more comprehensive understanding of the presence or absence of the crowding effect in the Brazilian economy by leveraging an extensive historical database. Our central argument posits that the recent decline in private capital accumulation over the last few decades can be attributed to shifts in economic policies – moving from a developmentalist orientation to nondevelopmental guidance since the early 1990s, which is reflected in the diminished levels of public investment and infrastructure since the 1980s.

**Design/methodology/approach** – We conducted a series of econometric regressions utilizing the autoregressive distributed lag (ARDL) model as our chosen econometric methodology.

**Findings** – Employing two different variables to measure public investment and infrastructure, our results – robust across various specifications – have substantiated the existence of a crowding-in effect in Brazil over the examined period. Thus, we have empirical evidence indicating that the state has influenced private capital accumulation in the Brazilian economy over the past decades.

**Originality/value** – Our article contributes to the existing literature by offering a more comprehensive understanding of the crowding effect in the Brazilian economy, utilizing an extensive historical database.

**Keywords** Infrastructure, Public investment, Private investment, Crowding-in effect

**Paper type** Research paper

## 1. Introduction

Private investment stands as a crucial variable in elucidating the disparities in economic performance. In the short run, it constitutes a component of aggregate demand, influencing the pace of demand growth. Over the long term, investments in machinery and equipment are linked to the adoption of state-of-the-art or more modern technology in production, thereby increasing the capital-labor ratio. Consequently, private capital accumulation yields positive effects on labor productivity and productive efficiency. This phenomenon explains why certain economies are more economically developed than others (Reis, de Araújo, & Gonzales, 2019).

In post-Keynesian economic analysis, the principle of dominant strategy is often underscored. According to this principle, firms' decisions regarding their production and investment levels are fundamental determinants of the economy, subsequently shaping employment and savings levels (Carvalho, 2020). Numerous studies have highlighted the importance of comprehending the determinants of private capital accumulation, with one strand of this literature emphasizing the complementarity between public investment, infrastructure and private capital accumulation – or the existence of a crowding-in effect from the former variables to the latter (e.g. Aschauer, 1989; Calderón & Servén, 2010; Bom and



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Lighthart, 2014; Tan & Conran, 2022). Several transmission channels justify this complementarity. Public investment and augmented infrastructure enhance firms' profitability by reducing production costs and the rate of capital depreciation. They also facilitate the development of tradable activities as national goods become more competitive in the international market while simultaneously increasing the competitiveness of national goods in the domestic market. Additionally, there is a positive effect on labor productivity. Consequently, the augmented profits arising from this combination of factors stimulate new private investments, thereby accelerating economic growth and paving the way for a growth path grounded in private capital accumulation.

From a post-Keynesian perspective, investment decisions revolve around entrepreneurs' long-term expectations. Private investment in machinery and equipment is tied to the anticipated quasi-rent generated by the capital employed in production. It's essential to note that quasi-rents are inherently speculative and subjective (Minsky, 1986), particularly in a non-ergodic world where entrepreneurs grapple with fundamental uncertainty about the unknown future. The validation of investments in long-term capital goods, such as machinery and equipment, hinges on whether entrepreneurs' expectations align with the profits derived from the difference between revenues and production costs. In this context, it can be argued that fiscal policies oriented toward economic development, including public investment and infrastructure, favor private investment by reducing production costs and boosting firms' sales, as previously mentioned. Moreover, there is an additional channel through which a crowding-in effect from the former to the latter variable can occur – entrepreneurs' expectations. The government, through active state planning involving increased public investments and infrastructure and institutions focused on economic development (Resende & Bittes Terra, 2017; Fraga & Resende, 2022), has the potential to mitigate uncertainty about the future faced by entrepreneurs. This, in turn, may contribute to fostering a positive environment for private investment.

Taking these considerations into account, our study aims to evaluate the impact of infrastructure and public investment on private investment in machinery and equipment in Brazil from 1947 to 2017. The contribution of our article to the existing literature is to provide a more comprehensive understanding of the existence or lack thereof, of the crowding effect in the Brazilian economy by utilizing an extensive historical database. Our central argument is that the recent decrease in private capital accumulation over the last decades is attributable to shifts in economic policies – from a developmentalist orientation to neoliberal guidance since the early 1990s – as reflected in the reduced values of public investment and infrastructure during this period (Neto & Vernengo, 2004). Additionally, our study can be utilized to formulate and justify active economic policies aimed at fostering private capital accumulation, such as the implementation of an active fiscal policy – public investment and infrastructure – oriented toward economic development, aligning with the post-Keynesian perspective.

For this purpose, we conducted a series of econometric regressions utilizing the autoregressive distributed lag (ARDL) model as our chosen econometric methodology. This method is particularly apt when the regressors exert an influence on the dependent variable in the contemporary period and generate effects distributed over time (Rossi & Neves, 2014). Employing two different variables to measure public investment and infrastructure, our results – robust across various specifications – have substantiated the existence of a crowding-in effect in Brazil over the examined period. Hence, we have empirical evidence indicating that the state – specifically, the diverse historical nuances of fiscal policies – has exerted an influence on private capital accumulation over the past decades in the Brazilian economy. This influence, in turn, has given rise to different growth paths – from a period characterized by development-oriented policies (marked by a rapid pace of private capital accumulation) to nondevelopment-oriented policies (marked by a decelerated pace of private capital accumulation).

In addition to this introduction, the article comprises four other sections. The second section delves into the theoretical arguments justifying the potential crowding-in effect of public investment and infrastructure on private capital accumulation. The third section reviews empirical literature, considering the Brazilian experience. The fourth section outlines the empirical strategy and database employed in our estimations. The empirical findings of the article are discussed in the fifth section. Finally, conclusions bring the study to a close.

## 2. Why does investment in infrastructure/public investment affect capital accumulation?

[Aschauer \(1989\)](#) provided a seminal contribution to the analysis of the effects of public investment and infrastructure on productivity and economic growth. The author argued that smaller public investment, to the detriment of increased government consumption, was an important factor in explaining reduced productivity in the United States of America, Germany, the UK, France, Italy and Canada between 1966 and 1985. Investment in infrastructure serves as a crucial transmission channel on the supply side of the economy, influencing the process of economic growth, as highlighted by [Aschauer \(1989\)](#). The crowding-in effect from public investment to private investment not only affects the composition of income but also has expansionary effects on the pace of economic growth ([Aschauer, 1989](#)).

