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How infrastructure investments affect economic activity? The case of Brazil

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HOW INFRASTRUCTURE INVESTMENTS AFFECT ECONOMIC ACTIVITY? THE CASE OF BRAZIL

Mario A. Margarido, Frederico Turolla, Maria Eduarda de Paula-Fernandes

This article presented an econometric evaluation, based on time series models, to analyze the long-term relationship between the gross capital formation index with emphasis on civil construction, considering that this index was developed and published by IPEA and the index of economic activity of the Central Bank as a proxy for GDP growth. Although simple, the exercise may yield important evidence that might feed into the literature from an anecdotal evidence perspective. The results show that a 1% variation in the fixed capital formation index induces a variation of approximately 0.4% in the GDP, in the long term, configuring an inelastic relationship between investments in infrastructure based on civil construction and the GDP.

Keywords: infrastructure, construction, economic activity, time series, Brazil.

Este artigo apresenta uma avaliação econométrica, baseada em modelos de séries temporais, para analisar a relação de longo prazo entre o índice de formação bruta de capital com ênfase na construção civil, considerando que este índice foi desenvolvido e divulgado pelo IPEA e o índice de atividade econômica do Banco Central como proxy para o crescimento do PIB. Embora simples, o exercício pode produzir evidências importantes que podem alimentar a literatura a partir de uma perspectiva de evidência anedótica. Os resultados mostram que uma variação de 1% no índice de formação de capital fixo induz uma variação de aproximadamente 0,4% no PIB, no longo prazo, configurando uma relação inelástica entre os investimentos em infraestrutura baseados na construção civil e o PIB.

Palavras-chave: infraestrutura, construção, atividade econômica, series temporais, Brasil.

CONTENTS

1. INTRODUCTION

Infrastructure investments are forms of capital formation that offer widely known twofold impacts on the economy. On the one hand, they contribute to aggregate demand with the purchase of capital goods that foster economic activity in the short term, even before the new assets begin to contribute to other social and economic improvements typically associated with their availability. On the other hand, they have long term impacts on cities, regions, and countries, especially in the case of developing countries, by providing a reduction in social inequality via new opportunities for the most vulnerable population to access sanitation, energy, health, telecommunications, in addition to reducing the costs involved with economic transactions, not only internally, but also in relation to the international market. The total impacts seem, however, not to be well researched in their aggregate, especially in the context of emerging markets like Brazil.

2. LITERATURE AND INTENDED CONTRIBUTION

The economic growth literature tradition and more recently a more applied literature have provided estimates of the contribution of infrastructure capital in the aggregate and by infrastructure sectors, and to social and environmental development through several channels of impact (e.g. Calderón et al, 2015; Banerjee et al, 2012; Agenor and Moreno-Dodson, 2006).

There is a buoyant literature on the ex-post analysis for impact evaluation of infrastructure investments which was recently applied to Brazil with large studies presented in the Benevenuto et al (2022) series, based on the first national study of ex-post evaluation carried out for seven infrastructure sectors in Brazil. A World Bank guide on the ex-post evaluation of infrastructure projects is also available (Andrés et al, 2013). Against that background, most studies on the topic of infrastructure use models based on panel data as a basic econometric instrument. In addition, their analysis involves comparing different countries and specific sectors, such as transport, energy, telecommunications, and others.

In this paper we have carried out a complementary analysis of the impact of infrastructure investments on economic activity. We estimate, using time series econometrics, a model that relates fixed capital formation in infrastructure assets to the basic economic activity measure that proxies the GDP growth figure. Although simpler, the exercise may yield important evidence that might feed into the literature from an anecdotal evidence perspective. Among the few more specific references, a technical study by the Projeto infra2038 (2022) evaluated the contribution of the CAPEX commitments in infrastructure auctions in Brazil on GDP growth, but with a narrower focus on direct impact of the stock exchange observed deals. The main ideia is that although infrastructure investments are hard to promote (Sader, 2000) considering the underlying market failures and contract issues involved (Nóbrega, Veras and Turolla, 2023; Turolla, 2013), whenever they are promoted, it pays off, and we try here to estimate directly by how much.

Here, time series models are used, with emphasis on cointegration and Vector Error Correction Model (VEC). Another aspect to highlight is that, in this case, the fixed capital formation indicator related to civil construction is being used, which is generated and published by the Institute of Applied Economic Research (IPEA), and which will be used as a [1]proxy *variable* for the formation of fixed capital, such as works related to sanitation, transport, energy, telecommunications, exclusively for Brazil. Therefore, unlike other studies, the aim is not to make comparisons with other countries in terms of infrastructure, but rather to verify how fixed capital formation - civil construction, impacts the country's GDP over time.

3. OBJECTIVE

The purpose of this text is to quantify what will be called infrastructure elasticity, that is, to evaluate how variations in the Gross Capital Formation Index - Civil Construction, impact the behavior of the Economic Activity Index (IBC-Br)[2], which is considered, by the market, as a *proxy variable* of the Gross Domestic Product (GDP) in Brazil. In other words, we intend to find empirical evidence on the relationship between infrastructure investment and economic activity in the long term. The theoretical bases for this relationship are not discussed here.

4. MATERIAL AND METHODS

The series used in this study are the Economic Activity Index (IBC-Br) developed and published by the Central Bank of Brazil (BACEN), which was extracted from the IPEADATA[3] *website* and the IPEA Fixed Capital Formation Index with emphasis on Civil Construction from the Institute of Applied Economic Research (IPEA), obtained from the February 2022

[1] Details about the IPEA indicator of capital formation – civil construction, can be found in Carvalho and Ribeiro (2017).

