INTERNATIONAL COMMODITY PRICE CYCLE AND THE DYNAMIC OF INVESTMENTS IN BRAZIL: EVIDENCE FROM THE 1996 – 2018 PERIOD

Eva Yamila da Silva Catela (UFSC – E-mail: evadasilvacatela@gmail.com)
Mario Augusto Gouvêa de Almeida (STN/UFSC – E-mail: mmarioaga@gmail.com)
Jaylson Jair da Silveira (UFSC – E-mail: jaylson.silveira@ufsc.br)

Resumo: O presente artigo mensura os impactos que os preços internacionais de commodities exercem sobre o investimento, notadamente sobre a FBCF em máquinas e equipamentos no Brasil, com dados trimestrais entre 1996 e 2017. A identificação de vetores cointegrantes entre os vários modelos propostos viabilizou a especificação de Modelos Autorregressivos de Correção de Erros Estruturais (SVEC), possibilitando distinguir as relações contemporâneas e persistentes dos choques estruturais. Os principais resultados encontrados são: i) relação positiva entre preços internacionais das commodities e investimento privado em máquinas e equipamentos; ii) choques positivos na taxa de câmbio efetiva real, ou seja, depreciações da moeda local, afetam negativamente a FBCF em máquinas e equipamentos; (iii) o investimento público exerceu uma influência complementar ao investimento privado, ou seja, percebeu-se um efeito *crowding-in* sobre o investimento em máquinas e equipamentos; e iv) os preços das commodities internacionais respondem por aproximadamente 56% da variação do investimento em máquinas e equipamentos, sendo, portanto, uma variável decisiva nas decisões de investimento no Brasil. Tais resultados ressaltam a influência externa sobre a dinâmica de investimento no Brasil, reforçando o debate sobre os conhecidos "voos de galinha" da economia brasileira.
Palavras-chave: investimento, SVAR, SVEC, commodities, flutuações macroeconômicas.

Abstract: The present article measures the impact of international commodity prices on investment, especially on gross fixed capital formation (GFCF) in machinery and equipment in Brazil, with quarterly data between 1996 and 2018. The identification of cointegrating vectors in the proposed models enabled the specification of Autoregressive Structural Error Correction Models (SVEC), making it possible to distinguish the contemporary and persistent relations of structural shocks. The main results are: i) a positive relationship between international commodity prices and GFCF in machinery and equipment; ii) positive shocks on the real exchange rate, i.e. local currency depreciations, negatively affect GFCF in machinery and equipment; (iii) public investment exerted a complementary influence on private investment, that is, it had a crowding-in effect on investment in machinery and equipment; and (iv) the prices of international commodities account for approximately 56% of the variance of the investment in machinery and equipment, being, therefore, a decisive variable on the investment decisions in Brazil. These results highlight the external influence on the investment dynamics in Brazil, reinforcing the debate about the known "chicken flights" of the Brazilian economy.
Keywords: investment, SVAR, SVEC, commodities, macroeconomic fluctuations.

JEL Classification: O1, E32, E62.

Área 06: Crescimento, Desenvolvimento Econômico e Instituições

1. INTRODUCTION

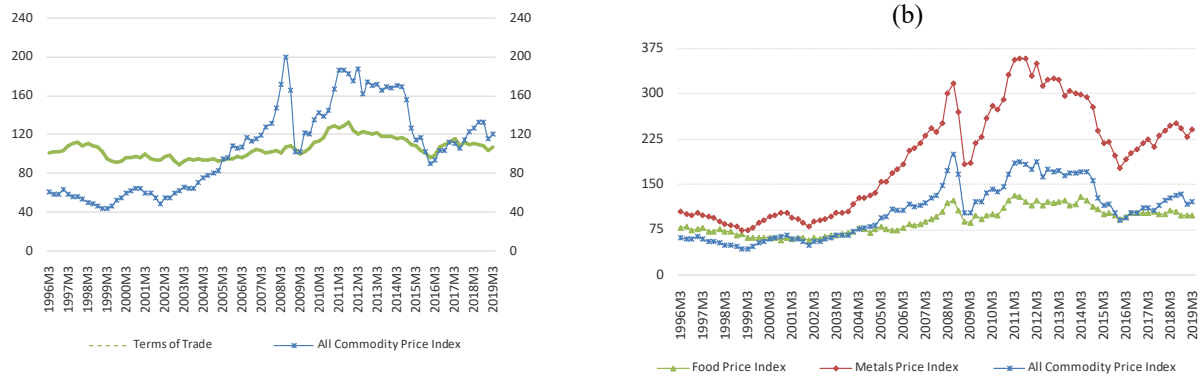
The commodity super cycle seen in the early 2000s has been the motivation of an intense debate in academy looking to understand its dynamic consequences over the economy due to