The positive relationship between infrastructure development and economic growth is widely discussed in the literature (e.g. [Bom Ligthart, 2014](#); [Wang, 2002](#); [Aschauer, 1998](#); [Sahoo & Dash, 2012](#)). Infrastructure development contributes to economic growth through three transmission channels: (1) investment itself creates production and stimulates economic activities (effective demand effect); (2) it reduces transaction costs and trade costs, improving competitiveness (supply effect) and (3) it provides employment opportunities and physical and social infrastructure to the poorest population ([Sahoo & Dash, 2009](#)) [1]. The complementarity effect (crowding-in) occurs when investment in infrastructure increases the marginal productivity of private inputs (labor and capital) and, therefore, the rate of return on private capital, inducing new investments in the private sector (e.g. [Fraga & da Cunha Resende, 2022](#); [Sahoo & Dash, 2009](#); [Turnovsky, 1996](#); [Barro, 1990](#)). The direct effect of increased marginal productivity occurs when the services provided by the augmented infrastructure become available to firms, reducing production costs (e.g. electricity) and transport/marketing costs (e.g. paving rural roads) ([Sahoo & Dash, 2009](#)).

Moreover, the increased productivity of a specific production factor, such as capital, particularly in activities that require skilled labor, due to augmented infrastructure generates long-term externalities over the productive structure of these sectors ([Agénor, Nabli, & Yousef, 2005](#)). In other words, public investment and improved infrastructure induce the modernization of the economy, yielding positive effects on long-term growth through the “learning by doing” effect. This effect encourages long-term growth and stimulates new private investments ([Agénor et al., 2005](#)).

In this context, given that a specificity of human capital lies in the productivity gain through “learning by doing” processes, which arise from the cumulative exposure of employees to more complex technology, improvements in infrastructure – enabling companies to adopt more advanced technologies, such as high-speed internet in rural areas – cumulatively result in an increase in human capital productivity ([Kupfer & Hasenclever, 2013](#)). This transmission mechanism, related to the supply side of the economy, was examined by [Isaksson, \(2009\)](#) for 79 countries in the period from 1970 to 2000. The author’s results indicated a strong and positive association between industrial growth and investments in energy infrastructure, which has been particularly important in explaining the industrialization of Asian economies. Following this line of argument, [Estache and Garsous \(2012\)](#) point out that the infrastructure sectors with the greatest potential to

influence the development of more complex and competitive industries are energy, water and sanitation, telecommunications and transport.

In the post-Keynesian view, public and infrastructure investments are linked to entrepreneurs' expectations. Investment decisions, being expectational variables resulting from entrepreneurs' choices in a non-ergodic world characterized by uncertainty about the future, position the government as a stabilizing force in economic reality. Public and infrastructure investments, in this context, are positively associated with firms' investments as they stimulate demand growth (i.e. reduce idle capacity) through the multiplier effect of autonomous spending, fostering entrepreneurs' animal spirits (Fraga & Resende, 2022; Fraga & da Cunha Resende, 2022). In simpler terms, there is an accelerating effect through the expansion of aggregate demand in the economy, achieved by increasing the utilization of installed capacity. Furthermore, public and infrastructure investments targeted at economic development benefit private investment by reducing production costs and increasing firms' sales, as previously mentioned. Another channel through which these effects influence entrepreneurs' expectations is the government's role in diminishing uncertainty about the future. This is accomplished through active state planning, involving augmented public investments, infrastructure and institutions oriented toward economic development (Resende & Bittes Terra, 2017; Fraga & Resende, 2022; Fraga & da Cunha Resende, 2022).

The level of private-sector investment in infrastructure has consistently fallen short, particularly in countries like the United States of America and the UK, as noted by Mazzucato and Wray (2015). Infrastructure bottlenecks in these nations have negatively affected their long-term growth prospects, leading to repercussions on GDP, employment, family income and exports. The authors emphasize the significance of investment and public financing in infrastructure to establish a sustainable growth trajectory. They also underscore that public investment in infrastructure aligns with Keynes' concept of the socialization of investment.

The significance of planning and public investments in infrastructure is evident in Tan and Conran's (2022) study on the growth drivers of China. According to the authors, in addition to the export-led strategy that propelled Chinese growth in recent decades, there has been a growth model centered on state investments in urbanization and infrastructure. The concept is that the Chinese economy accommodated various growth drivers simultaneously, with the export-led strategy being more predominant in coastal areas while the state investment-led strategy was more prevalent in the interior. The key to the success of the infrastructure-based growth model led by the Chinese state lies in the short-term demand and long-term supply effects, as discussed earlier.

In the same vein, Dávila-Fernández (2015) conducted a comprehensive theoretical and historical analysis of public investment in infrastructure in Brazil. Aligned with the insights of Baumol (1986), the author emphasized the substantial costs and prolonged maturation period intrinsic to these investments, creating a dilemma between productive and allocative efficiency. Dávila-Fernández (2015) argued that the presence of external economies of scale and information asymmetries justifies state intervention in this complex scenario. Even with increased private sector involvement, the author emphasized the critical need for regulation and public financial support to achieve the optimal investment level. This imperative condition is essential to prevent impediments that could adversely impact other industries led by the private sector.

The author posited infrastructure as the focal point of investments in a successful industrial policy, highlighting its substantial returns and extensive possibilities for political viability compared to public investments in specific industries. Dávila-Fernández's perspective gains credence from the scrutiny of investment levels in infrastructure post-1995, marked by the enactment of the "*Lei das Concessões*." Despite the substantial engagement of the private sector during this period, the observed investments proved to be insufficient, underscoring the persistent challenges in achieving the desired infrastructure development.

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The following section briefly reviews the empirical literature and examines private investment in machinery and equipment as well as public investment in the Brazilian economy from 1947 to 2021.

### 3. Review of the empirical literature in light of the Brazilian experience

Many scholars have investigated the association between public investment, infrastructure investment and private investment in Brazil. Within this literature, [Rocha and Teixeira \(1996\)](#) analyzed the effects of public capital accumulation on private investment in Brazil between 1965 and 1990. There was a certain degree of substitutability (crowding-out) between public and private investment in Brazil. Due to the significant participation of state-owned enterprises in the investments during that period, they were separated from private investment and included in public investment. Their results indicated that these variables are cointegrated, providing evidence of crowding-out. This means that an increase in public physical capital expenditure reduces private investments as both compete for physical and financial resources in the economy.