[2]Methodological details of the IBC-Br can be found in the Central Bank of Brazil's Inflation Report, March 2016, volume 18, n.1, p.23. https://www.bcb.gov.br/htms/relinf/port/2016/03/ri201603P.pdf

[3] Data collected from IPEADATA at http://www.ipeadata.gov.br/Default.aspx

GFCF Ipea Indicator Letter[4]. It should be noted that the Fixed Capital Formation Index is made up of three other indicators, Civil Construction, Apparent Consumption of Machinery and Equipment, Apparent Consumption of Others. The analyzed period starts in January 2003 and ends in February 2022.

The choice of the variable of fixed capital formation is in line with other papers like Berk and Biçen (2018), who also took a broader approach to infrastructure by defining "construction refers to building and infrastructure works in sectors such as energy, defense, and transportation, in both individual and commercial residential areas". We can thus identify construction as the activity that forms the stock of infrastructure assets.

The variable Fixed Capital Formation Index – Civil Construction is called *FBKCC,* while the Central Bank Economic Activity Index is called *IBCBR*. Given that the two variables show seasonality, it was necessary to pass them through the X13-ARIMA-SEATS Decomposition Method [5]to remove the respective seasonal patterns, thus, the two variables were named *FBKCC_d11* and *IBCBR _ d11*.

After removing the respective seasonality, the neperian logarithm operator was applied to the two variables. The application of the logarithm operator has two purposes. First, it reduces the variance of the two variables. Furthermore, the coefficients associated with the logarithms of the respective variables directly provide the respective elasticity. Therefore, each variable was named *l_FBKCC_d11* and *l_IBCBR _ d11,* respectively.

After the procedures presented above, the following econometric methods were used. Augmented Dickey-Fuller Unit Root Test-ADF (Dickey and Fuller, 1979, 1981), Granger Causality Test, Johansen Cointegration Test, Vector Error Correction Model (VEC), Impulse Response Function, Variance Decomposition of Forecast Errors and Cointegration test of Hansen's Stability Parameters.

5. RESULTS ANALYSIS

The results of the ADF unit root tests for the variable *l_IBCBR _ d11* in level, show that, for the three models, the respective null hypotheses that the series has a unit root, cannot be rejected, since the probability of committing the Type I Error, that is, rejecting the null hypothesis and making a mistake, in each model, are above the 10% significance level,

[4] Available at: https://www.ipea.gov.br/cartadeconjuntura/index.php/tag/indicador-ipea-de-fbcf/

[5]Details on how to use the X13-ARIMA-SEATS Decomposition Method can be found in Margarido (2021).

therefore, it can be inferred that this series in level, has a unit root (Table 1). A similar analysis applies to the variable *l_FBKCC_d11,* therefore, it can be inferred that the referred variable in level also has a unit root (Table 1).

Given that the variables have a unit root in level, the ADF tests were performed again for the two variables, this time with the two series differentiated of order one. For both variables, considering all models, all results show that all the respective null hypotheses of the presence of a unit root can be rejected, since the probability of rejecting the respective null hypotheses are below the level of significance, therefore, it can be inferred that the two variables became stationary after the application of the order one difference operator on each of the variables (Table 2). Therefore, the two series are integrated of order one, since only a difference of order one was necessary to make each of the variables stationary.

Table 1 - Results of the ADF Unit Root Tests, variables in level, *l_IBCBR _ d11* and *l_FBKCC_d11,* January 2003 – February 2022

Level Variables	Model	Statisticτ	Prob < Tau
l_IBCBR _ d11	With trend and constant(τ_τ)	-1.69685	0.753
	only with constant(τ_μ)	-2.3815	0.147
	No trend and no constant(τ)	1.60247	0.9738
l_FBKCC_d11	With trend and constant(τ_τ)	-1.33281	0.8796
	only with constant(τ_μ)	-1.46452	0.5518
	No trend and no constant(τ)	0.672519	0.8611

Source: Based on basic data from IPEADATA and IPEA.

Table 2 - Results of the ADF Unit Root Tests, variables in level, *l_IBCBR _ d11* and *l_FBKCC_d11,* January 2003 – February 2022

Differential Variables of Order One	Model	Statisticτ	Prob < Tau
l_IBCBR _ d11	With trend and constant(τ_τ)	-15.1444	9,491e-44*

Differential Variables of Order One	Model	Statisticτ	Prob < Tau
	only with constant(τ_μ)	-15.0035	3.57e-35*
	No trend and no constant(τ)	-14.8666	7,064e-32*
l_FBKCC_d11	With trend and constant(τ_τ)	-18.6582	3,039e-62*
	only with constant(τ_μ)	-18.6752	9,249e-45*
	No trend and no constant(τ)	-18.6813	8,912e-39*

*Cientific notation.

Source: Based on basic data from IPEADATA and IPEA.

Once the order of integration of each variable was determined, the Granger Causality test was performed. At this point, it is necessary to emphasize that, given that this test requires the variables to be stationary, then, in this case, the causality test must be estimated with the differentiated variables of order one. In economic terms, working with stationary series implies the fact that their results refer to the short term.