commodity price variation. Over this period, a steep increase of international prices was seen, going over 100% in average real terms. For some commodities, such as iron and other industrial materials, global prices increased more than three times in real terms, as can be seen on Figure 1, panel a. As a consequence, this long expansion cycle translated into gains in terms of trade for many countries, which came along with an overall improvement in the results of those economies focused on production and exportation of commodities (IMF, 2017).

Brazil was no exception to that process, sharing the same improvement seen in the terms of trade, aligned with the performance of international commodity prices, Figure 1, panel b. Between 2003 and 2008, the country saw an increase in exportation numbers of US$ 72 billion to US$ 197 billion, with an average GDP growth of 4,8%. Costa *et al.* (2016) indicate that, between 2000 and 2010, three sectors of the agricultural and extractive industries in Brazil were responsible for 82% growth in exportations to China: non-precious metal mining (45%), soy (23%) and oil and gas (14%).

Despite the fact that the macroeconomic effect of commodity price fluctuation has a extensive coverage in academic literature, many of the studies have focused on the impact of the shock in oil prices in developed countries, i. e. Blanchard and Galí (2007) and Killian (2009). Recent studies, such as Camacho and Perez-Quiros (2014), Gruss (2014), Fornero *et al.* (2016) and Fernandez *et al.* (2018), have examined these effects on developing and emerging economies who are strongly dependent on commodity exportation. In general, their findings points out that fluctuation in commodity prices are a major driver of economic cycles in these economies.

Figure 1 – Evolution of the Terms of Trade and the Commodities Price Index



Source: Commodities index: IMF's International Financial Statistics and the World Economic Outlook, and the series used were: (i) All Commodity Price Index, 2016 = 100; (ii) Food Price Index, 2016 = 100; (iii) Metals Price Index, 2016 = 100. Terms of Trade: (FUNCEX) Foundation Center for Foreign Trade Studies, Terms of Trade Index, 2006 = 100.

The studies for Brazil are still scarce, with the main reference being dos Santos *et al*. (2016). In this study, the international commodity index was used as an instrument for Brazilian GDP in a structural autoregressive vector analysis to test the relationships between gross capital formation and commodity prices. In fact, according to Figure 2, the Gross Fixed Capital Formation (GFCF) index is highly correlated with international commodity prices suggesting that the effects of shocks on the terms of trade have an impact on macroeconomic fluctuations, especially on the level of aggregate investment in the country.

Figure 2 – Evolution of GFCF and commodity Price Index

Source: Gross Fixed Capital Formation Index (GFCF): (IBGE) Brazilian Institute of Geography and Statistics in Quarterly National Accounts, Quarterly Volume Index, 1995= 100; Commodities index: IMF's International Financial Statistics and the World Economic Outlook, All Commodity Price Index, 2005 = 100.

