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The effects of infrastructure and public investment on the elasticity of private investment: an empirical investigation for Brazil*

Os efeitos da infraestrutura e do investimento público na elasticidade do investimento privado: uma investigação empírica para o Brasil

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RESUMO: Aplicando a abordagem Bayesian Model Averaging e Weighted-Average Least-Squares em um modelo do acelerador flexível de investimento e usando técnicas de filtragem de Kalman, este estudo estima os determinantes das elasticidades do investimento privado e do investimento total para a economia brasileira para o período entre 1960 e 2013. Concluímos que o índice agregado de infraestrutura, retirado da análise de componentes principais, e o investimento público estimulam o investimento privado. Os resultados também indicam que o investimento privado é limitado pela disponibilidade de crédito bancário. Além disso, é constatado que o estoque de infraestrutura e o investimento público são dois dos principais determinantes das elasticidades do investimento privado. Isso confere ao investimento público, principalmente em infraestrutura, grande importância para elevar a sensibilidade do investimento privado na economia brasileira.
PALAVRAS-CHAVE: Infraestrutura; investimento privado; elasticidades.

ABSTRACT: This study estimates the determinants of the elasticities of private investment and total investment for the Brazilian economy for the period between 1960 and 2013. It uses a Bayesian model averaging and weighted-average least-squares approach with a flexible accelerator model of investment equation and Kalman filtering techniques. We conclude that the aggregate infrastructure index (taken from the main component analysis) and public investment crowd-in private investment. The results indicate that private investment is constrained by the availability of bank credit. Furthermore, we find that infrastructure

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stock and public investment are two of the main determinants of the elasticities of private investment. This demonstrates that public investment, mainly in infrastructure, is of great importance in raising the sensitivity of private investment in the Brazilian economy.
KEYWORDS: Infrastructure; private investment; elasticities.
JEL Classification: H54; O40; E20.

1. INTRODUCTION

Private investment is essential for economic growth, which raises the important question of how public policy affects private investment. Public investment in infrastructure is believed to have a positive impact on private investment. In other words, public investment may not only stimulate economic growth directly but also indirectly, promoting private investment. However, other studies suggest that public investment excludes private investment, which would lead to substantially different conclusions regarding public investment policies. This is an important issue, which in itself motivates empirical examinations of the effects of public investment on private investment. Moreover, understanding what the main determinants of private investment are and in particular its sensitivity has implications for public policies to stimulate economic growth.

The main objective of this article is to investigate the determinants of the elasticity of private investment for the Brazilian economy with a special focus on the role of infrastructure stock and public investment for the period from 1960 to 2013. The determinants of private investment itself are also investigated. We build an empirical framework centred on the private investment flexible accelerator model. We estimate the elasticity of private investment using the Kalman filter, which allows us to obtain a variable estimate over time for the Brazilian economy. Then we discuss the determinants of the elasticity of private investment with the help of Bayesian Model Averaging (BMA) and Weighted-Average Least-Squares (WALS) techniques. Our analysis provides relevant information for policy makers to encourage private investment. We aim to determine if the infrastructure stock and/or public investment influence the elasticities of private investment.

This paper is particularly relevant for the Brazilian economy as the country has been facing a low and deteriorating level of investment in infrastructure in the last 30 years. As a result, the inefficiency of ports, airports, energy production, roads, etc. has been increasingly reducing competitiveness and return on investment, comparative to international standards, negatively affecting expectations about the future. Among the empirical studies that seek to identify the determinants of private investment in Brazil, the studies by Ferreira and Miliagros (1998) and Ribeiro and Teixeira (2001) are among the most influential in the literature. The former finds that, for an increase of 1% in infrastructure capital, productivity increases vary from 0.482% to 0.49%. They concluded that the fall in factors' productivity, observed since the 1980s in Brazil, is explained by the reduction in infrastructure investments that occurred in the same period. The second study suggests positive effects of aggregate demand on investment, a negative relationship between private and public investment in the short term, a positive influence of credit availability and an adverse impact of economic instability on private sector investment in Brazil. In a heterogeneous panel-regression for economies in Latin America, Fraga (2019) found a positive impact of infrastructure on the formation of private capital. Also, the physical deterioration of the infrastructure stock decreases the elasticity of private investment in relation to its determinants, resulting in a lower sensitivity of private investment to positive shocks.

Reis et al., (2019) investigated whether the crowding-in effects of complementarity or the crowding-out effects of substitution occurred between public investment and private investment in Brazil from 1982 to 2013. The authors carried out a theoretical analysis of the general dynamics of investment and an econometric analysis applying a Vector Error Correction (VEC) model. The trajectory of the Brazilian economy and the empirical results reveal the presence of crowding-in between public and private investment. For the authors, the crowding-in was justified by the effects on demand through the Keynesian multiplier and through the expansion of the domestic market (particularly provided by infrastructure) and by the effects on the supply of private capital through the reduction in production costs, the increase in productivity, and through structural changes facilitated by public policy. Complementarity regarding both the investment of the public administration and of federal government-owned (or controlled) enterprises is confirmed.

This article is organized as follows. The next section discusses the factors that influence private investment. Section 3 presents the specification of the investment model, the method and the data. The empirical results are in section 4. In section 5 we present the conclusions of the article.

2. FACTORS THAT INFLUENCE PRIVATE INVESTMENT

Investment models in the literature are based on different theoretical frameworks, for example, the Keynesian and Kaleckian models, the Investment Accelerator model, the Flexible Accelerator model, the Neoclassical Investment model, the Options Approach model, the Private Investment model in Developing Countries and the models based on the Microfoundations of Investment. However, these models "allow a myriad of non-trivial and essentially inconclusive sophistications" (Santos; Pires, 2007, p. 9).

Among other approaches that analyse the effects of public investment on economic growth, we highlight two. The first one is based on the neoclassical production function, in which public capital is a separate input and productivity measures derive from a production function. The results of Aschauer (1989a, 1989b) and Munnell (1990) for the USA indicate that non-military public investment, essentially in basic infrastructure, contributes to production and productivity. In addition, data for a larger set of countries support the previous results (Aschauer, 1990;

Cashin, 1995). Later studies, such as Tatom (1991), Holtz-Eakin (1994) and Evans and Karras (1994) found an insignificant impact of public investment on productivity. Khan and Reinhart (1990) and Khan and Kumar (1997), for example, found that, for developing countries, even if public investment contributes to productivity, private investment has a greater influence on growth. In general, empirical studies using the "growth accounting" approach indicate that public investment contributes to economic productivity, although it is not the main source of productivity variations.