In turn, [Melo and Rodrigues Júnior \(1998\)](#) conducted an analysis of the determinants of private investment from 1970 to 1995, revealing long-term cointegration among government investment, GDP, interest rates and inflation rates. The findings indicate an inhibition of private investments in response to economic instability and an increase in government investment, suggesting a substitution effect. However, the authors propose that this might be a consequence of the government's diminishing capacity to invest in infrastructure, an area with greater potential for complementarity with private investments. Also, through a historical analysis, [Melo and Rodrigues Júnior \(1998\)](#) identified a growing rigidity in public spending, with investments favoring the expansion of the public sector and a decline in public investment directed toward infrastructure. Consequently, the substitution effect observed in empirical studies could stem from this shift in the overall composition of the public budget, especially in the realm of investment expenditures.

[Jacinto and Ribeiro \(1998\)](#) also discovered evidence of crowding-out effects between public and private investment in the Brazilian economy, albeit with elasticities lower than those found in previous studies. According to the authors, this could be attributed to the inadequate treatment of the non-stationarity of economic series in earlier research. Their analysis utilized time series data on public and private investment, credit provided by BNDES, levels of capacity utilization and inflation rates as a proxy for macroeconomic instability. The authors also emphasized the challenge associated with using aggregated data for public investment. They underscored the importance of considering the disaggregation of infrastructure expenditures, as it could yield different results with implications for various economic policy directions.

In contrast, [Rodrigues \(2006\)](#) found evidence suggesting a positive impact of infrastructure expansions on labor productivity and output in Brazil from 1950 to 1995. Investment in infrastructure was disaggregated into five areas: electricity, telecommunications, railways, highways and ports. The areas with the greatest long-term income elasticities were electricity and transport.

[Sonaglio, Braga, and Campos \(2010\)](#) analyzed the period from 1995 to 2006 in Brazil using the vector error correction model methodology. The authors identified a substitutability effect between public and private investment. Variables associated with investment costs, such as interest rates, tax burden and the price of capital goods, had a more significant effect on inducing private investments. [Luporini and Alves \(2010\)](#), on the other hand, investigated the determinants of private investment in Brazil, spanning the period from 1970 to 2005. The authors conducted econometric estimates using ARDL methodology, with private investment (gross fixed capital formation of companies and families) as the dependent variable. The independent variables included demand growth, real interest rates, credit



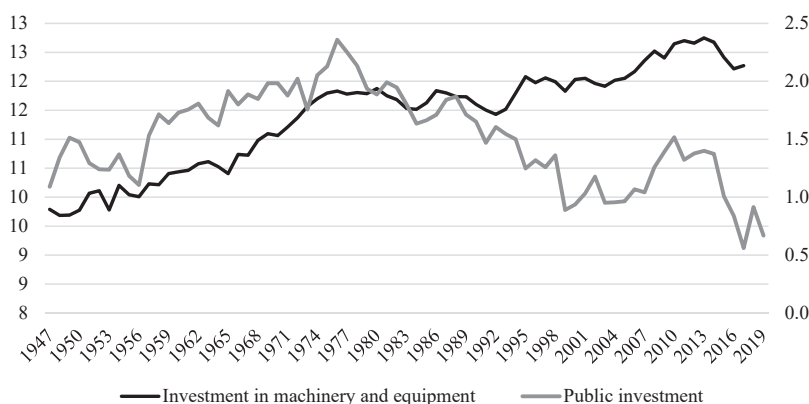
volume, public investment (gross training – public administration), external constraint (debt service/GDP), real exchange rate and an indicator of economic instability. The authors' findings indicated that demand growth and credit provided by financial institutions are positively associated with private capital formation. They did not find evidence that public investment or the real interest rate is statistically significant in explaining their dependent variable. Additionally, their findings suggested that currency devaluations negatively influence private investment.

Lélis, Bredow, and Cunha (2015) aimed to discuss the determinants of private investment in Brazil from 1996 to 2012, using investment in machinery and equipment as a proxy. The study found that variables associated with Keynesian theory, such as the level of activity measured by household consumption, financing availability and entrepreneurs' expectations measured by the level of capacity utilization, had greater explanatory power compared to variables related to the cost and relative prices of investment. Granger causality revealed that an increase in household consumption and the level of capacity utilization boosted spending on machinery and equipment. In contrast, Fernandez, Shikida, Menezes, and de Almeida (2017), employing an ARDL model, identified a positive relationship between government consumption and private investment during the period from 1995 to 2014. Government spending was measured by the final consumption of the public administration, and private investment was measured by gross fixed capital formation. In this context, Reis *et al.* (2019) demonstrated, through estimates using vector error correction (VEC), the complementarity between public investment and private investment for the period from 1982 to 2013. Typical variables in post-Keynesian and structuralist studies, such as the real exchange rate, profit share and the level of capacity utilization, were utilized as control variables to capture entrepreneurs' expectations. The Johansen test identified a long-term relationship among all variables specified in the model. The results demonstrated that measures to reduce public investment, especially in infrastructure, observed in Brazil in the 1980s resulted in a slower growth trajectory. Bredow, Cunha, and Lélis (2022) found a similar result when using private investment in machinery and equipment as a proxy.

In addition to the discussion above, Ferreira (1996) studied the period from 1970 to 1993. Employing cointegration techniques, the author calculated the long-term elasticity between gross domestic product (GDP) and metrics related to infrastructure stock. The resulting elasticity, 0.70, signifies a substantial correlation between these variables over time. Also, Mussolini and Teles (2010) explore the impact of the relationship between public and private capital on TFP from 1950 to 2000. Their analysis, grounded in the concept of complementarity, asserts that private capital becomes more productive when supported by robust infrastructure services. The authors emphasize that, in the Brazilian context, this relationship remains notably low. The estimated elasticity of TFP concerning the public capital stock fluctuates between 0.32 and 0.5, according to the study's findings. Mussolini and Teles contend that the substantial decline in public investments relative to private investments likely triggered the pronounced productivity dip observed post-1970s, adversely impacting Brazil's long-term economic growth. Moreover, a deficiency in adequate infrastructure compelled the Brazilian economy to operate below the technological frontier, particularly evident post-1970s (Mussolini & Teles, 2010).

In summary, empirical literature provides mixed evidence about the influence exerted by public investment on private investment. Considering this discussion, Figure 1 displays the historical values of investment in machinery and equipment and public investment in Brazil from 1947 to 2021.