The results of the Granger Causality tests show that the Null Hypothesis that *d*l_FBKCC_d11* does not Granger Cause *d*l_IBCBR _ d11,* cannot be rejected, since the probability of committing the Type I Error, i.e., rejecting the Null Hypothesis and making a mistake, is above the significance level of 10% (29.35%), therefore, it can be inferred that gross capital formation – civil construction does not cause the economic activity index, the which is a *proxy* for short-term GDP (Table 3). The second test also shows that the Null Hypothesis that *d*l_IBCBR _ d11* does not Granger Cause *d*l_FBKCC_d11,* too, cannot be rejected, since its respective P-value is above the 10% significance level (22.04%), as shown in Table 3. This result also shows that GDP does not cause gross capital formation – civil construction, in the short term. Therefore, it can be inferred absence of causality between the two variables. This result was already expected, given that investments in infrastructure, such as civil construction, are characterized by being long-term, since their impacts effectively on GDP are characterized by being long-term.

Table 3. Results of the Granger Causality Tests, variables *d*l_IBCBR _ d11* and *d*l_FBKCC_d11,* January 2003 – February 2022

Null Hypothesis: Sense of Causality	lags	F statistics	P-Value
*d*l_FBKCC_d11* not Granger Cause *d*l_IBCBR _ d11*	1	1,1086	0.2935
*d*l_IBCBR _ d11* not Granger Cause *d*l_FBKCC_d11*	1	1,5099	0.2204

*The letter d before the name of each variable indicates that the variable was distinguished from order one.

Source: Based on basic data from IPEADATA and IPEA.

Having determined the short-term relationship between the two variables, a long-term analysis will now be performed, using the Johansen cointegration test. In this case, the normalized variable was the GDP, that is, this variable corresponds to the dependent variable of the system, therefore its coefficient corresponds to one. To perform the Johansen cointegration test, the Trait and Maximum Eigenvalue statistics were used. However, before carrying out the cointegration test, it is necessary to identify which of the five cases described in Johansen (1995) should be used. After some tests, the Case that best fits is Case 4, which imposes restriction on the deterministic trend in the Vector Error Correction Model (VEC).

The results presented in Table 4 show that the results of the two statistics converge. Therefore, the analysis of results will focus on the Trait statistic. The initial Null Hypothesis is that there is no cointegration vector against the Alternative Hypothesis that there is only one cointegration vector. The probability of committing the Type I Error, that is, rejecting the Null Hypothesis that there is no cointegration vector and making a mistake, is below the significance level of 1% (0.19%), therefore, the Null Hypothesis is rejected, and it can be inferred that there is at least one cointegration vector (Table 4). Given that, there are two variables in the system, and a cointegration vector was found, the test must continue, and now, the Null Hypothesis is that there is only one cointegration vector, while the Alternative Hypothesis is that there is two cointegration vectors. In this case, the probability of committing the Type I Error is above the significance level of 10% (31.38%), so the Null Hypothesis is not rejected, and it can be inferred that there is only one cointegration vector (Table 4). As the system has two variables and a co-integration vector, the next step is to estimate a Vector Error Correction Model (VEC). Also, it is necessary to emphasize that it was necessary to include two intervention variables in relation to the temporal evolution of the

IBC-Br variable. An intervention variable [6]with a temporary effect of the *Additive Outlier type* (*AO*) in February 2016. It was also necessary to include an intervention variable with a permanent impact of the *Level Shift type* (*LS)* in April 2020. It is necessary to emphasize that the two intervention variables were inserted in the cointegration vector itself.

Table 4. Results of the Johansen Cointegration Tests, Variables *l_IBCBR _ d11* and *l_FBKCC_d11,* Level, January 2003 – February 2022

null hypothesis	Alternative Hypothesis	Trait Statistics	P-value	Maximum Eigenvalue Statistics	P-Value
Rank = 0	*Rank* = 1	35,225	0.0019	27,825	0.0015
Rank = 1	*Rank* = 2	7.4002	0.3138	7.4002	0.3143

Source: Based on basic data from IPEADATA and IPEA.

IBC-Br series in February 2016 is related to the impeachment process of Dilma Rousseff, which began in December 2015, and, at least temporarily, impacted the agents' expectations economic factors on the future of the country in the short term. The second structural break is related to the COVID-19 crisis, which had a more negative effect on the economy, exactly, in April 2020, which demonstrates to have permanent structural effects, not only on the Brazilian economy, but, also on the world economy.

Given that the system contains two variables, and only one cointegration vector, a Vector Error Correction model must be estimated. The VEC Model estimates are shown in Table 5.

Table 5.- Results of the Error Correction Vector Model (VEC), Variables *l_IBCBR _ d11* and *l_FBKCC_d11,* Level, January 2003 – February 2022

Short Term Parameters	Long Term Parameters
α_{11}=- -0.072169	β_{11}= 1.0000
α_{21}= 0.056389	β_{12}= -0.39587

Source: Based on basic data from IPEADATA and IPEA.

[6] Details about the types, as well as the use of intervention variables in time series models, can be found in Vandaele (1983).

The analysis of the VEC Model starts with the long-term elements. Mathematically, the cointegration vector is represented as:

$$l\_IBCBR\_d11_{t-1} + -0.00083935 * \mathrm{t} - 0.39587 * l\_FBKCC\_d11_{t-1} + 0.41535 * \mathrm{INT0216}_{\mathrm{t-1}} + 0.081030 * \mathrm{COVID0420}_{t-1}$$

The variable to be normalized is $l\_IBCBR\_d11_{t-1}$, therefore, its coefficient assumes a value equal to unity. The value -0.00083935 * t, in the above formula, refers to the deterministic trend of the Error Correction Term. The value 0.41535 refers to the value of the intervention variable related to February 2016, while the value 0.081030 refers to the intervention variable related to the COVID-19 crisis in April 2020, also, both in the Error Correction Term.