Inspired by this literature, the main objective of this study is to measure the impact of international commodity prices on investment, especially on gross fixed capital formation in machinery and equipment in Brazil, using quarterly data between 1996 and 2018. This objective is related to the working hypothesis that permeates this research, in which fluctuations in international commodity prices are a key determinant of short flights or "chicken flights" to which the Brazilian economy is subject. For this, we employ a Structural Vector Autoregression (SVAR) approach, using the following variables: i) gross fixed capital formation in machinery and equipment (GFCF_ME) or called here as private investment[1]; ii) gross fixed capital formation of the public administrations (GFCG_PA)[2]; iii) price index of international commodities; and iv) the real effective exchange rate. The identification of cointegrating vectors in the models proposed in this study enabled the specification of Structural Vector Error Correction (SVEC) models, an approach not yet published for this dataset, making it possible to distinguish contemporary and persistent relationships from structural shocks.

Among the main results, the following stand out: i) a shock of standard deviation on international commodity prices results in a persistent growth in the level of investments of around 6%; ii) shocks on the real effective exchange rate, depreciation of the local currency, have negative effects on the investment, with persistent effects that converge to approximately 2.3% after 9 quarters; iii) public investment exerted a complementary influence on private investment, that is, it had a *crowding in* effect on investment in machinery and equipment, with a persistent effect of 3.7% after 07 quarters; and iv) the analysis of variance decomposition points to commodity prices as the main source of forecast error of private investment, accounting for approximately 53% of the variance of the investment as of the 8th quarter. In this way, the results are in line with the recent studies for commodity exporting countries as Camacho and Perez-Quiros (2014), Gruss (2014), Fornero *et al.*(2016) and Fernandez *et al.* (2018), indicating that the dynamics of investment in Brazil are strongly impacted by the fluctuations in terms of trade resulting from changes in international commodity prices.

We believe that our preliminary results will contribute to the economic debate regarding the role of fiscal policy in a commodity export economy. Given the obtained results, its correlation with the known "chicken flights" of the Brazilian economy appears naturally. In terms of policy

[1] According to the methodology proposed by Carvalho and Ribeiro (2014). Although not a precise measure of private investment, we adopted this nomenclature given the preponderance of private investment in machinery and equipment as opposed to the share of public investment (GFCF of PA).
[2] The GFCF of public administrations (PA) does not include the investment made by state-owned enterprises (SOEs).

implications, our results strengthen the necessity for reforms, enabling a countercyclical fiscal policy, which could act as a cushion for these cycles and could help the growth of the potential GDP, minimizing the occurrence of these short flights associated to the expansion and recession dynamics originated from the commodity cycles.

2. METHODOLOGY: STRUCTURAL VECTOR AUTOREGRESSION MODELS

2.1. DATABASE, STATIONARY TESTS AND COINTEGRATION

According to dos Santos *et al.* (2016), the GFCF variable in machinery and equipment is the measure that best represents the investment dynamics, given the general GFCF profile of the Brazilian economy. In fact, starting from the decomposition of GFCF into machinery and equipment and into construction, according to the methodology of Carvalho and Ribeiro (2014), it is possible to measure the investment dynamics of non-financial corporations, the latter being responsible for a preponderant part of the general GFCF of the Brazilian economy.

In this sense, given the empirical strategy described in the next section, we chose to use the following variables, all in logarithmic terms, in our autoregressive models: (i) GFCF in machines and equipment (GFCF_ME); (ii) GFCF of public administration (GFCF_PA); (iii) international commodity price index (COMM); and (iv) the real effective exchange rate (REER). Figure A.1, in the Appendix, shows the evolution of the series, in log-levels and seasonally adjusted by the X-13 Arima method, using quarterly data between 1996 and 2018.

It is worth highlighting that due to the different methodologies for calculating GFCF in Brazil in each of its components, it can be assumed that public investment data is not contemporaneously related to the data of other investment components. The calculation of the general indicator gives greater weight to the information calculated on the supply side. On the other hand, the GFCF indicator of the PA uses a view of the demand of the public administrations for investment goods, under the cash regime[3].

Regarding to the stationarity of the series, the Augmented Dickey-Fuller (ADF) tests, Dickey and Fuller (1981), were performed. The tests point to the same result of non-stationarity of the level series, being stationary in the first differences. Thus, it is assumed that all the series used are I (1), according to the statistics provided in Table A.1 of the Appendix.