Figure 1 allows us to identify three distinct periods regarding the historical values of private investment and public investment. First, between 1947 and 1980, it was characterized by a fast pace of private capital accumulation and a robust expansion of public investment. This period is marked by a significant phase of state-led growth, during which the government guided economic development through the industrialization and diversification



**Note(s):** Both variables are in logarithm form

**Source(s):** Figure by authors using data from Junior and Cornelio (2020)

**Figure 1.**  
Investment in  
machinery and  
equipment and public  
investment (% of GDP),  
1947–2021

of the Brazilian economy. Public investment played a crucial role during this period, as numerous infrastructure projects were undertaken by the government. The decades of the 1950s and 1960s were marked by the expansion of the road network, driven by significant public investment, owing to the vast continental dimensions of Brazil (Ferreira & Azzoni, 2011). The key sectors of infrastructure experienced a notable increase during the Second National Development Plan (II PND), which took place from 1974 to 1979. This period witnessed substantial growth in state-owned enterprises, facilitated by low-interest loans due to the abundance of petrodollars (Ferreira & Azzoni, 2011). Second, between 1980 and 1990, it was characterized by a combination of stagnation, on average, in private capital accumulation, a crisis in public finance and hyperinflation, which reduced the state's capacity to guide the development process through public investment. The 1980s were characterized by the debt crisis and a strong commitment to public expenditures, as outlined in the 1988 Constitution, resulting in a significant decline in public investment. While, in the 1990s, the context of hyperinflation and macroeconomic adjustment prevented the increase in public investments (Ferreira & Azzoni, 2011). In addition, state-owned companies witnessed a drastic reduction in investments during this period, representing a mere fraction of 1970s levels. Infrastructure investments dwindled by over 60% between 1976 and 1993 (Ferreira, 1996). Third, between 1990 and 2021, characterized by a slower and erratic pace of capital accumulation and a notable reduction in public investment. Nevertheless, it should be highlighted that private capital accumulation presented some peaks of growth, especially between 2003 and 2014, during the Program for Accelerating Economic Growth (PAC).

Empirical literature delivers mixed evidence on the association between public investment and private capital accumulation. However, international studies suggest a crowding-in association between these variables. Cook and Munnell (1990) analyzed data from the US states spanning the period from 1970 to 1986. Their findings revealed that investments in infrastructure not only foster economic growth but also stimulate private investment, with a calculated public capital coefficient of 0.15.

Wang (2002) examined East Asian economies from 1979 to 1998, utilizing the generalized least squares method. The results provided compelling evidence supporting positive spillover effects between the public and private sectors, concluding that there exists a significant interrelationship between public infrastructure development and the advancement of the private sector. In a broader analysis, Erden and Holcombe (2005)



examined data encompassing both developed and developing countries during the period from 1980 to 1997. Their research demonstrated that public investment complements private investment in developing countries, showing that a 10% increase in public investment correlates with a 2% increase in private investment. Conversely, for developed economies, public investment appeared to displace private investment.

Calderón and Servén (2010) estimated the relationship between basic infrastructure (electricity, roads and electricity), economic growth and private investment in sub-Saharan Africa over the period from 1960 to 2005 using the generalized method of moments (GMM) technique. Their results indicate the existence of a complementary effect between infrastructure expansions and private investment, with accelerating effects on the economic growth of these countries. In the context of OECD countries, Bom and Ligthart (2014) quantified the effect of public infrastructure on private output. They obtained a short-term elasticity of public capital provided at the central government level of around 0.08, which increases to 0.12 in the long run. Considering only the “core” infrastructure, these estimates are almost doubled, and the averaged elasticity of a public capital product is 0.10. Audretsch, Heger, and Veith (2015) found evidence suggesting that expansions in broadband internet access are positively related to the development of startup activities in high-tech manufacturing, technology-oriented services, consumer-related services and retail trade in the German economy. These results align with Dreger and Reimers's (2016) findings, indicating that the lack of public investment has constrained private investment and, therefore, GDP growth in the Eurozone, raising questions about the austerity policies applied in the region. In turn, Fraga and Resende (2022), within the post-Keynesian tradition, demonstrated that infrastructure investment affects private investment. More specifically, infrastructure influences the elasticity of determinants of private capital accumulation. That is, the greater the infrastructure investment, the greater the effect of installed capacity, the real interest rate, credit and the real exchange rate on the former variable. They showed that, in periods of infrastructure decline, the impulse generated by the determinants of private investment is smaller.

The next section presents our empirical strategy and discusses the database used in our econometric regressions.

#### 4. Empirical strategy and database

The empirical strategy employed in this study involved estimating time-series regressions to assess the impact of infrastructure and public investments on the private capital accumulation of the Brazilian economy from 1947 to 2017. The two estimated equations are represented as follows:

$$\begin{aligned} \Delta(\text{Private investment})_t = & \alpha_0 + \alpha_1 \tau + \beta_1 (\text{Private Investment})_{t-1} \\ & + \beta_2 (\text{Infrastructure investment})_{t-1} + \beta_3 (\text{Demand growth})_{t-1} \\ & + \beta_4 (\text{Inflation})_t + \sum_{i=1}^p \beta_a \Delta(\text{Private investment})_{t-i} \\ & + \sum_{i=0}^{q1} \beta_b \Delta(\text{Infrastructure investment})_{t-i} \\ & + \sum_{i=0}^{q2} \beta_c \Delta(\text{Demand growth})_{t-i} + \sum_{i=0}^{q3} \beta_d \Delta(\text{Inflation})_{t-i} + \epsilon_t \end{aligned} \quad (1)$$

$$\begin{aligned}
\Delta(\text{Private investment})_t = & \alpha_0 + \alpha_1 \tau + \beta_1(\text{Private investment})_{t-1} \\
& + \beta_2(\text{Public Investment})_{t-1} + \beta_3(\text{Demand growth})_{t-1} \\
& + \beta_4(\text{Inflation})_{t-1} + \sum_{i=1}^p \beta_a \Delta(\text{Private investment})_{t-i} \\
& + \sum_{i=0}^{q1} \beta_b \Delta(\text{Public Investment})_{t-i} \\
& + \sum_{i=0}^{q2} \beta_c \Delta(\text{Demand growth})_{t-i} + \sum_{i=0}^{q3} \beta_d \Delta(\text{inflation})_{t-i} + \epsilon_t
\end{aligned}
\tag{2}$$