The other approach estimates investment models incorporating public investment focusing on its direct effect on private investment and its indirect effect on economic growth. Greene and Villanueva (1991) and Odedokun (1997) using a panel for developing countries, Ramirez (1994) for Mexico and Ramirez (2000), in a panel for Latin American countries, all found positive effects of public investment on private investment. Employing a panel for developing countries, Blejer and Khan (1984), and Oshikoya (1994), using one for African countries, presented evidence that public infrastructure has a positive impact on private investment, while investment in areas other than in infrastructure have a negative impact on investment by the private sector. In more recent works using a panel regression for developing economies, Erden and Holcombe (2005) concluded that public investment complements private investment (crowding-in), and that on average a 10 percent increase in public investment is associated with a 2 percent increase in private investment, but not for developed economies. Regarding the Italian economy, Briguglio et al., (2019) concluded that well-targeted public investment, as well as more adequate training of the workforce, boosts private investment in the long run.

Martins Neto (2015) and Porcile and Martins Neto (2017) theoretically analysed the positive effects of public spending on infrastructure on economic growth. In the first study, the main results of the model were: (i) a greater investment in infrastructure results in higher productivity in the tradable sector; (ii) greater investment in infrastructure leads to a decrease in inflation in the economy as the development process advances with an increase in productivity in the non-tradable sector. In the latter work, the conclusions are that fiscal austerity policies do not work if innovation and technology diffusion are highly dependent on public investment. Every gain in terms of external balance and reducing internal absorption is lost with the deterioration of the infrastructure and the loss of diversification of the productive structure.

It is relevant to note there are other variables which play an important role in private investment. For instance, Tori and Onaran (2020) estimated the effects of different financial channels on physical investment in Europe using the balance sheets of publicly listed non-financial corporations (NFCs) for the period 1995–2015. The evidence suggests that both financial payments and financial income have an adverse effect on investment in fixed assets. The authors found that a higher degree of financial maturity in the country is associated with a stronger negative effect of financial income on investment.

The availability of credit for the private sector is another key variable that determines private investment activities, especially in developing countries (Blejer; Khan 1984; Ramirez, 1994; Erden; Holcombe, 2005; Fraga, 2019). In some cases, credit restrictions may be more restrictive for developing economies than the interest rate, if credit is explicitly rationed or its availability limited. In the various theoretical investment models analysed empirically, the chosen variables are public investment, the real interest rate, credit and the real exchange rate. (Greene; Villanueva, 1991; Peltonen et al., 2012; Rodrik, 2008; Kopp, 2018; Briguglio et al., 2019; Fraga, 2019).

Institutions, including public ones, can also have significant effects on private investment. Some studies argue that institutions protect and encourage market exchanges, such as the protection of property rights, low barriers to international trade, low taxes and minimum regulatory barriers. These factors together are thought to encourage private investment. For Gwartney et al., (2000), economic freedom means that property rights are protected, people have freedom of exchange, the government provides a stable currency, and the government minimally interferes in the economy through taxes and regulations. Other macroeconomic variables frequently included in the estimations are: expected real GDP, GDP, utilization of installed capacity or lagged private investment to reflect the conditions of aggregate demand and represent the accelerator model. The gross fixed capital formation of the public administration is generally used to identify the relationship between public and private investment. Additionally, measures to capture economic instability on private investment and external indebtedness, together with the real exchange rate, are used to investigate the influence of changes in foreign conditions on private investment.

Despite taking into account these variables, the main objective of this article is to investigate the determinants of the elasticity of private investment for the Brazilian economy with a special focus on the role of infrastructure stock and public investment. To this end, the study constructs an empirical framework on the flexible accelerator model of private investment, one of the approaches initially mentioned in this section. Potentially the strongest argument in support of public investment is that public infrastructure investment may have substantial spillover benefits for private investment. If public infrastructure investment is complementary to private investment, the rate of return to private sector investment will increase, leading private sector investors to undertake more capital investment. Public investment may also play a countercyclical role in the economy, reducing the volatility of output and prices, raising private sector investment. If public investment in infrastructure is complementary to private investment, the profitability of the private sector will increase, also increasing investment. However, if public investment competes for the same resources, it can impede private investment, and this crowd-out effect can be more significant. In other words, this can occur if public investments are made by state-owned companies that produce goods and services that are in direct competition with those provided by the private sector (Erden; Holcombe, 2005).

Fraga (2019) assumes that sharp cuts in investment in infrastructure and the continuous deterioration of its stock (infrastructure deficiency) foster the emergence of a "negative" convention that promotes reductions in the elasticity of private investment in relation to its main determinants, such as private credit and public investment in infrastructure. The continuous deterioration of the infrastructure influences the perception of agents, in particular the business community, that the level of infrastructure and related services is noticeably insufficient. Consequently, it can stimulate a collective belief (convention) that leads to a reduction in the sensitivity of private investment.[1]

3. SPECIFICATION OF THE MODEL AND DATA SOURCES

There are several models of investment in the literature originating from distinct theoretical backgrounds. For instance, the Keynesian and the Kaleckian models, the investment accelerator model, the flexible accelerator model, the Neoclassical model of investment, the real options approach and the models based on investment microfoundations. According to Torres and Resende (2015, p. 279) part of "the estimates of these models by several authors present results that are often not very satisfactory in terms of explaining the investment", however, the Investment Accelerator model is among those that produce the best data adjustment.[2]

This model is reformulated in this study to capture the effect of other determinants of private investment, as proposed by Blejer and Khan (1984), Ramirez (1994) and Erden and Holcombe (2005). Therefore, we have included the infrastructure stock in our version of the flexible accelerator model as shown below, as well as the variables that, according to Kopp (2018) and Briguglio et al., (2019), are the most frequently used: lagged private investment (or capacity utilization), real interest rate, credit, public investment and real exchange rate, in addition to infrastructure.

Equation (1) in a reduced form for gross private investment incorporates the infrastructure stock and a set of other relevant variables.

$$I_t = \alpha a_0[1-(1-\delta)L]Y_t^e + \gamma_1 Z_t + \gamma_2 X_t + (1-a_0)I_{t-1} + u_t \qquad (1)$$

When adding the infrastructure stock and other determinants of private investment (vector X_t), equation (1) is expanded to equation (2):

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[1] The deterioration of the infrastructure generates its overuse and increasing restrictions in the provision of its services. This scenario affects productivity and expectations of costs, of aggregate demand and of profits, and may stimulate conventions associated with "negative" expectations that depress their elasticities.