Given that the mentioned series are not stationary, we proceeded with Johansen's (1991) cointegration tests, as can be seen on Table 1. In this case, the variables listed above were grouped into three models in which the impacts of the real effective exchange rate (REER) and public investment (GFCF_PA) on private investment (GFCF_ME) were taken individually at first (Model 1 and Model 2) and then had their joint impacts analyzed (Model 3).

Table 1 – Johansen cointegration tests

Rank	Test Statistics	Critical Value 90%	Critical Value 95%	Critical Value 99%
Model 1 - VAR with 1 lag and endogenous variables: COMM, REER, GFCF_ME				
r=0	42.48**	39.06	42.44	48.45
r<=1	12.24	22.76	25.32	30.45
r<=2	3.01	10.49	12.25	16.26
Model 2 - VAR with 1 lag and endogenous variables: COMM, GFCF_PA, GFCF_ME				

[3] For more details see dos Santos *et al. (*2016).

r=0	52.24***	39.06	42.44	48.45
r<=1	18.31	22.76	25.32	30.45
r<=2	3.58	10.49	12.25	16.26
Model 3 - VAR with 1 lag and endogenous variables: COMM, GFCF_PA, REER, GFCG_ME				
r=0	59.45**	49,65	53,12	60,16
r<=1	31.66	32,00	34,91	41,07
r<=2	12.07	17,85	19,96	24,60
r<=3	1.53	7,52	9,24	12,97

Source: Elaborated by the authors based on the estimated results. *** Rejection of the null hypothesis at the 1% level; ** Rejection of the null hypothesis at the 5% level. * Rejection of the null hypothesis at the 10% level.

The results point out that the null hypothesis of non-existence of at least one cointegrating vector can be rejected for all models. In all cases, diagnostic tests of the model were made, in particular, the existence of autocorrelation, non-normality and heteroscedasticity in the residues were tested. In general, it was possible to assume that model residues exhibit the desired characteristics of non-autocorrelation, homoscedasticity and normality, as can be seen in Table A.2 of the Appendix. Also, the estimates of the coefficients of the cointegration vectors and the speed of adjustments are presented in Tables A.3 and A.4 of the same Appendix.

2.2. EMPIRICAL MODEL

The empirical model is a standard version of the Structural Vector Error Correction Models (SVECM), as established by Breitung *et al.* (2004), which has the following general representation[4]:

$$A\Delta y_t = \Pi^* y_{t-1} + \Gamma_1^* \Delta y_{t-1} + \cdots + \Gamma_{p-1}^* \Delta y_{t-p+1} + C^* D_t + B^* z_t + v_t, \quad (1)$$

being $y_t = (y_{1t}, \ldots, y_{kt})$ is a k x 1 vector of endogenous variables, with k = (COMM, REER, GFCF_ME) for model 1 and k = (COMM, GFCF_PA, GFCF_ME) for model 2, and k = (COMM, REER, GFCF_PA, GFCF_ME) for model 3; z_t is a vector of exogenous or non-modeled stochastic variables; D_t contains all deterministic terms[5]; Π^* represents the co-integrating vector, identified in Table 1 and described in Table A.4, $\Gamma^*, C^* e\ B^*$ are arrays of parameters in structural form; v_t is a k x 1 vector of errors in the structural form with zero mean, white noise with invariant covariance matrix at time Σ_v. The square matrix A, of order k, with defined inverse, permits the modeling of instantaneous relations between the variables y_t.

Since we are looking for structural shocks, which are not directly observed, it is necessary to adopt assumptions to identify them. Thus, it is assumed that structural shocks or innovations, denoted by ε_t, are related with the residues from the model by linear relations $v_t = B\varepsilon_t$, where B is a square matrix of order k.