To generate the model equation, it is necessary to set the cointegration vector equal to zero, thus implying:

$$l\_IBCBR\_d11_{t-1} + -0.00083935 * \mathrm{t} - 0.39587 * l\_FBKCC\_d11_{t-1} + 0.41535 * \mathrm{INT0216}_{\mathrm{t-1}} + 0.081030 * \mathrm{COVID0420}_{t-1} = 0$$

The next step consists of isolating the normalized variable ($l\_IBCBR\_d11_{t-1}$), and inverting the sign of the others, which are considered as independent variables:

$$l\_IBCBR\_d11_{t-1} = 0.00083935 * \mathrm{t} + 0.39587 * l\_FBKCC\_d11_{t-1} - 0.41535 * \mathrm{INT0216}_{\mathrm{t-1}} - 0.081030 * \mathrm{COVID0420}_{t-1}$$

Student 's *t* Test Value, Cointegration Vector with Intervention Variables

Estimated Parameter Value	Standard Error of Estimation	Calculated *Student* 's *t*-value
0.39587	0.050556	7.83*
0.00083935	0.00014378	5.83*
– 0.41535	0.10779	-3.83*
– 0.081030	0.028525	-2.84*

*Statistically significant at the 5% significance level. The critical value of *Student* 's *t distribution* is|1.65168|

Source: Based on basic data from IPEADATA and IPEA.

The long-term analysis provided from the estimated values for the cointegration vector, show that a 1% variation in $l_FBKCC_d11_{t-1}$induces a 0.3958% variation in $l\_IBCBR\_d11_{t-1}$, in the long term (Table 5). Therefore, it can be inferred that the relationship between gross capital formation – civil construction and *IBC-Br* is positive, as expected and inelastic. Also, from the cointegration vector, it can be inferred that the intervention variable inserted in February 2016 determined a 41.35% drop in the level of the *IBC-Br series* (Table 6). Apparently, the beginning of the impeachment process had a strong impact on the market, however, its effect was transitory. The COVID-19 crisis determined an 8.10% drop in the level of the *IBC* -Br series (Table 6). The two variables have the respective negative signs, as expected.

Once the long-term parameters have been analyzed, it is now necessary to analyze the short-term parameters. The parameter α_{11}, with a value equal to -0.072169, in Table 5, shows that imbalances in the variable $l\_IBCBR\_d11_{t-1}$, on average, are corrected by 7.21% each month. Therefore, for all imbalance to be eliminated, 13.85 months are needed. Still, based on Table 5, a variation of 1% in $l\_FBKCC\_d11_{t-1}$, induces a variation of 0.39587% in $l\_IBCBR\_d11_{t-1}$, in up to 13.8 months, which, in this model, corresponds to the long term.

Regarding the parameter α_{21}, its positive sign, this indicates that the variable $l_FBKCC_d11_{t-1}$is weakly exogenous, that is, it does not react to short-term imbalances. In other words, variations in the gross capital formation variable – civil construction, determine variation in the economic activity indicator variable, not the opposite, (Table 5), the positive sign of the respective parameter, confirms this fact that the referred parameter is weakly exogenous. However, a hypothesis test was performed to confirm this result. In this case, the linear restriction was imposed that $\alpha_{21} = 0$, that is, the imposition of this restriction means that it is being admitted that the gross capital formation index – civil construction is a weakly exogenous variable, that is, it does not react to short-term imbalances. term, therefore, variations in gross capital formation impact the indicator of economic activity in Brazil, but the opposite does not occur. Mathematically, this restriction is represented as:

$$\begin{pmatrix}\alpha_{11}\\ \alpha_{21}\end{pmatrix} = \begin{pmatrix}1\\ 0\end{pmatrix}(\varphi)$$

For any significance level adopted (1%, 5% and 10%), the null hypothesis that the international oil price variable is weakly exogenous is not rejected, since the P-value is equal to 34.63%, that is, very above the 10% significance level (Table 7). Therefore, it can be inferred that the variable gross capital formation – civil construction is weakly exogenous, that is, it does not react to short-term imbalances, thus confirming that the variation in this variable determines variations in the economic activity index variable, which is a *proxy* of GDP, not the opposite.

Table 7 - Result of the Restriction Significance Test on the Short-Term parameter (α_{21}), Variables *l_IBCBR _ d11* and *l_FBKCC_d11,* Level, January 2003 – February 2022

Statistics and Degree of Freedom	Statistics Value	P-value
$\chi^2(1)$	0.886927	0.346312

Source: Based on basic data from IPEADATA and IPEA.

Two other instruments provided by the VAR/VEC models are the Variance Decomposition of Forecast Errors and the Impulse Response Function. These two instruments are very useful for analyzing the dynamics between model variables. According to Margarido (2000, p. 132-133), "the decomposition of forecast errors shows the dynamic behavior presented by economic variables. More specifically, this instrument makes it possible to separate the forecast error variance for each variable into components that can be attributed by the other endogenous variables in isolation, that is, it reveals in percentage terms what effect an unanticipated shock on a given variable has on the others. variables belonging to the system".