[2] For investment models in the literature, see Aschauer (1989a, b), Calderón and Servén (2009; 2004a, b), Kopp (2018), Briguglio et al., (2019), Greene and Villanueva (1991), Odedokun (1997), Ramirez (2000) Blejer and Khan (1984), Oshikoya (1994), Peltonen et al., (2012), Santos and Pires (2007), Torres and Resende (2015), among others.

$$I_t = \alpha_0 + \alpha_1 Y_t^e + \alpha_2 Z_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + \alpha_6 I_{t-1} + u_t \quad (2)$$

In order to test other forms and a larger set of relevant variables, other private investment equations are estimated in equations (3) and (4):

$$I_t = \alpha_0 + \alpha_1 Y_t^e + \alpha_2 Z_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + \alpha_6 \mathrm{INST}_t + \alpha_7 RER_t \ldots + \alpha_8 I_{t-1} + u_t \quad (3)$$

$$I_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 GI_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + \alpha_6 \mathrm{INST}_t + \alpha_7 RER_t \ldots + \alpha_8 \mathrm{EE}_t + \alpha_9 \mathrm{UTCAP}_t + u_t \quad (4)$$

Table 1: Variables and data sources

	Variable	Expected Sign	Data source
Real Private Investment	*I*	(+)	IMF (2015)
General government investment	*GI*	(+/-)	IMF (2015)
Aggregate infrastructure stock index	*Z*	(+)	Some sources[3]
Real interest rate (Selic)	*R*	(-)	BCB (2020)[4]
Real exchange rate	*RER*	(+/-)	BCB (2020)
Domestic credit to the private sector/GDP	*CRED*	(+)	World Bank Indicators
External debt stock (% of GNI)	*EE*	(-)	World Bank Indicators
Lagged private investments	I_{t-1}	(+)	-
Economic freedom index	*FREE*	(+)	Fraser Institute[5]
Indicator of Economic Instability	*INST*	(-)	FGV (2022)[6]
Capacity Utilization Level (%)	*UTCAP*	(+)	FGV (2022)[7]
The expected GDP	Y^e	(+)	
GDP	*Y*	(+)	

Source: Authors' own.

[3] The Principal Component Analysis (PCA) sectors are: i) length of the train lines and length of the paved roads in kilometers, taken from Canning D. (1998), Federation International Roads (IRF) and the World Bank; ii) fixed telephone subscriptions and mobile phone subscriptions, by Canning D. (1998) and the World Bank; iii) generation of Gigawatt electrical capacity (GW) obtained in Canning D. (1998), World Bank and United Nations Statistics Division.

[4] The first years of the series were represented by the commercial banks' average annual lending rate. Data was also taken from the Central Bank of Brazil and deflated by the General Price Index (IGP-DI).

[5] Which consists of five components: i) Government size; ii) rule of law and protection of private property; iii) Currency strength; iv) Commercial freedom; v) Regulation of the economy. The better the economy is evaluated, the higher the index value, which ranges from 0 to 10, data retrieved from Fraser Institute.

[6] $INST = (1 + P) + \Delta R + \Delta E$ where P is the inflation rate (EM %)/100, measured by the variation of the General Price Index – Internal Availability (IGP-DI), released by Fundação Getulio Vargas (FGV).

[7] Average of the quarterly observations of the Installed Capacity Utilization – General series. It is fundamentally based on the industrial sector.

In order to estimate the expected GDP (Y_t^e), which is not observed, we use the strategy of Erden and Holcombe (2005), a first order autoregressive model, AR (1), the real GDP logarithm is estimated. $\Delta\, expected\ GDP = [Y_t^e - (1 - 0.000)Y_{t-1}^e]$ where depreciation rates are chosen as 0 percent and Y^e are the predicted values obtained from the estimation of an autoregressive process of first order univariate (AR [1]) for real GDP, which represents expected real GDP. The data for real GDP are taken from the Penn World Table. Finally, u_t = random disturbance.

In these specifications, the models are quite flexible, as they allow private investment to be determined not only in terms of the expected level of real product, but also by other relevant variables. As previously discussed, the coefficients of Z and GI can be negative or positive, depending on which effect (substitution or complement) is greater.

The econometric exercise is carried out for the period 1960-2013 for the Brazilian economy. Our series of the infrastructure index Z showed a correlation coefficient of 85.4%, with general government investment GI acting as another proxy for public investment. For the econometric analysis, all the variables were log-linearized using the natural logarithm.

3.1 Method and the elasticity of private investment

The analysis of the determinants of I_t and p_t is performed using the Bayesian Model Averaging (BMA) approach developed by Magnus et al., (2010). The BMA estimator is based on a classical linear regression structure with two subsets of explanatory variables: "focus regressors and auxiliary regressors". The first subset is composed of explanatory variables that are always included in the model for theoretical reasons or other considerations on the investigated phenomenon. The second subset is made up of additional independent variables whose inclusion in the model is less certain.

The problem of model uncertainty and variable selection arises because different subsets of auxiliary regressors can be excluded from the model to improve (in terms of the mean square error) unrestricted ordinary least squares estimates. When there are k_2 auxiliary regressors, the number of possible models to be considered is 2^{k_2} The BMA estimator provides a coherent method of inference on the regression parameters of interest, explicitly taking into account the uncertainty due to the estimation and selection steps of the model. This Bayesian estimator uses conventional non-informative priors in the focus parameters and error variance, and a multivariate Gaussian prior in the auxiliary parameters. The non-conditional BMA estimates are obtained as a weighted average of the estimates for each of the possible models in the model space, with weights proportional to the marginal probability of the dependent variable in each model. An auxiliary regressor is considered robust if the ratio 't' in its coefficient is greater than one in absolute value or, equivalently, the corresponding standard error band does not include zero. Alternatively, the robustness of the auxiliary regressors can be judged on the basis of their subsequent inclusion probabilities. More specifically, Masanjala and Papageorgiou (2008) suggest that a probability of subsequent inclusion of 0.5 corresponds approximately to a ratio 't' of one in absolute value.

The Weighted-Average Least-Squares (WALS) approach is also employed as an alternative technique. WALS was originally introduced by Magnus and Durbin (1999) and Danilov and Magnus (2004) to investigate the statistical properties of pre-test estimators. Unlike BMA, WALS depends on preliminary orthogonal transformations of the auxiliary regressors and their parameters, which greatly reduce the computational power required by this model's average estimator and allow us to explore previous distributions corresponding to a more transparent concept of the role of auxiliary regressors (De Luca and Magnus, 2011).[8] The interpretation of WALS results is similar to that of BMA. However, the main difference is that the WALS estimator does not allow the calculation of the probabilities of subsequent inclusion because this technique of averaging the model considers only k_2 linear combinations of the weights of the model λ_i.

Finally, we carry out autocorrelation, stationarity and cointegration tests in order to compare these results with those of the BMA and WALS estimators.[9] The set of procedures adopted was as follows: the series were subjected to Durbin Watson tests for autocorrelation and Breusch-Godfrey test (or LM test), Augmented Dickey Fuller (ADF) unit root tests; the number of lags in each case was determined by the Schwarz (SC) information criterion; the Johansen Cointegration Test and the Granger Causality Test were also performed.