For our current proposition, the deterministic terms and the exogenous variables can be ignored, turning equation 1 into the following equation:

$$A\Delta y_t = \Pi^* y_{t-1} + \Gamma_1^* \Delta y_{t-1} + \cdots + \Gamma_{p-1}^* \Delta y_{t-p+1} + B\varepsilon_t, \quad (2)$$

with $\varepsilon_t \sim (0, I_K)$. Still,

$$u_t = A^{-1} B \varepsilon_t, \quad (3)$$

which relates the disturbances of the reduced form (u_t) to the underlying structural shocks (ε_t).

For the analysis of impulse response of non-stationary models in the form of VECM it is known that from Johansen's version of Granger's Representation Theorem, according to Johansen

[4] Implementation of the empirical model was performed through the VARS package of R, following Pfaff (2008).

[5] For all models we use impulse dummy variables, avoiding structural breaks as observed in 1999:Q1, change in the exchange policy, 2008:Q04 the financial crises, or 2015:Q1 associated with political crises observed in Brazil at that time.

(1995), if y_t is generated by a reduced form VECM $\Delta y_t = \alpha\beta' y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1}\Delta y_{t-p+1} + u_t$, it has the following MA representation:

$$y_t = \Xi \sum_{i=1}^{t} u_i + \Xi^*(L)u_t + y_0^*, \quad (4)$$

where $\Xi = \beta(\alpha'(I_K - \sum_{i=1}^{p-1}\Gamma_i)\beta_\perp)^{-1}\alpha'$ e$\Xi^*(L) = \sum_{j=0}^{\infty}\Xi_j^* L^j$.

Notice that Ξ has rank $(K - r)$ if the given cointegration is r. Thus, this methodology permits the estimation of the short and long-term effects, since matrix Ξ represents the long-term effects of the impulse response functions (IRFs), while Ξ_j^* contains the transitory effects.

The IRFs based on Ξ and on Ξ_j^* are subject to the same criticism than structural VAR processes in the sense that shocks must be properly identified for a significant impulse response analysis. If u_t is substituted by $A^{-1}B\varepsilon_t$, the orthogonalized "short-term" impulse responses can be obtained as $\Xi_j^* A^{-1}B$, in a manner analogous to the stationary VAR. In addition, the long-term effects of shocks ε are given by:

$$\Xi\, A^{-1}B \quad (5)$$

In the context of the models to be estimated, it is assumed that international commodity prices are not influenced by contemporaneous shocks to the real exchange rate, public investment and investment in machinery and equipment. On the other hand, the exchange rate is affected only by contemporary shocks to international commodities prices. Shocks in commodity prices and the exchange rate affect public investment and investment in machinery and equipment at the same time. It is also assumed that shocks in public investment affect the investment in machinery and equipment. This strategy for identification guarantees a just-identification of the models, generating constraints only in the matrix of transitory effects. The estimated matrices of contemporary impacts (B) and long-term (ΞB) are presented in Table A.5 of the Appendix. Also, over-identification tests were evaluated, and the results presented in the Appendix, Table A.6.

3. RESULTS OF THE MODELS

In line with the proposed objectives, three autoregressive models were estimated, exploring the influence of international commodity prices on the dynamics of investments in machinery and equipment in Brazil. According to the IMF report (2015)[6], gains in commodity terms of trade affect macroeconomics through two channels, mainly: income and investment. On the scope of income, the boom of commodity prices creates unexpected revenue, since more revenue is generated with no increase in the level of production. A higher income increases domestic demand and thus stimulates domestic production. As the unexpected income is generated by more favorable terms of trade, the response of real domestic production is more moderate than that of income and domestic demand. Consistent with the effect of the Dutch disease, the response of domestic supply to the increase in domestic income occurs disproportionately in the sector of non-tradable goods because the demand for tradable goods can be partly satisfied by an increase in imports. In the process, the prices of goods and services that are relatively scarce and non-tradable increase relative to the prices of tradable goods, and the real exchange rate increases.

On the scope of investment, the raise in commodity prices increases the incentives to invest in commodities and support industries - such as construction, transportation, and logistics. The resulting increase in economic activity ultimately generates spillovers for the rest of the economy and further increases incomes. Moreover, in the medium term, the increase in commodity supply can reverse the boom in commodity prices, contributing to the commodity cycle itself.