Figure 2 shows the Variance Decomposition of Forecast Errors for the variable *l_IBCBR _ d11*. Sixty months after an unanticipated shock [7] to the variable *l_IBCBR _ d11,* it is observed that, in percentage terms, 75.47% of the value of this variable is due to itself, while the variable *l_FBKCC_d11* contributed with 24.52% in the formation of the variable *l_IBCBR _ d11*. Therefore, it can be inferred that, given a shock to GDP, 60 months after this initial shock, almost 25% of GDP value is due to Gross Fixed Capital Formation - Civil Construction, thus showing the importance of investments in infrastructure for the composition of the country's GDP.

Figure 3 shows the Variance Decomposition of Forecast Errors for the variable *l_FBKCC_d11*. Sixty months after the initial shock on this variable, it is observed that it is losing strength, while the participation of the variable *l_IBCBR _ d11* gains space. In percentage terms, at the end of the 60-month period, after the initial shock, only 39.59% of the value of *l_FBKCC_d11* is due to the variable itself, while the variable *l_IBCBR _ d11* contributes with 60.40% in the formation of the value of *l_FBKCC_d11,* as can be seen in Figure 3.

[7] The justification for using a shock cannot be anticipated by economic agents, lies in the fact that, if economic agents are aware that a possible shock may occur, they will have time to create measures to protect themselves from such a shock, nullifying thus, totally or partially, the effects of that shock.

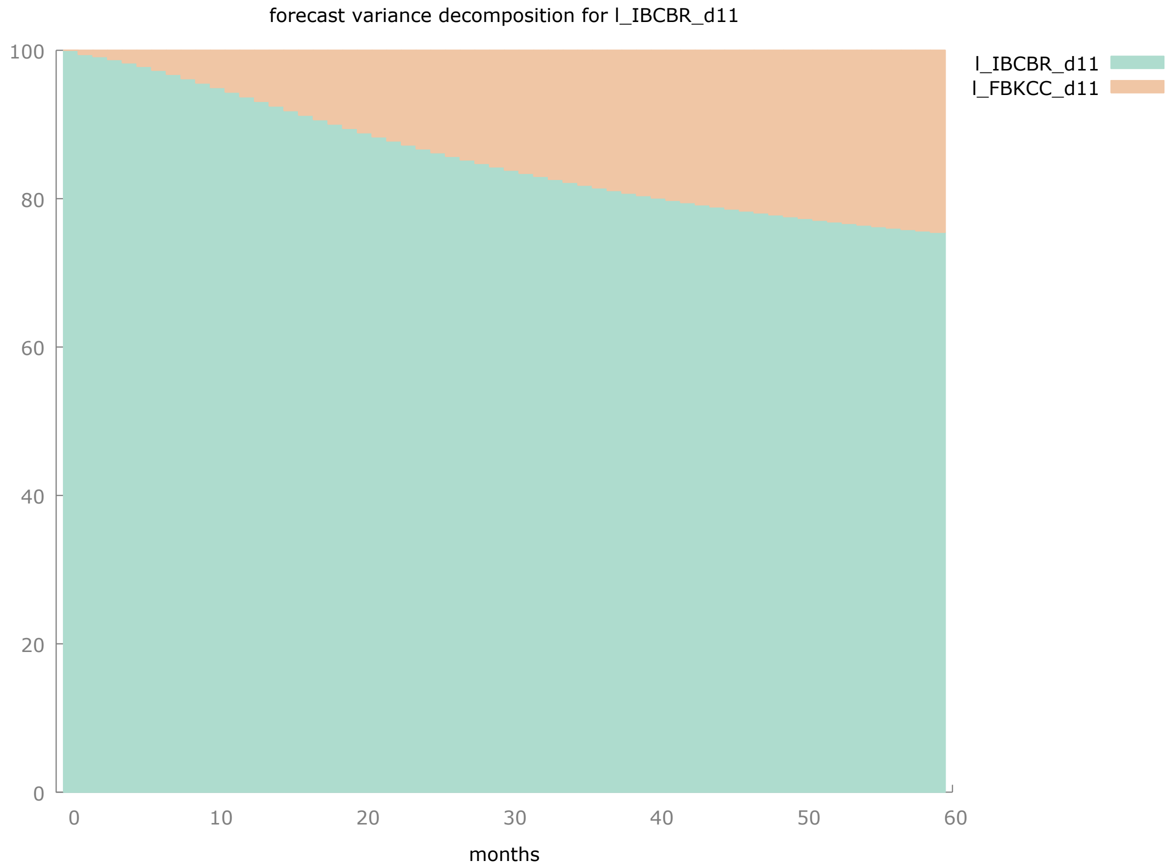

Figure 2. Variance Decomposition of Forecast Errors, Variable *l_IBCBR _ d11,* January 2003 – February 2022.

Source: Based on basic data from IPEADATA and IPEA.