Based on Kalman filtering techniques,[10] models with time-varying parameters can accommodate and account for changes in the structural characteristics of an economy. This can, for example, have an impact on the elasticities of private investment. In this article, the elasticities of private investment are specified in a space-state model with time-varying parameters and estimated based on the recursive algorithm of the Kalman filter, commonly used to estimate time-varying coefficients.[11] A space-state model consists of two sets of equations, called measurement and state. Kalman's filtering approach provides optimal estimates for state variables based on information from these two sources. Therefore, our model consists of the following system of equations, with the private investment function (5) being the measurement equation and (6) – (7) the two state equations:

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[8] A real value of q in the range of (0,1) corresponding to a neutral Subbotin prior and q (1) Laplace prior is used, with changes in the maximum number of iterations. See De Luca and Magnuss (2011) for more details.

[9] For comparison, we present only the results for equation (2).

[10] The Kalman filter is a tool widely used in the literature to estimate trends of long-term variations over time and evidence shows that it performs well in this regard. For example, a number of contributions found evidence of time variation in the trend of the rate of growth of production or of productivity (e.g., Roberts, 2001; Gordon, 2003), energy prices (e.g., Pindyck, 1999), unemployment (Richardson et al., 2000), estimated income elasticity of imports and exports (Felipea and Lanzafame, 2020).

[11] A wide variety of time series models can be written and estimated as special cases of a space-state specification. Many examples of applications of these models can be found in Harvey (1989).

$$I_t^T = \theta_t r_t + p_t I_{t-1}^T + \mu_t \quad (5)$$

$$\theta_t = \theta_{t-1} + v_t \quad (6)$$

$$p_t = p_{t-1} + \tau_t \quad (7)$$

where the real interest rate is r_t and the terms v_t and τ_t are the independent normally distributed errors, with zero mean and constant variance. The parameters θ_t and p_t are, respectively, the elasticities of the cost of capital (both applied here as a control variable), as suggested by the various versions of the firm's neoclassical decision model and the elasticity of private investment, which vary over time.[12] Therefore, in order to estimate equation (5), we have I_t^T and I_{t-1}^T, which denote the growth rates of the private investment trend and its lagged rate, respectively.[13] Also note that, to capture possible level breaks or trend patterns, we impose a unit root on the state equations – this is a standard procedure in the state-space modelling literature (for example, Harvey 1989). To obtain time series for the state variables, we apply the Kalman smoothing procedure, which uses all the information in the sample to provide smoothed state estimates.[14] This procedure differs from the Kalman filter in the construction of the state series, since the latter technique uses only the information available until the beginning of the estimation period. Smoothed series tend to produce more gradual changes than filtered ones and, as discussed by Sims (2001), they provide more accurate estimates of real-time variation in the data.

Thus, in order to estimate the determinants of the elasticity of private investment, that is, of its sensitivity in the Brazilian economy, the previous econometric exercise is reproduced for the elasticity of private investment equations (8, 9 and 10):

$$p_t = \alpha_0 + \alpha_1 Y_t^e + \alpha_2 Z_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + u_t \quad (8)$$

$$p_t = \alpha_0 + \alpha_1 Y_t^e + \alpha_2 Z_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + \alpha_6 \mathrm{INST}_t \ldots + \alpha_7 REE_t + u_t \quad (9)$$

$$p_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 GI_t + \alpha_3 R_t + \alpha_4 CRED_t + \alpha_5 FREE_t + \alpha_6 \mathrm{INST}_t + \alpha_7 REE_t + \alpha_8 \mathrm{EE}_t + \alpha_9 \mathrm{UTCAP}_t + u_t \quad (10)$$

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[12] To control the short-term effects on private investment – changes in the costs of using capital were included in equation (5).

[13] The two growth trend rates are obtained through the frequency domain filter developed by Corbae et al., (2002) and Corbae and Ouliaris (2006). The Corbae-Ouliaris filter has several advantages over the available alternatives, such as the commonly used Hodrick-Prescott filter or the Baxter-King filter: it can deal with stochastic and deterministic trends, avoids the end-point problem by estimating points directly, does not require the investigator to define any parameters, except for the business cycle interval.

[14] Suppose we look at the sequence of data up to period t: The process of using all this information to form expectations in any period up to t is known as smoothing.

4. EMPIRICAL RESULTS

4.1 Infrastructure stock aggregate index

The aggregate index of infrastructure stock consists of the number of fixed and mobile telephone subscriptions, the generation of electricity in GW, and total length of highways and railways in kilometres. All of these indicators are in natural logarithm. The first main component generated from this analysis has eigenvalues greater than one ($\lambda i > 1$) and is responsible for 86.49% of the total variance of the three infrastructure inventory measures. Therefore, the first main component effectively summarizes the total sample variance and is presented in the equation below:

$$Z_t = 0.6163\ln(Z_1)_t + 0.5411\ln(Z_2)_t + 0.5722\ln(Z_3)_t \tag{11}$$

Where Z_t represents the first major component, $(Z_1)_t$ is the generation of electricity (in GW), $(Z_2)_t$ is the sum of the extension of roads and railways (in km) and $(Z_3)_t$ is the number of subscriptions of landlines and mobile phones.

4.2 Determinants of private investment: a Bayesian Model Averaging and Weighted-Average Least-Squares approach

For robustness checking with alternative methodologies, the Vector Error Correction (VEC) is also implemented. Tests for autocorrelation showed that there is no autocorrelation.[15] The results of the stationarity tests indicated that some series are stationary in level, but all are in first order (Annex, Table A1). Thus, a Johansen Co-integration test was carried out, which concluded that there is a cointegration vector in the model under analysis (Annex, Table A3) and Selection of information criteria (Annex, Table A2). The results for the robust determinants of private investment and their long-term estimation are shown in Table 2.

The results for the long-term estimation maintain the same pattern of results as the robust BMA and WALS estimates. In general, the signs of the coefficients for the conventional determinants of private investment are consistent with theoretical expectations. The estimated coefficient of the lagged dependent variable is between 0.55 and 0.94.[16] The estimated coefficient of expected GDP is significant in BMA and in VEC, indicating the presence of an accelerating effect for the Brazilian economy. It is worth remembering that the expected GDP is the predicted values

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[15] The Cochrane-Orccut Iterative procedure was applied – corrective measure for autocorrelation and the results were maintained, excluding the possibilities of spurious regression. The results for the autocorrelation tests, performed before the stationarity tests are not reported in this article, but can be obtained upon request to the authors.