[6] Other good description of transmission channels of the commodity cycles can be found in Fornero *et al.* (2016).

In this way, three models are presented. First, according to Model 1, the channel between international commodity prices, effective real exchange rate and private investment was explored. Model 2 seeks to explore the role of public investment in private investment by isolating the effect of the exchange rate. Finally, according to Model 3, these relations are estimated together. It is also worth noting that in the structural approach used here, in addition to the Cholesky Decomposition, over-identification tests were performed, according to Table A.6 of the Appendix.

3.1. IMPULSE RESPONSE FUNCTIONS (IRFS)

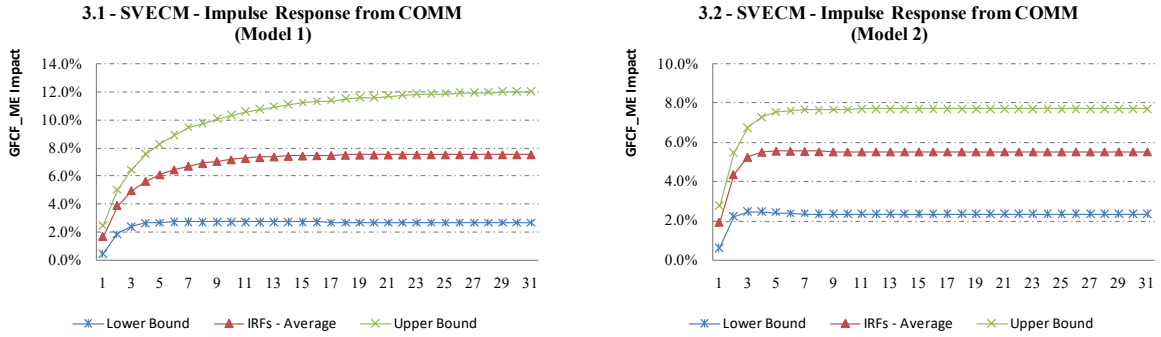
Functions were obtained by the simulation of a standard deviation shock of each of the variables in the models over investment in machinery and equipment. The IRFs of Figures 3.1 to 3.10 were calculated with 95% confidence intervals constructed by bootstrapping, from two thousand simulations. The IRFs 3.11 to 3.14 present the average values of the impulse of each of the variables in each model, in order to have a comparative effect of the answers according to the model that was analyzed.

Analyzing IRFs, a shock of a standard deviation in international commodity prices (COMM) results in a positive impact on investment (GFCF_ME), within the 95% confidence interval limit. The impact is of about 2% in the index of machinery and equipment in the first quarter, and it stabilizes in a long-term equilibrium, with persistent effect of 7.5% after 17 quarters for Model 1. For Model 2, the persistent effect converges more rapidly to a rate of 5.5% after 7 quarters and for Model 3, this convergence occurs after 9 quarters to about 5.96%.

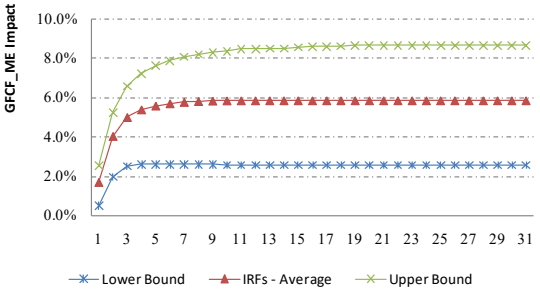
IRFs of a standard deviation devaluation at the real effective exchange rate (REER), result in a negative impact on investment (GFCF_ME) all within the 95% confidence interval. For Models 1 and 3, exchange rate shock results in initial shocks of -1.6% and -1.0%, respectively, on investment in machinery and equipment. These shocks converge to the long-term equilibrium with a permanent effect of -6.0% and -2.3%, after, respectively, 20 and 10 quarters.