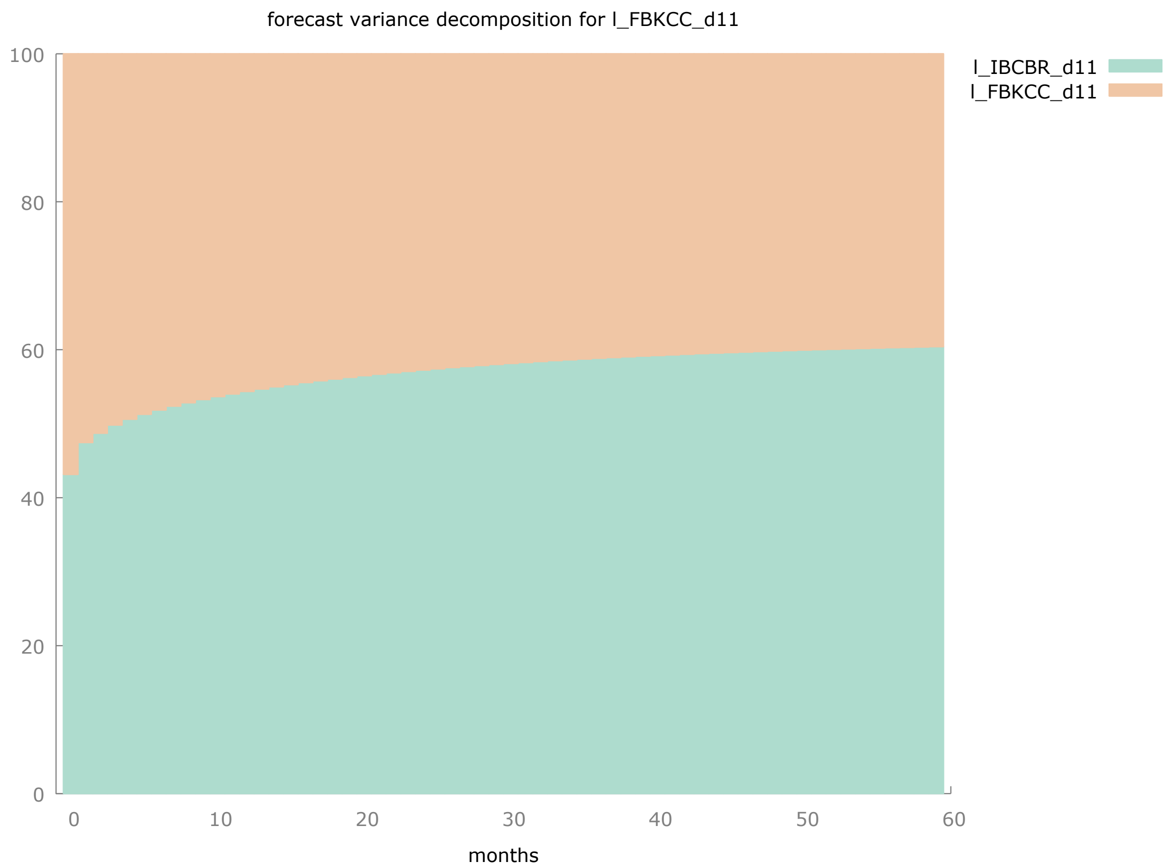

Figure 3. Variance Decomposition of Forecast Errors, Variable *l_FBKCC_d11,* January 2003 – February 2022.

Source: Based on basic data from IPEADATA and IPEA.

The Impulse Response Function was used to determine the trajectory of the variable *l_IBCBR _ d11* from an unanticipated shock at *l_FBKCC_d11* with a magnitude of one standard deviation. After an unanticipated shock with a magnitude of one standard deviation at *l_FBKCC_d11,* the variable *l_IBCBR _ d11* grows rapidly up to one month after the initial shock. One month after this initial shock, the variable *l_IBCBR _ d11* continues to grow at increasing rates until the eighth month. From then on, it continues to grow, but at decreasing rates until it stabilizes around the sixtieth [8] month after the initial shock (Figure 4). From this

[8] In this case, the period of 60 months or 5 years is being used as a parameter, as the average period for the construction and start-up of large infrastructure works, such as hydroelectric plants, large airports, ports, sanitation, etc.

result, it can be inferred that investments in infrastructure, with a focus on civil construction, have a significant impact on the economy's GDP, and its most intense effects occur in the period of one year after the initial shock. Afterwards, their effects lose their effect, however, their impacts on the behavior of the GDP, and, consequently, on the other sectors of the economy, are felt for a long period. This result demonstrates that investments in infrastructure have a considerable multiplier effect on other sectors of the country's economy.