[16] The lagged private investment coefficient shows the speed of adjustment, which represents the gap between real and desired levels of private investment.

obtained from the adjustment of an AR (1) of the real GDP logarithm.[17] The coefficient of real credit available to the private sector is significant and positive. The real interest rate coefficient has the correct sign (and it is significant), which reinforces the conclusions of previous studies that the availability of credit, and not the cost of financing investment projects, is more binding in developing countries.

Table 2: BMA, WALS and VEC Estimates: robust determinants of I (equation 2)

	BMA		WALS (q=1)		WALS (q=0.5)		WALS (q=0.2)		VEC	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	z
cons	1.662	3.69*	1.706	4.40*	2.07a	6.46*	2.132a	7.14*	-4.249	-
Y^e	0.816	0.96*	0.788	0.90	0.406a	0.48	0.342a	0.40	0.280	-4.02b
Z	0.088	3.13*	0.091	3.52*	0.106a	5.04*	0.117a	5.60*	0.187	-8.04b
R	-0.053	-3.68*	-0.054	-4.35*	-0.065a	-5.40*	-0.069a	-5.53*	-0.231	10.04b
CRED	0.107	2.90*	0.106	2.99*	0.128a	3.65*	0.131a	3.65*	0.523	-6.46b
FREE	-0.035a	-1.10*	-0.040a	-1.78*	-0.059a	-2.59*	-0.063a	-2.80*	-0.234	4.24b
I_{t-1}	0.631	7.72*	0.626	8.38*	0.553	9.00*	0.543a	9.46*	0.945	-2.60b

Source: Statistics estimated using STATA 16 Software. Auxiliary regressors.
*robust coefficient. bsignificant at 1%.

Regardless of the econometric specification used, the results indicate that the impact of the infrastructure stock on private investment is positive (0.088 to 0.187) and significant. This suggests that investment in infrastructure stimulates private investment in the Brazilian economy. Interpreting the coefficient of the WALS specification (q = 0.2), keeping everything else constant, a 10% increase in the infrastructure stock increases private investment by approximately 1.2%. Therefore, in general, there is strong evidence in favour of a complementary relationship between infrastructure and private investment, which is in line with the findings of Greene and Villaneuva (1991), Erden and Holcombe (2005) and Fraga (2019). The impact of institutional differences, measured by the variable economic freedom, is not significant in basically all specifications, following the same pattern of results as Erden and Holcombe (2005).[18]

Table 3 shows the results of equations 3 and 4.[19] In equation 3 the real exchange

[17] However, using real GDP instead of expected GDP or a 2 percent depreciation rate instead of 0 has little effect on estimates.

[18] For Erden and Holcombe (2005), the presence of other regressors, such as the expected GDP, the availability of credit to the private sector and government investment can be highly correlated with the economic freedom index, obscuring any effect that the measure of freedom economic impact on private sector investment.

[19] The results of the Vector Error Correction Model (VEC) are not reported in this table, but they follow the same pattern as the results presented and can be obtained upon request to the authors.

rate regressors were added in order to investigate the influence of changes in external conditions on private investment and a proxy for economic and political instability (inflation variability, interest rate and exchange rate). It can be observed that the previous results were maintained, however, both the regressors inserted were insignificant.[20] Finally, in the specification for Equation (4), the expected GDP is replaced by real GDP, and the infrastructure index is replaced by public investment. A proxy for external restriction and the variable level of capacity utilization are also added to reflect the conditions of aggregate demand and represent the accelerator model.

Table 3: BMA and WALS Estimates: robust determinants of I (equations 3 and 4)

	Equation 3											
	BMA			WALS (q=1)			WALS (q=0.5)			WALS (q=0.2)		
	Coef.	Std. Err	t	Coef.	Std. Err	t	Coef.	Std. Err	t	Coef.	Std. Err	t
cons	1.890	0.444	4.26*	1.823	0.464	3.93*	1.996a	0.377	5.29*	2.023a	0.349	5.79*
Y^e	0.851	0.998	0.85*	0.973	0.906	1.07*	0.866a	0.842	1.03*	1.069a	0.828	1.29*
Z	0.102	0.028	3.65*	0.105	0.026	3.93*	0.109a	0.019	5.51*	0.113a	0.017	6.51*
R	-0.061	0.023	-2.56*	-0.057	0.022	-2.61*	-0.058a	0.017	-3.37*	-0.057a	0.015	-3.67*
FREE	-0.058	0.025	-2.31*	-0.064	0.026	-2.39*	-0.049a	0.026	-1.87*	-0.049a	0.027	-1.77*
INST	0.007	0.027	0.29*	0.007	0.027	0.27	0.000a	0.023	0.00	-0.000a	0.022	-0.00
CRED	0.089a	0.048	1.84*	0.073a	0.033	2.16*	0.111a	0.035	3.12*	0.108a	0.035	3.02*
REE	0.004a	0.024	0.17	0.027a	0.055	0.48	0.010a	0.061	0.17	0.005a	0.063	0.09
I_{t-1}	0.606	0.081	7.45*	0.609	0.079	7.69*	0.559a	0.059	9.40*	0.557a	0.052	10.56*
	Equation 4											
	BMA			WALS (q=1)			WALS (q=0.5)			WALS (q=0.2)		
	Coef.	Std. Err	t	Coef.	Std. Err	t	Coef.	Std. Err	t	Coef.	Std. Err	t
cons	-12.363	1.547	-7.99*	-10.924	2.300	-4.75*	-11.117a	2.187	-5.08*	-11.292a	2.177	-5.19*
Y	0.598	0.052	11.40*	0.557	0.054	10.22*	0.556a	0.052	10.64*	0.566a	0.051	11.03*
GI	0.105	0.064	1.64*	0.119	0.026	1.91*	0.089a	0.063	1.41*	0.082a	0.063	1.30*
R	-0.089	0.020	-4.36*	-0.109	0.023	-4.71*	-0.110a	0.019	-5.54*	-0.109a	0.018	-6.00*
CRED	0.086	0.038	2.23*	0.102	0.041	2.47*	0.113a	0.041	2.71*	0.115a	0.043	2.64*
REE	0.158	0.078	2.02*	0.141	0.079	1.78*	0.221a	0.082	2.68*	0.223a	0.083	2.67*
FREE	-0.126a	0.028	-4.39*	-0.095a	0.028	-3.38*	-0.114a	0.029	-3.83*	-0.120a	0.030	-3.99*
INST	0.016a	0.029	0.55*	0.049a	0.030	1.62*	0.044a	0.028	1.57*	0.041a	0.028	1.47*
EE	0.006a	0.016	0.40	0.025a	0.020	1.22*	0.035a	0.021	1.66*	0.032a	0.020	1.56*
UTCAP	-0.010a	0.130	-0.08	-0.097a	0.350	-0.28	-0.115a	0.353	-0.33	-0.132a	0.363	-0.37

Source: Statistics estimated using STATA 16 Software. Auxiliary regressors.
*robust coefficient.