Shocks of a standard deviation of public investment (GFCF_PA) result in a positive average impact on investment in machinery and equipment. For Models 2 and 3, the public investment shock results in initial 1.1% and 1.5% impact on the investment in machinery and equipment. This shock converges to the long-term equilibrium with permanent average effects of 1.5% and 3.7%, after, respectively, 7 and 8 quarters.

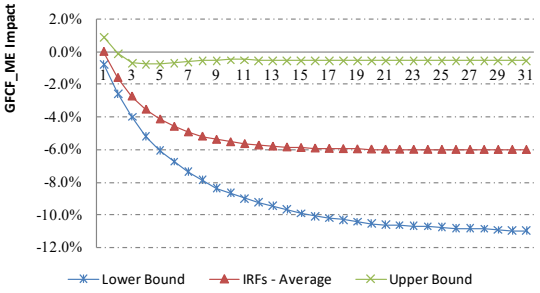
Figure 3 – Response of private investment (GFCF_ME) to shocks of a standard deviation in model variables



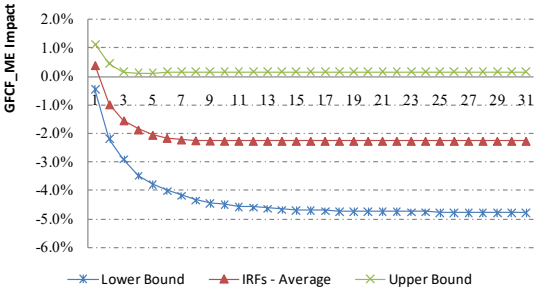
3.3 - SVECM - Impulse Response from COMM (Model 3)



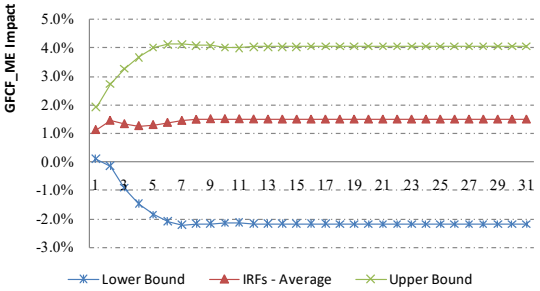
3.4 - SVECM - Impulse Response from REER (Model 1)



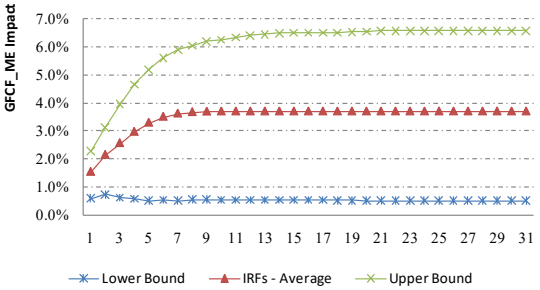
3.5- SVECM - Impulse Response from REER (Model 3)



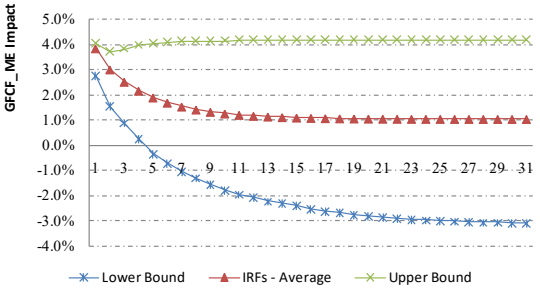
3.6 - SVECM - Impulse Response from GFCF_PA (Model 2)



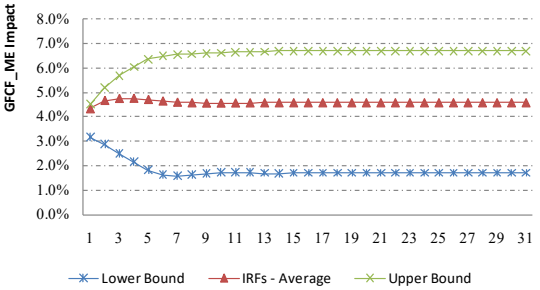
3. 7- SVECM - Impulse Response from GFCF_PA (Model 3)