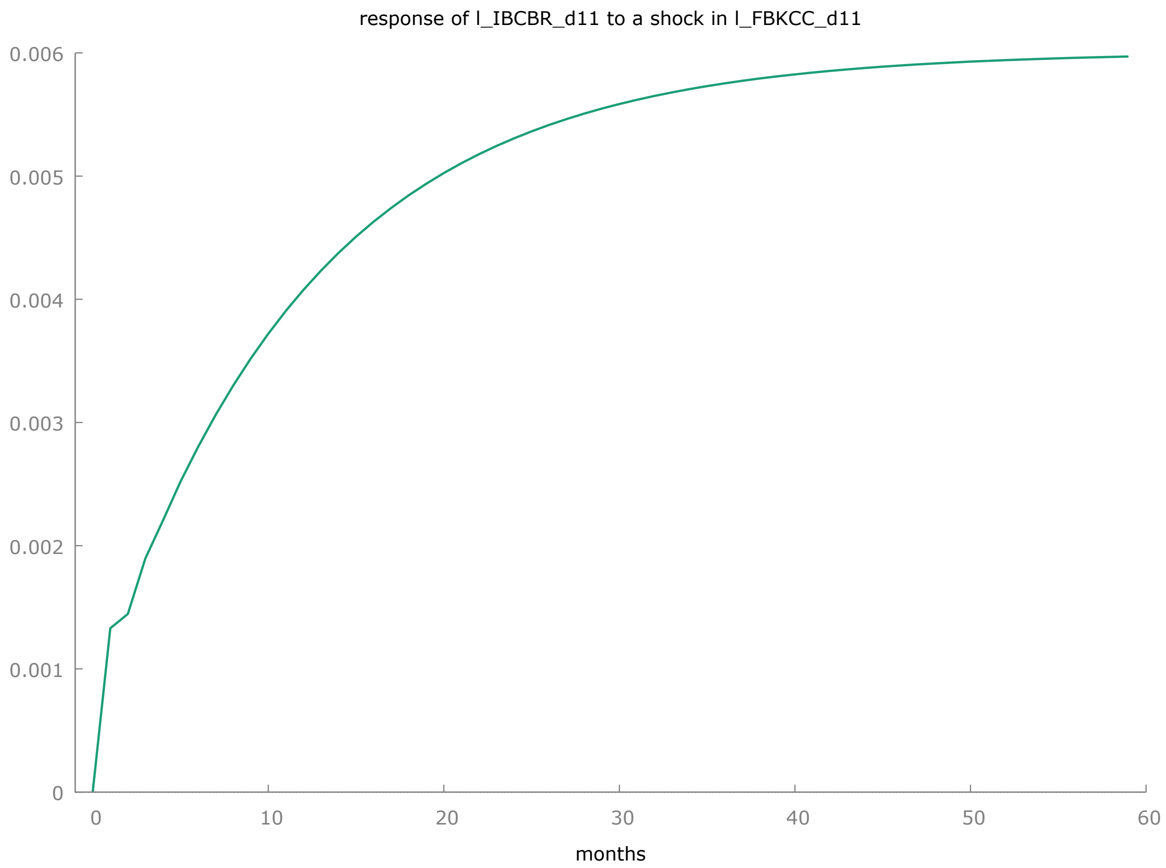

Figure 4.- Impulse Response Function, Shock at *l_FBKCC_d11,* Response at *l_IBCBR _ d11.*

Source: Based on basic data from IPEADATA and IPEA.

Finally, the Hansen and Johansen (1992) cointegration test is used to verify the constancy of the cointegration vector parameters. The constancy of the parameters over time is essential when the user aims to estimate a forecast model. To determine the constancy of the cointegration vector parameters, two procedures are used, graphical analysis and hypothesis testing.

Figure 5 shows the time evolution of the long-term beta coefficients of the cointegration vector. The green horizontal line represents the critical value at the 5% significance level. The red line shows the variation of the beta coefficients over time. Despite observing a change in the level of the beta coefficients from January 2017 to April 2020, it is observed that the estimated values for the beta coefficients over time are below the critical value at the 5% significance level, this implies that the null hypothesis that the estimated beta parameters are constant cannot be rejected. Therefore, in statistical terms these coefficients can be considered as constants.

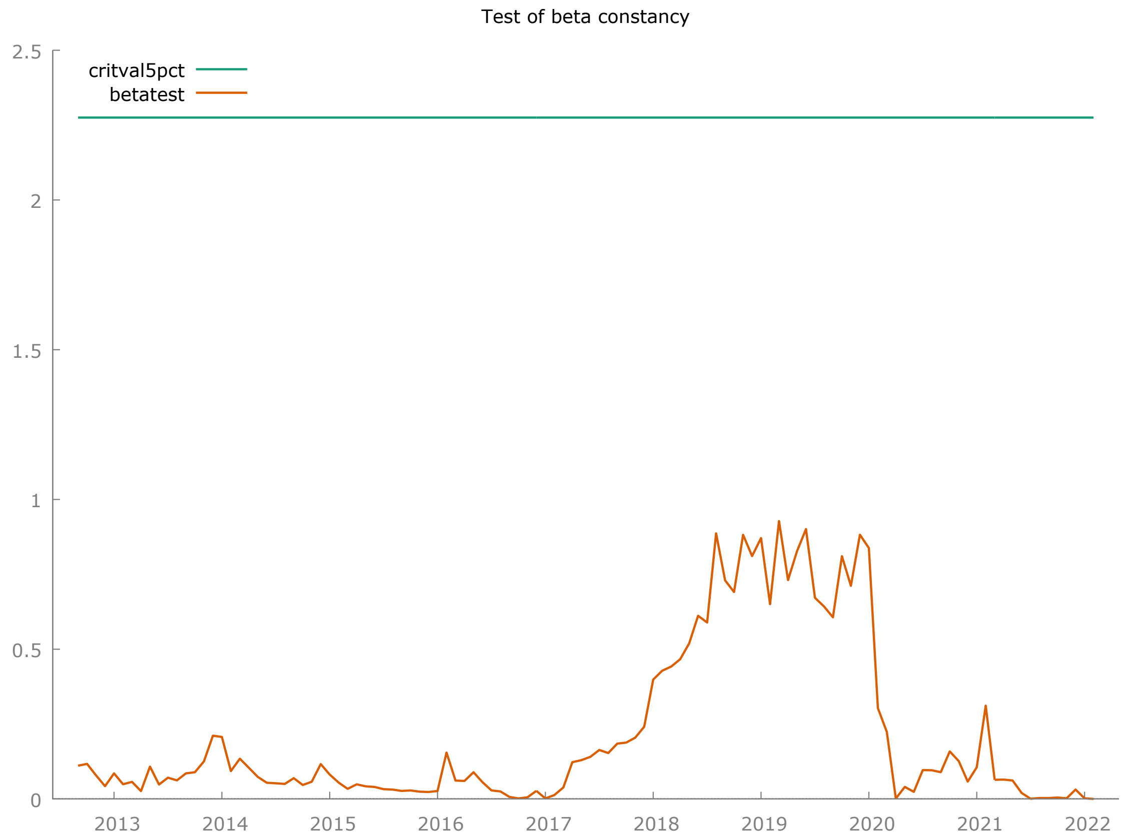

Figure 5. Time Evolution of Long-Term Beta Coefficients, September 2012 – February 2022.