[20] Dailami (1987), one of the first to empirically investigate the determinants of investment in Brazil, found negative effects of economic instability on private investment.

The replacement of expected GDP with real GDP has little effect on previous estimates. The results for public investment suggest that it has a positive and significant effect on private investment in Brazil, following the same pattern of results as the infrastructure index. In this specification, the real exchange rate shows a positive and significant sign on private investment (0.14 to 0.22). According to Rodrik (2008), market failures and weak institutions increase the stimulus of exchange rate depreciation for investment in the tradable goods sector whilst discouraging investment in the non-tradable goods sector. The positive impact of exchange rate depreciation on aggregate investment also occurs because firms which produce tradable goods are more dynamic and subject to increasing returns to scale. They have a greater learning-by-doing process and accumulation of technological progress, contributing more to innovation and increasing the productivity of the economy, stimulating profits and investment.

The proxy for economic freedom continued with the negative sign, however, with higher absolute values. It is worth noting that the indicator considers the size of the State as a measure of freedom, yet our results suggest that public investment is complementary to private investment, therefore the crowding out effect expected by the proxy may not be observed. The coefficient of the measure of external conditions suggests that external debt services did not affect investment during the analysed period. Regarding the use of installed capacity, the signs found for the estimated coefficients were negative, but not statistically significant. Positive and significant signs had been expected, however. The remaining results followed the standards of previous estimates. Table 4 summarizes the main results considering the significance of the parameters of the private investment parameters.

Table 4: Summary of determinants of real private investment

	Avg	Min	Max	Median	StdDev
Y^e	0.809	0.280	1.069	0.858	0.275
Z	0.113	0.088	0.187	0.106	0.029
GI	0.098	0.082	0.119	0.097	0.016
R	-0.086	-0.231	-0.053	-0.065	0.048
$CRED$	0.137	0.073	0.523	0.108	0.116
I_{t-1}	0.625	0.543	0.945	0.606	0.124
Y	0.569	0.556	0.598	0.561	0.019

Source: Authors' own.

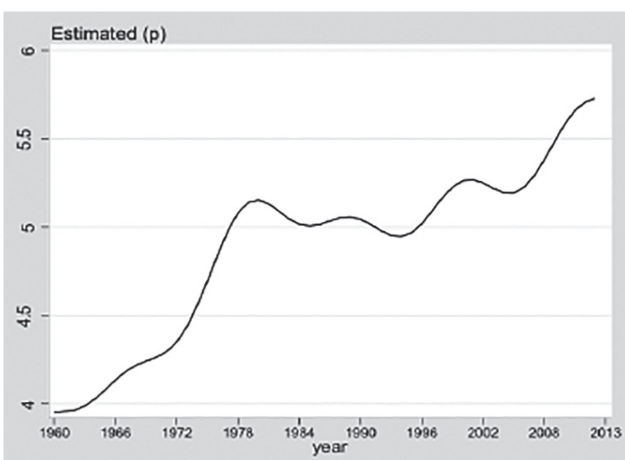
4.3 Determinants of the elasticity of private investment: a BMA and a WALS approach

Figure 1 shows the estimated elasticity of private investment (*p*) for the Brazilian economy, where (*p*) is obtained from the state-space model in (5) – (7).[21] As previously mentioned, the elasticity or sensitivity of the investment varied significantly throughout the analysed period (1960-2013). There was a steady growth rate of around 3.8 in 1960 to 5.15 in 1980. This upward trend halts and there is a slight decrease between 1980 and 1996, reflecting the economic recession of the period. There is stability between 1997 and 2003, followed by another period of increase, which reaches a peak of 5.7 in 2013, reflecting economic growth of about 4% per year average. All of these variations are consistent with the trajectory of private investment in Brazil.

The BMA and WALS analysis of the determinants of the elasticity of private investment is carried out with a total of 5, 7 and 9 regressors (Tables 5 and 6) potentially robust.

In Table 5, the expected GDP coefficient is positive and significant in all estimates (0.12 approximately). The greatest determinant of the elasticity of private investment is the infrastructure stock (0.28). As previously highlighted by Fraga (2019), the deficiency in infrastructure promotes reductions in the elasticity of private investment. As with private investment, the real interest rate showed relevant values in determining investment elasticity. The second major determinant of the elasticity of private investment, private credit (0.12), is significantly positive, reinforcing that the availability of credit rather than the cost of financing investment projects is more relevant in developing countries. Finally, the proxy for economic freedom sign is negative, which means it contributes negatively to the elasticity of private investment.

Figure 1: Estimated elasticity of private investment: Brazil 1960–2013



Note: The elasticity of private investment is constructed from Kalman filtering techniques. Source: Statistics estimated using STATA 16 Software.

[21] Tables 5 and 6 reports the BMA and WALS results from our search for robust determinants of p.

Among the results with alternative methodologies (such as VEC),[22] it is worth noting the strong effect of the real interest rate and the availability of credit on the sensitivity of private investment. Thus, the problem of credit rationing is even more relevant for developing economies because in such economies it is a significant issue for many firms. It is true that real interest rates in Brazil have decreased substantially over time, but they remain well above the average of the inflation targeting regimes in emerging markets (UBIERGO, 2012). According to our results, high interest rates have been very damaging to the sensitivity of private investment. Furthermore, the expectation of improved infrastructure and future demand stimulates profit expectations, favouring a positive convention, which induces private investment and increases its sensitivity to its determinants.

Table 5: BMA and WALS Estimates: robust determinants of p (equation 8)

	BMA		WALS (q=1)		WALS (q=0.5)		WALS (q=0.2)		VEC	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	z
cons	5.020	23.50*	4.938	23.77*	4.966a	23.52*	4.987a	23.60*	4.182	15.10b
Y^e	0.124	2.67*	0.122	2.65*	0.113a	2.45*	0.118a	2.54*	0.229	-2.76b
Z	0.288	18.11*	0.283	18.22*	0.280a	17.73*	0.283a	17.91*	0.177	-6.38b
R	-0.086	-5.71*	-0.083	-5.59*	-0.087a	-5.78*	-0.087a	-5.82*	-0.306	11.13b
CRED	0.113	2.10*	0.124	2.33*	0.125a	2.32*	0.122a	2.25*	0.634	-6.56b
FREE	-0.148a	-3.84*	-0.126a	-3.41*	-0.141a	-3.78*	-0.145a	-3.89*	-0.280	4.25b

Source: Statistics estimated by STATA 16 Software. Auxiliary regressors. *robust coefficient. bsignificant at 1%.