Where  $\alpha_0$  represents the intercept,  $\alpha_1 \tau$  the trend parameter,  $\beta_1, \beta_2, \beta_3$  and  $\beta_4$  are the long-run parameters,  $\beta_a, \beta_b, \beta_c$  and  $\beta_d$  are the short-run parameters,  $p$  is the number of lags in the dependent variable and  $qn$  is the number of lags in the independent variable  $n$ . The dependent variable in [equations \(1\) and \(2\)](#) is private investment in machinery and equipment, measured in constant 2010 values and millions of reais, sourced from [Junior and Cornelio \(2020\)](#). In [equation \(1\)](#), the primary independent variable is infrastructure investment, represented by gross fixed capital formation in infrastructure, also obtained from [Junior and Cornelio \(2020\)](#). Meanwhile, in [equation \(2\)](#), the primary independent variable is public investment (as a share of GDP), sourced from [Pires' \(2022\)](#) study. Both variables are lagged to ensure that causality runs from the right to the left side of the equations. A positive signal for  $\beta_2$  indicates a crowding-in effect of expansions in infrastructure or public investment on private investment in machinery and equipment, while the opposite suggests a crowding-out effect. It is important to note that all variables in [equations \(1\) and \(2\)](#) were transformed using logarithms, allowing the parameter  $\beta_2$  to represent the elasticity of private investment in response to changes in infrastructure or public investment. [Table 1](#) below presents the database used in our estimates.

In addition to the primary independent variables of interest in this study, namely infrastructure and public investment, we controlled for other variables typically associated with private investment in machinery and equipment, as outlined in [Table 1](#).

Our empirical strategy involved introducing additional explanatory variables into [equations \(1\) and \(2\)](#). In addition to the variables considered in the baseline estimates ([equations 1 and 2](#)), [equations \(1b\) and \(2b\)](#) also incorporate the terms of trade as a control variable. [Equation \(1c\)](#) includes the real exchange rate, while [equation \(1d\)](#) accounts for labor costs. [Equation \(1e\)](#) considers both the terms of trade and labor costs and finally, [equation \(1f\)](#) includes the real exchange rate and labor costs. [Equation \(2c\)](#) considers labor costs and [equation \(2d\)](#) includes both the terms of trade and labor costs. Furthermore, [equation \(2e\)](#) incorporates the real exchange rate and labor costs. The rationale behind the inclusion of each control variable is explained in what follows:

- (1) The manufacturing consumption of electric energy (Demand growth), provided by the Brazilian Ministry of Mines and Energy, is used to gauge the accelerator/positive effect that demand growth exerts on private capital accumulation.
- (2) The inflation rate (Inflation) is included in our estimates as a proxy for macroeconomic instability. Our rationale is that elevated inflation rates may impede private investment by shortening entrepreneurs' forecasting horizons, thereby increasing uncertainty about the economy's future.

Variable	Definition	Source
Private investment	Private investment in machinery and equipment	<a href="#">Junior and Cornelio (2020)</a>
Infrastructure investment	Gross fixed capital formation in infrastructure	<a href="#">Junior and Cornelio (2020)</a>
Public investment	Public investment as a share of GDP	<a href="#">Pires (2022)</a>
Demand growth	Manufacturing consumption of electric energy	Brazilian Ministry of Mines and Energy
Inflation	Inflation rate	Institute of Applied Economic Research (IPEA)
Terms of trade	Terms of trade: the ratio of exports and imports prices	Institute of Applied Economic Research (IPEA)
Labor cost	Minimum salary expressed in purchasing power parity	Institute of Applied Economic Research (IPEA)
Real exchange rate	Real exchange rate	<a href="#">Darvas (2021)</a>
Public credit for manufacturing	Share of the credit's volume provided by BNDES (National Bank for Economic and Social Development) to manufacturing sectors	<a href="#">Barboza, Furtado, and Gabrielli (2019)</a>
Public credit for infrastructure	Share of the credit provided by BNDES (National Bank for Economic and Social Development) to finance infrastructure projects	<a href="#">Barboza et al. (2019)</a>

Table 1.  
Database

Source(s): Table by authors

- (3) The variable terms of trade (Terms of trade), representing the ratio of prices of exported and imported goods, holds particular significance in the Brazilian context due to periods of external constraints on economic growth. During times of acute shortage of international currency, caused by the chronic deterioration of the terms of trade in line with [Prebisch's \(1949\)](#) argument, the Brazilian economy faced challenges in meeting its financial commitments to the rest of the world. Consequently, the required equilibrium in the balance of payments constrains the pace of capital accumulation and demand growth. In this context, improved terms of trade alleviate the external constraints on Brazilian growth, enabling a faster pace of capital accumulation.
- (4) Labor costs (Labor cost), specifically the minimum salary expressed in purchasing power parity, are also factored into our regressions. Our contention is that higher labor costs could impede the profit rate as they escalate firms' expenses. Despite the potential for increased sales in firms producing goods geared toward workers' consumption or in aggregate terms, expanding demand growth in wage-led economies, a la [Bhaduri and Marglin \(1990\)](#), there may be possible negative consequences for new investments. This variable, like the last two, is sourced from the Institute of Applied Economic Research (IPEA).
- (5) Many authors contend that the real exchange rate (RER) is a crucial factor influencing the profit rate of domestic firms (e.g. [Rodrik, 2008](#); [Pereira, 2010](#); [Ros, 2015](#); [Rapetti, 2020](#), among others). The argument posits that a competitive RER expands the markup rate of domestic firms, following the framework of [Blecker \(1989\)](#), with consequential effects on their profit rates and, consequently, their pace of capital accumulation. However, this effect may be negative as it increases costs associated with imports. In any case, we controlled for it in our regressions. This variable is sourced from [Darvas \(2021\)](#).

- (6) Finally, we introduced two variables into our regressions to capture the potential association between the expansion in bank credit and private investment in machinery and equipment: (1) the share of the total credit volume provided by BNDES (National Bank for Economic and Social Development) directed toward manufacturing sectors (public credit for manufacturing) and (2) the share of all credit provided by BNDES to finance new infrastructure projects (public credit for infrastructure). It is essential to note that BNDES is the primary financial institution providing credit for long-term investment in the Brazilian economy. Moreover, (3) there is no available data on interest rates for the period studied in our article or information on the volume of banking credit. Consequently, in the absence of precise information, these variables serve as proxies for the influence of the financial system on private investment.