Source: Based on basic data from IPEADATA and IPEA.

The results for the tests of hypotheses involving the fluctuation of the long-term beta coefficients show that the null hypothesis of stability of these coefficients cannot be rejected, since their calculated value (0.93) is below their respective tabulated value (2.28) at a significance level of 5%. This result confirms the stability of the beta parameters (Table 8).

Table 8. Test for Fluctuation of Estimated Beta Parameters, September 2012 – February 2022.

Value of Calculated Statistics	Critical Value at the 5% Significance Level
0.93	2.28

Source: Based on basic data from IPEADATA and IPEA.

Figure 6 presents the results of the stability tests of the *eigenvalues* (eigenvalues) [9]. The blue horizontal line corresponds to the critical value (1.22) of the test at the 10% significance level. Likewise, it applies in relation to the red and green horizontal lines, which correspond to the values of the critical statistics at the significance levels of 5% (1.36) and 1% (1.63), respectively. The value of the calculated statistic is equal to 0.85. The Null Hypothesis is that the *eigenvalues* are stable. Given that the calculated value is lower than the respective critical values, as can be seen in Figure 6, the Null Hypothesis is not rejected. Stable *eigenvalues imply*

[9] Details about the *eigenvalues* can be found in Margarido (2020).

that the model is stable, that is, it has no unit root, and consequently its respective variance is not explosive.

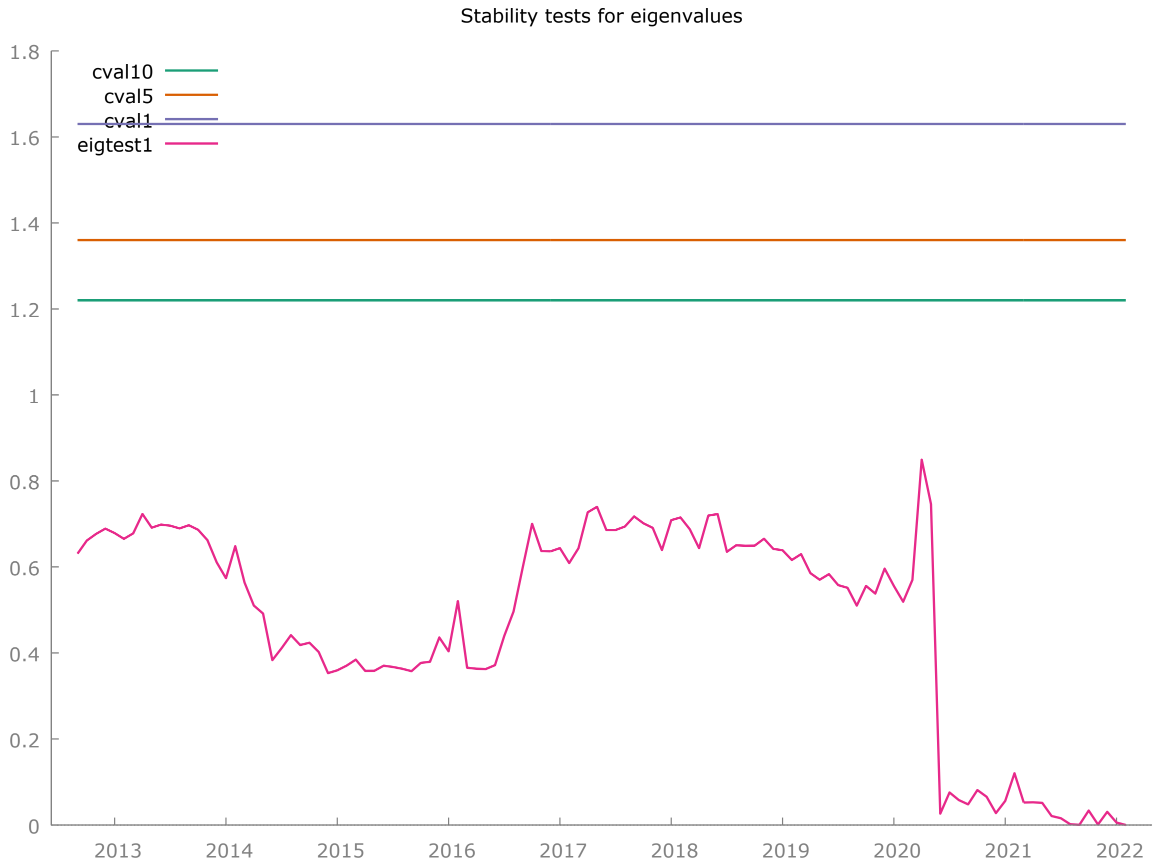

Figure 6. Time Evolution of *Eigenvalues,* September 2012 – February 2022.

Source: Based on basic data from IPEADATA and IPEA.

6. FINAL REMARKS

This article presented an econometric evaluation, based on time series models, to analyze the long-term relationship between the gross capital formation index with emphasis on civil construction, considering that this index was developed and published by IPEA and the index of economic activity of the Central Bank, which is considered by the market as an indicator of the GDP of the economy. The results show that a 1% variation in the fixed capital formation index induces a variation of approximately 0.4% in the GDP, in the long term, configuring an inelastic relationship between investments in infrastructure based on civil construction and the GDP. It is noteworthy that this aggregate estimate may not capture many indirect effects portrayed by the specialized literature, offering just additional anecdotal evidence.

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