Table 6 includes the real exchange rate and the proxy for economic and political instability (equation 9). Both were not significant (real exchange rate) in determining the elasticity of private investment. Finally, equation 10 presents another specification. Again, the expected GDP is replaced by real GDP, the infrastructure index replaced by public investment and a proxy for external restriction and the variable related to the level of capacity utilization are added.

Table 6: BMA and WALS Estimates: robust determinants of p (equations 9 and 10)

	Equation 9									
	BMA		WALS (q=1)		WALS (q=0.5)		WALS (q=0.2)		VEC	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	z
cons	5.145	10.84*	5.261	11.63*	5.285a	11.55*	5.358a	11.49*	2.266	-
Y^e	0.130	2.64*	0.130	2.74*	0.107a	2.23*	0.105a	2.15*	0.232	-3.84b
Z	0.288	17.29*	0.284	18.09*	0.283a	17.65*	0.287a	-4.10*	0.216	-11.02b
R	-0.114	-3.20*	-0.132	-4.60*	-0.126a	-4.09*	-0.129a	-4.10*	-0.184	4.80b
CRED	0.112	2.02*	0.123	2.33*	0.105a	1.95*	0.099a	1.83*	0.461	-6.89b
REE	-0.009	-0.09	-0.042	-0.42	-0.036a	-0.36	-0.046a	-0.45	0.488	-3.84b
FREE	-0.146a	-3.21*	-0.120a	-3.19*	-0.120a	-2.94*	-0.118a	-2.81*	-0.299	5.95b
INST	0.047a	0.85	0.094a	2.04*	0.075a	1.63*	0.079a	1.69*	-0.142	2.54b

[22] The Johansen Co-integration test and Selection of information criteria are in the Annex, Tables A4 and A5.

Equation 10										
	BMA		WALS (q=1)		WALS (q=0.5)		WALS (q=0.2)		VEC	
	Coef.	t	Coef.	t	Coef.	t	Coef.	t	Coef.	z
cons	-14.098	-3.81*	-14.525	-4.44*	-14.799a	-4.69*	-15.318a	-4.96*	8.060	-
Y	0.624	6.95*	0.626	7.79*	0.581a	7.11*	0.590a	7.28*	0.255	-4.07b
GI	0.166	1.69*	0.146	1.62*	0.128a	1.35*	0.120a	1.24*	0.711	-9.01b
R	-0.024	-0.64	-0.048	-1.32*	-0.053a	-1.74*	-0.052a	-2.00*	-0.026	0.52
CRED	-0.030	-0.44	-0.049	-0.79	-0.044a	-0.71	-0.050a	-0.79	0.568	-8.37b
REE	-0.064	-0.43	0.001	0.01	0.137a	1.37*	0.143a	1.41*	-0.418	3.08b
FREE	-0.041a	-0.82	-0.054a	-1.62*	-0.053a	-1.28*	-0.053a	-1.22*	-0.153	3.44b
INST	0.020a	0.46	0.060a	1.31*	0.071a	1.72*	0.074a	1.95*	-0.371	6.00b
EE	0.027a	0.54	0.057a	1.24*	0.109a	2.27*	0.114a	2.39*	-0.411	10.96b
UTCAP	0.395a	0.71	0.439a	0.96	0.622a	1.33*	0.683a	1.46*	-0.043	5.27b

Source: Statistics estimated by STATA 16 Software. Auxiliary regressors. *robust coefficient. bsignificant at 1%.

In this specification, the greatest determinant of the elasticity of private investment is the level of capacity utilization "degree of warming of the economy" (0.65) on average, for the WALS estimators (0.5 and 0.2). Therefore, increases in activity stimulate private investment. The second major determinant is GDP, (0.60) on average, followed by the real exchange rate and public investment (0.14) on average. It is worth mentioning that, in this econometric exercise, the real interest rate is significant for determining the elasticity of private investment. The proxies for external constraint and economic and political instability remained insignificant, in general. Furthermore, the results suggest that external debt services and the proxy for instability did not significantly affect private investment during the period analysed. In this specification, private credit was not significant. Finally, the proxy for economic freedom maintained its negative sign.

For the alternative method (VEC)[23] used to verify the robustness of previous results, in general, the pattern of preceding estimations was reinforced. Nevertheless, we should highlight the negative sign for external debt stock, an indicator of economic instability. Table 7 summarizes the main results related to the significance of the parameters of the elasticity of private investment determinants.

[23] Due to lack of space, the results of autocorrelation tests, Akaiki and Schwarz information criteria and Johansen Co-integration test, for the next error correction vector model, are not reported in this article but can be obtained upon request to the authors.

Table 7: Summary of determinants of the elasticity of private investment

	Avg	Min	Max	Median	StdDev
Y^e	0.141	0.105	0.232	0.123	0.047
Z	0.266	0.177	0.288	0.283	0.038
GI	0.254	0.120	0.711	0.146	0.255
R	-0.114	-0.306	-0.048	-0.087	0.069
CRED	0.235	0.099	0.634	0.123	0.208
Y	0.535	0.255	0.626	0.590	0.157

Source: Authors' own.

4.4 Causality analysis: elasticity of private investment x infrastructure stock and public investment

Considering the results presented in the previous section, we verify the causality among variables of great interest in this study. The analysis of the causal relationship between the elasticity of private investment, the aggregate index of the infrastructure stock and public investment is made using the Granger Causality Test (Table 8).

Table 8: Granger causality: Brazil (1960-2013)

Variables	Chi2	p-probability
p <— *z*	82.305	0.000
z <— *p*	10.374	0.110
p <— *GI*	95.389	0.000
GI <— *p*	20.155	0.003

Source: Statistics estimated by STATA 16 Software.

First, the series lag test was performed using the information criteria of Akaiki and Schwarz. It started with 12 lags and they were reduced gradually, based on the principle of parsimony, reaching 4 lags (Annex, Table A6).[24] The Granger-cause approach suggests a causal relationship between the aggregate index of infrastructure stock to the elasticity of private investment[25] and a two-way relationship between public investment and the elasticity of private investment.

In the Brazilian economy, there has been a discontinuity of investment in infrastructure, as well as public investment, which has caused a deterioration of its stock

[24] It is worth noting that, between the planning and execution of infrastructure projects, there are usually large lags in developing economies. It is worth noting that the results consider the elasticity of private investment as the dependent variable.

[25] For greater lags, this test suggests a bidirectional relationship.

over the last 30 or 40 years. Our infrastructure index and the elasticity of private investment showed a causal relationship, with infrastructure being one of the main determinants of the elasticity of private investment in the BMA and WALS estimates. We can therefore say that investment in infrastructure is of great importance in raising the sensitivity of private investment in the Brazilian economy.

5. CONCLUDING REMARKS

The main objective of this article was to investigate the determinants of the elasticity of private investment for the Brazilian economy with a primary focus on the role of infrastructure stock and public investment. The determinants of private investment were also investigated.