#### 4.1 Econometric method

equations (1) and (2) were performed using the ARDL cointegration analysis and the ARDL bounds-testing approach developed by Pesaran *et al.* (1999) and Pesaran, Shin, and Smith (2001). This methodology offers several advantages compared to cointegration methods such as Engle and Granger (1987) and Johansen (1988). The ARDL approach is suitable when variables are  $I(0)$ ,  $I(1)$  or a combination of  $I(0)$  and  $I(1)$  variables. ARDL estimates are well-suited for investigating long-term relationships, especially in small samples. The use of variables at different lags enhances estimate efficiency. Lastly, both short- and long-term relationships are estimated within a single equation, as opposed to a system of equations. Further, the choice of the ARDL methodological approach stems from its well-known capability to handle time series with limited observations, as noted by Rossi and Neves (2014). This choice is particularly relevant in our case, given the use of annual data for Brazil that cover the period between 1947 and 2017. The ARDL model allows for different lag orders for distinct independent variables, along with the inclusion of a trend parameter.

The appropriate number of lags was determined based on the Akaike information criterion (AIC). We assessed the presence of a long-term relationship using the bounds-testing procedure, employing a Test-F with a null hypothesis of no cointegration ( $H_0: \delta = 0$ ) against the alternative of cointegration ( $H_1: \delta \neq 0$ ). If we reject the null hypothesis (indicating a long-term relationship between our variables), the long-term multipliers are represented by the estimated coefficients for the dependent variables in levels. Short-term multipliers are the estimated coefficients for the dependent variables in the first difference. The estimated parameter for the speed of adjustment toward long-run equilibrium (the error correction term) should be negative and statistically significant.

The rationale behind our empirical strategy is to estimate equations (1) and (2) using various combinations of dependent variables [2]. This approach has proven essential for checking the robustness of the results and avoiding potential collinearity. The following section presents our empirical findings.

#### 4.2 Empirical findings

All regressions were found to fit well, as indicated by the Breusch–Pagan test revealing a noncorrelated error term. The bounds-testing procedure (Bound *F*-test) suggested a long-term relationship (cointegration) between our variables at a 1% significance level in most regressions. The estimated parameter for the speed of adjustment toward equilibrium was consistently negative and statistically significant across all regressions. Furthermore, we conducted unit root tests to assess the stationarity of the residuals from the estimated equations, confirming their stationarity.

Table 2 presents the estimates of equation (1). In all regressions, there is a positive influence of augmented infrastructure investments on private investment in machinery and equipment, both in terms of their short-run impact (the effect of changes in the dependent variable in the first difference) and their long-run effect (the effect of changes in the dependent variable in level). Regarding the long-run multipliers, our findings indicate that all parameters were positive and statistically significant at the 1% critical values in all regressions, hovering around 0.60. A 1% increase in gross fixed capital formation in infrastructure, conducted by the public sector, leads to a 0.60% expansion in private capital accumulation.

The same pattern is observed for the short-run multipliers of infrastructure investment in Table 2. However, the magnitude of the parameters is somewhat lower than its long-run multiplier, approximately around 0.50. These results suggest that the low levels of private investment in Brazil are, in part, attributable to the modest value of infrastructure investment, whether public or private. On the other hand, the empirical findings imply the existence of a crowding-in effect, indicating that new investments in infrastructure, induced by public policies, may have the potential to stimulate additional private investment in machinery and equipment – an essential variable in a development strategy. Our findings align with Rodrigues' (2006) study, which reported a positive effect of infrastructure expansions on output growth from 1950 to 1995.

Furthermore, the estimates presented in Table 2 indicate a negative parameter for the long-run multiplier associated with the inflation rate variable. This negative impact is statistically significant, at least at the 1% critical values in all regressions. In the context where inflation serves as a proxy for macroeconomic instability, this implies that, in the long term, greater instability hinders private investments. These results align with the findings of Loporini and Alves' (2010) study. Notably, the short-run multiplier of the inflation rate was not statistically significant.

Furthermore, our findings indicated that periods of favorable terms of trade for the Brazilian economy are positively associated with private investment in machinery and equipment, as both the estimated short-run and long-run multipliers for this variable were positive and statistically significant, in alignment with the Latin American structuralist approach, exemplified by Prebisch's (1949) seminal study. Table 2's results, however, do not provide robust evidence that the remaining controlled variables are associated with private investment in machinery and equipment in the Brazilian economy.

The estimates of equation (2) are presented in Table 3. All regressions suggest the existence of a crowding-in effect from the variable public investment to private investment in machinery and equipment, indicating that expansions in public investment foster private capital accumulation. This result holds across all regressions in Table 3, as all parameters estimated for public investment were statistically significant at the 1% critical values and positive. The estimated parameter ranges from approximately 0.50 to 0.66. Therefore, a 1% increase in public investment relative to GDP is associated with an approximate 0.50% increase in private investment in machinery and equipment. These results align with the findings in Aschauer's seminal paper (1989) on the positive effects of public investment on productivity gains and economic growth in G7 economies. However, they diverge from the results obtained by Jacinto and Ribeiro (1998) for Brazil.

In turn, Table 3's estimates indicate that only the short-run multiplier estimated for demand growth was statistically significant and positive. Similar to the output in Table 2, Table 3's findings suggest that favorable terms of trade are positively associated with private investment in machinery and equipment. Additionally, Table 3's results do not provide further evidence that the remaining controlled variables are associated with private investment in machinery and equipment in the Brazilian economy. Tables 2 and 3 are presented below.