We conclude that the aggregate infrastructure index (taken from the main component analysis) and public investment complement private investment during the period studied. The results also indicated that private investment and its elasticities were limited by the availability of bank credit. This is particularly important in the Brazilian case given the low development of its capital market. Interest rates ranking among the highest in the world and practiced for decades are notably responsible for this.

Other relevant variables for determining private investment and its elasticities are: expected GDP, real exchange rate, GDP and the level of utilization of installed capacity. In general, the real interest rate had the expected impact. High interest rates have long been a problem in Brazil, often seen as a puzzle, and this has proved to be detrimental to private investment, as demonstrated in this paper. We found that political and economic instability and external restrictions were not significant for private investment. The proxy for institutions (economic freedom) suggested negative impacts on all estimated specifications, either for private investment or for its elasticity. Finally, by applying different models, our estimates have shown that public investment, particularly in infrastructure, is very relevant for the dynamics of private sector investment, with its role being complementary instead of competitive.

The industrialization process of the Brazilian economy was characterized by high investment in infrastructure. In the period from 1950 to 1978 there was an accelerated increase in investment in electricity and transport, contributing to a great growth in GDP. However, from the 1980s, this investment was discontinued, resulting in the deterioration of infrastructure over the last 30-40 years. This process resulted from the reforms of the 1990s which removed from the State responsibility for the formation of the infrastructure stock. As a result, the inefficiency of ports, airports, energy production, roads, etc., in relation to international standards has damaged domestic competitiveness and return on investment.

The conclusions drawn in this study also have public policy implications. To begin with, it is interesting to promote a favourable investment environment so that the private sector can react positively with more investment. This can be done either with lower interest rates or with greater funding availability. In addition, it is advisable to prioritize investments in infrastructure. On the private side, legal frameworks should be updated, while on the public side, public-private partnerships could be intensified. In addition, public investment in infrastructure itself should be increased, always aiming to improve the accountability of such investment. For this purpose, a new fiscal framework may be necessary, and investment spending should be minimally preserved.

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ANNEX

Table A1: Unit Root Tests

Level Variables				Variables in First Difference			
Series	ADF	PP	Integration Order	Series	ADF	PP	Integration Order
I	-1.15	-1.13	I (0)	I	-5.75***	-5.74***	I (1)
Y^e	-2.43	-2.38	I (0)	Y^e	-8.23***	-8.24***	I (1)
Z	-2.21	-1.99	I (0)	Z	-9.36***	-9.37***	I (1)
R	-3.65***	-3.14***	I (0)	R	-5.65***	-5.66***	I (1)
FREE	-1.76	-1.78	I (0)	*FREE*	-7.07***	-7.07***	I (1)
INST	-2.50	-2.65*	I (0)	*INST*	-7.60***	-7.60***	I (1)
I_{t-1}	-1.45	-1.32	I (0)	I_{t-1}	-5.40***	-5.40***	I (1)
CRED	-1.87	-1.82	I (0)	*CRED*	-4.96***	-6.22***	I (1)
REE	-2.55	-2.68*	I (0)	*REE*	-6.24***	-6.25***	I (1)
GI	-1.45	-1.53	I (0)	*GI*	-8.27***	-8.29***	I (1)
EE	-3.13**	-6.94***	I (0)	EE	-4.71***	-6.94***	I (1)
UTCAP	-2.30	-2.36	I (0)	*UTCAP*	-7.24**	-7.24**	I (1)
p_t	-4.33***	-0.93	I (0)	p_t	-6.88***	-2.62*	I (1)

*** Indicates rejection of the null hypothesis at the level of 1% significance.
** Indicates rejection of the null hypothesis at the level of 5% significance.
* Indicates rejection of the null hypothesis at the level of 10% significance.
Source: Statistics estimated by STATA 16 Software.

Table A2: Model Selection: Information Criteria

Lag	Logl	LR	FPE	AIC	SC	HQ
0	-205.105		0.000	8.616	8.704	8.848
1	48.008	506.23	0.000	-0.245	0.369*	1.376*
2	85.445	74.875	0.000*	-0.303	0.838	2.707
3	121.193	71.494	0.000	-0.293	1.376	4.107
4	172.074	101.76*	0.000	-0.900*	1.296	4.890

AIC – Akaike criterion, SC – Schwarz criterion and HQ the Hannan-Quinn criterion
Source: Statistics estimated by STATA 16 Software.

Table A3: Johansen Co-Integration Tests

Cointegration Rank Test					
H_0	*H_1*			Critical Value	Critical Value
Rank=r	Rank>r	Eigenvalue	Trace	5%	1%
0	0	-	124.9419	94.15	103.18
1	1	0.699	63.6603***	68.52	76.07

***indicates the number of co-integration vectors at levels of significance 1% and 5%
Source: Statistics estimated by STATA 16 Software.

Table A4: Model Selection: Information Criteria

Lag	Logl	LR	FPE	AIC	SC	HQ
0	-374.142		2.654	15.165	15.238	15.356
1	-72.988	602.31	0.000	4.119	4.556	5.266*
2	-40.524	64.927	0.000*	3.820	4.621	5.924
3	-4.447	72.154	0.000	3.377	3.813*	6.437
4	47.894	104.68*	0.000	2.284*	3.542	6.299

AIC – Akaike criterion, SC – Schwarz criterion and HQ the Hannan-Quinn criterion
Source: Statistics estimated by STATA 16 Software.
Note: Given the divergent results of the information criteria, it was chosen the smallest lag indicated, based on the principle of parsimony.

Table A5: Johansen Co-Integration Tests

Cointegration Rank Test					
H_0	*H_1*			Critical Value	Critical Value
Rank=r	Rank>r	Eigenvalue	Trace	5%	1%
0	0	-	74.622	47.21	54.46
1	1	0.621	24.070***	29.68	35.65

***indicates the number of co-integration vectors at levels of significance 1% and 5%
Source: Statistics estimated by STATA 16 Software.

Table A6: Model Selection: Information Criteria

Lag	Logl	LR	FPE	AIC	SC	HQ
0	100.842		0.000	-4.034	-4.005	-3.957
1	145.532	89.381	0.000	-5.695	-5.607	-5.463
2	206.144	121.22	1.1e-06	-8.005	-7.859	-7.619
3	264.515	116.74	1.2e-07	-10.225	-10.02	-9.684
4	297.579	66.128*	3.8e-08*	-11.411*	-11.147*	-10.716*

AIC – Akaike criterion, SC – Schwarz criterion and HQ the Hannan-Quinn criterion
Source: Statistics estimated by STATA 16 Software.
Note: the information criteria considered the elasticity of private investment as the dependent variable.