Variable/Model	Parameter	(l)	(lb)	(lc)	(ld)	(le)	(lf)
Infrastructure investment	<i>Long-run</i>	0.69*** [0.06]	0.63*** [0.06]	0.68*** [0.06]	0.70*** [0.06]	0.62*** [0.07]	0.71*** [0.06]
	<i>Short-run</i>	0.49*** [0.06]	0.42*** [0.06]	0.48*** [0.06]	0.49*** [0.06]	0.49*** [0.07]	0.47*** [0.06]
Demand growth	<i>Long-run</i>	0.06 [0.08]	0.25*** [0.12]	0.09 [0.09]	0.01 [0.08]	0.22 [0.13]	0.03 [0.09]
	<i>Short-run</i>	0.06 [0.08]	0.25*** [0.12]	0.09 [0.09]	0.01 [0.08]	0.22 [0.13]	0.03 [0.09]
Inflation rate	<i>Long-run</i>	-0.03*** [0.01]	-0.03*** [0.01]	-0.04*** [0.01]	-0.02** [0.01]	-0.02** [0.13]	-0.03** [0.01]
	<i>Short-run</i>	-0.01 [0.01]	-0.01 [0.01]	-0.02 [0.01]	-0.01 [0.01]	-0.008 [0.01]	-0.01 [0.01]
Terms of trade	<i>Long-run</i>		0.35* [0.17]			0.35* [0.19]	
	<i>Short-run</i>		0.35*** [0.17]			0.35* [0.19]	
Real exchange rate	<i>Long-run</i>			0.07 [0.12]			0.09 [0.11]
	<i>Short-run</i>			-0.04 [0.12]			0.02 [0.02]
Labor cost	<i>Long-run</i>				-0.15* [0.08]	-0.07 [0.09]	-0.18* [0.09]
	<i>Short-run</i>				0.02 [0.08]	0.10 [0.09]	-0.09 [0.09]
Best model	(2, 3, 0, 1)		(2, 3, 0, 1, 0)	(2, 3, 0, 1)	(2, 3, 0, 1, 2)	(2, 3, 0, 1, 0, 2)	(2, 3, 0, 1, 2, 2)
BG test (p-value)	0.87		0.55	0.64	0.68	0.80	0.66
Bound <i>F</i> -test	0.00		0.00	0.02	0.00	0.00	0.00
Ect. (p-value)	-0.88*** [0.16]		-0.86*** [0.16]	-0.84*** [0.16]	-0.88*** [0.16]	-0.85*** [0.15]	-0.85*** [0.16]

**Note(s):** (a) Standard errors are in brackets; (b) regressions were performed with the introduction of a time trend; (c) the intercept and trend parameters are not presented due to limited space, but are available upon request; (d) \*, \*\* and \*\*\* mean, respectively, statically significant at 10, 5 and 1 % and (e) the lag for each variable utilized in our regressions was determined based on the Akaike information criterion (AIC)

**Source(s):** Table by authors

**Table 2.**  
Empirical findings:  
estimates of  
equation (1)





Table 4, below, presents the estimates of equations (1) and (2) while controlling for an additional variable, our proxy representing the influence of the financial system over private investment, as discussed in the previous section.

The outputs in Table 4 align with our previous estimates, confirming a positive association between infrastructure investment/public investment and private capital accumulation. In other words, the results affirm the presence of a crowding-in effect, as the long-run parameter estimated for these variables was statistically significant at the 1% critical value, positive and around 0.50 in all regressions. Moreover, the remaining results remain consistent with the previous estimates. Regarding the estimated parameters for the variables public credit for manufacturing and public credit for infrastructure, they were not statistically significant in Table 4's regressions. Therefore, based on our results, there is no evidence to suggest that BNDES's credit to manufacturing activities or infrastructure is associated with greater values of private investment [3]

#### 4.3 Robustness check

This section presents additional estimates to assess the robustness of our previous results. The rationale behind this strategy is to alter the time span of our regressions. If the early results remain valid, our regressions demonstrate robustness across different periods of time. The previous estimates were re-evaluated using data from 1970 to 2017. Table 5 presents the estimated equations.

In general, the regressions presented in Table 5 confirm the previous results indicating that expansions in infrastructure investment or public investment are positively associated

Variable/Model	Parameter	(3)	(3b)	(3c)	(3d)
Infrastructure investment	<i>Long-run</i>	0.58*** [0.08]	0.58*** [0.09]		
	<i>Short-run</i>	0.57*** [0.08]	0.47*** [0.09]		
Public investment	<i>Long-run</i>			0.52*** [0.16]	0.45** [0.19]
	<i>Short-run</i>			0.52*** [0.16]	0.04 [0.19]
Demand growth	<i>Long-run</i>	0.31** [0.12]	0.33** [0.15]	0.34 [0.22]	0.46* [0.23]
	<i>Short-run</i>	-0.23* [0.12]	0.53*** [0.09]	2.36*** [0.22]	2.42*** [0.23]
Inflation rate	<i>Long-run</i>	-0.01 [0.01]	-0.02* [0.01]	-0.02 [0.02]	-0.03 [0.02]
	<i>Short-run</i>	0.004 [0.01]	0.001 [0.01]	-0.02 [0.02]	0.004 [0.02]
Terms of trade	<i>Long-run</i>	0.54*** [0.20]	0.54** [0.22]	0.60* [0.32]	0.67* [0.39]
	<i>Short-run</i>	0.27 [0.20]	0.54** [0.22]	0.60* [0.32]	1.14*** [0.39]
Labor cost	<i>Long-run</i>	-0.07 [0.08]	-0.07 [0.10]	-0.13 [0.18]	-0.08 [0.18]
	<i>Short-run</i>	0.13 [0.08]	-0.02 [0.10]	-0.13 [0.18]	-0.04 [0.18]
Public credit for manufacturing	<i>Long-run</i>	-0.25 [0.09]		0.15 [0.17]	
	<i>Short-run</i>	-0.09 [0.09]		0.15 [0.17]	
Public credit for infrastructure	<i>Long-run</i>		-0.04 [0.05]		-0.08 [0.12]
	<i>Short-run</i>		-0.02 [0.05]		-0.08 [0.12]
Best model (Aic)	(2, 3, 1, 1, 3, 1)		(2, 3, 2, 1, 0, 2)	(1, 0, 2, 0, 0, 0)	(2, 1, 3, 1, 2, 2, 3)
BG test (p-value)	0.81		0.93	0.42	0.61
Bound F-test	0.00		0.00	0.02	0.04
Ect. (p-value)	-0.99*** [0.16]		-0.79*** [0.15]	-0.52*** [0.11]	-0.61*** [0.16]

**Note(s):** (a) Standard errors are in brackets; (b) regressions were performed with the introduction of a time trend; (c) the intercept and trend parameters are not presented due to limited space, but are available upon request; (d) \*, \*\* and \*\*\* mean, respectively, statically significant at 10, 5 and 1% and (e) the lag for each variable utilized in our regressions was determined based on the Akaike information criterion (AIC)

**Source(s):** Table by authors

**Table 4.**  
Empirical findings  
controlling for the  
public credit provided  
by BNDES

Variable/Model		(1)	(2)	(3)	(4)
Infrastructure investment	<i>Long-run</i>	0.24** [0.09]	0.29** [0.10]	0.37** [0.15]	
	<i>Short-run</i>	0.24** [0.09]	0.29** [0.10]	0.36** [0.15]	
Public investment	<i>Long-run</i>				0.33* [0.18]
	<i>Short-run</i>				0.35* [0.18]
Demand growth	<i>Long-run</i>	0.37** [0.16]	0.41*** [0.14]	0.27* [0.15]	0.32* [0.16]
	<i>Short-run</i>	0.37** [0.16]	0.41*** [0.14]	0.27* [0.15]	1.58** [0.16]
Inflation rate	<i>Long-run</i>	−0.01 [0.01]	0.005 [0.01]	−0.004 [0.01]	0.00 [0.01]
	<i>Short-run</i>	−0.01 [0.01]	0.005 [0.01]	0.01 [0.01]	0.01 [0.01]
Terms of trade	<i>Long-run</i>	0.90*** [0.22]	0.97 [0.20]	0.95*** [0.26]	1.17*** [0.27]
	<i>Short-run</i>	0.67*** [0.22]	0.67*** [0.20]	0.77 [0.26]	1.00 [0.27]
Labor cost	<i>Long-run</i>	0.35*** [0.11]	0.17 [0.14]	0.12 [0.17]	0.06 [0.18]
	<i>Short-run</i>	0.35*** [0.11]	0.46*** [0.14]	0.05 [0.17]	−0.04 [0.18]
Public credit for manufacturing	<i>Long-run</i>		−0.20 [0.12]		
	<i>Short-run</i>		0.04 [0.12]		
Public credit for infrastructure	<i>Long-run</i>			0.21* [0.12]	−0.09 [0.12]
	<i>Short-run</i>			−0.02 [0.12]	0.20* [0.12]
Best model (AIC)	(2, 0, 0, 0 2, 0)		(2, 0, 0, 0 0, 2, 3, 1)	(2, 3, 0, 1 2, 2)	(2, 3, 1, 1 2, 3, 1)
BG test (p-value)	0.35		0.89	0.74	0.65
Bound <i>F</i> -test	0.00		0.00	0.00	0.00
Ect. (p-value)	−0.81*** [0.13]		−0.90*** [0.14]	−0.87*** [0.16]	−0.89*** [0.17]

**Note(s):** (a) Standard errors are in brackets; (b) regressions were performed with the introduction of a time trend; (c) the intercept and trend parameters are not presented due to limited space, but are available upon request; (d) \*, \*\* and \*\*\* mean, respectively, statically significant at 10, 5 and 1% and (e) the lag for each variable utilized in our regressions was determined based on the Akaike information criterion (AIC)

**Source(s):** Table by authors

**Table 5.**  
Robustness check  
(1970–2017)

with private investment in machinery and equipment, suggesting a crowding-in effect. Although their estimated long-run parameters are statistically significant and positive, the size of these parameters is notably smaller, and their standard deviations are greater than those in [Tables 2 and 3](#). In other words, the results indicate that an expansion of 1% in public investment in relation to GDP increases private investment in machinery and equipment by 0.24%, while a 1% expansion in infrastructure investment expands the same variable by 0.30%.

Interestingly, in the estimates presented in [Table 5](#), the acceleration effect has been confirmed, as the estimated long-run parameter for the variable demand growth was

statistically significant and positive in all regressions. Consequently, a 1% increase in demand growth expands private investment by approximately 0.30%. The other results remained consistent, except for the negative influence of inflation.

## 5. Concluding remarks

The objective of this article was to investigate the impact of public investment and infrastructure on private investment in machinery and equipment in the Brazilian economy. More specifically, we sought to examine the existence of a crowding-in effect in Brazil. Our contribution to the existing literature lies in providing empirical evidence on the potential association between these variables, which is original given the limited literature on this topic.

Theoretical literature suggests the presence of a complementary association between public investment, infrastructure and private investment. This occurs because expansions in the latter variable are positively linked with firms' profits, reducing costs and enhancing the efficiency/productivity of inputs in production. This, in turn, favors profitability and contributes to the capital accumulation of the private sector. Additionally, in line with post-Keynesian scholars, the government can alleviate uncertainty about the future faced by entrepreneurs through active state planning, involving policies such as public investments in infrastructure and institutions oriented toward economic development.

For the purpose of this article, we conducted a series of econometric regressions by combining annual variables from various sources. Our findings offer evidence that the government can indeed influence private decisions to make new investments in machinery and equipment in Brazil. Expansions in public investment and infrastructure, by fostering profitability and shaping expectations about the future, exert a positive influence over private investment. This indicates the presence of a crowding-in effect or a complementary relationship between these variables. On one hand, this finding helps elucidate the rapid pace of private capital accumulation during the period of Brazilian industrialization until the 1980s, which was guided by government planning and public investment. On the other hand, it helps explain the subsequent slowdown in private investment since the 1990s, following reductions in public investment.

Given the significance of firms' investment in machinery and equipment for economic growth, both in the short and long run, and recognizing the complementarity of this variable with public investment and infrastructure investment, we contend that the Brazilian government should formulate a comprehensive set of public policies aimed at expanding public investment and promoting new investments in infrastructure. Such a strategy is crucial for fostering the capital accumulation of the private sector. Designing and implementing these policies can serve as a catalyst for private investment, thereby accelerating the pace of growth in the Brazilian economy.

## Notes

1. There are three crucial dimensions concerning public investment ([Aschauer, 1998](#)): (1) quantity; (2) financing and (3) efficiency. These factors play a pivotal role in elevating the standard of living and fostering economic growth. Infrastructure policy, however, is not a standalone condition for economic growth; it requires suitable sources of financing and effective utilization policies. In other words, concerns about the growth of public debt are significant, as these factors impact the potential for crowding-out or crowding-in effects in infrastructure investment.
2. Although the literature suggests there is no need for unit root tests, we performed the usual tests to check the existence of unit roots (see [Appendix A](#)). No variable has shown  $I(2)$ , as is required.
3. It is important to emphasize the necessity of conducting additional tests using different measures of BNDES involvement in both infrastructure and manufacturing activities. This is a task for future studies.

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## Appendix

The supplementary material for this article can be found online.

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