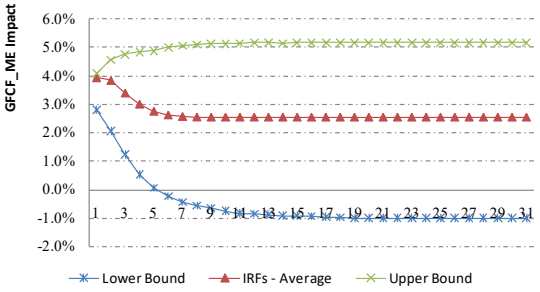
3.8 - SVECM - Impulse Response from GFCF_ME (Model 1)



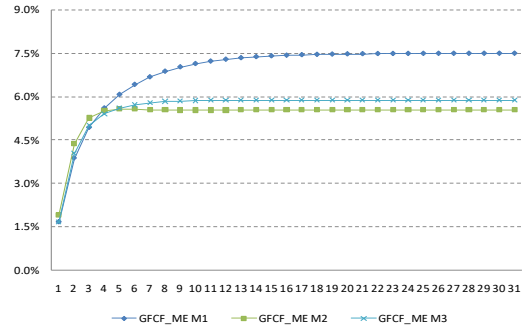
3.9- SVECM - Impulse Response from GFCF_ME (Model 2)



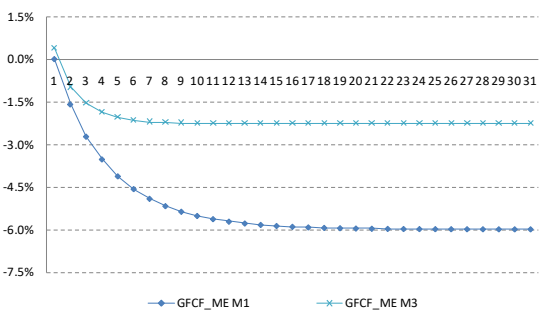
3.10- SVECM - Impulse Response from GFCF_ME (Model 3)

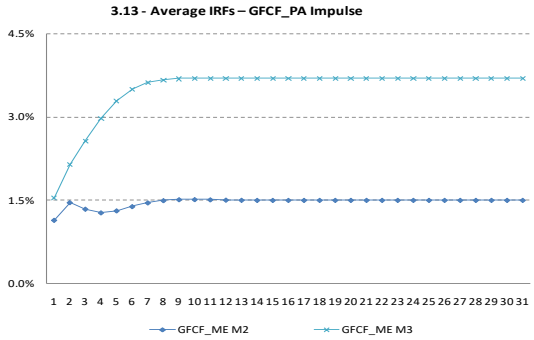


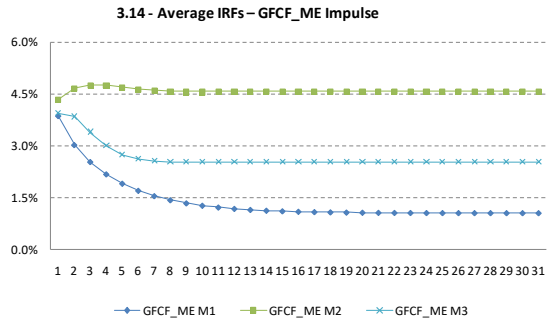
3.11 - Average IRFs – COMM Impulse



3.12 - Average IRFs –REER Impulse







Source: Elaborated by the authors based on estimation results. The 95% confidence interval limit was constructed using bootstrapping with 2000 runs.

IRFs of an investment shock on machines and equipment in Models 1, 2 and 3, result in initial impacts of 3.8%, 4.3% and 3.9% on the same variable. These shocks tend to converge to the long-term equilibrium with average permanent effects of 1.1% and 4.6% and 2.5%, after, respectively, 13, 7 and 8 quarters. It is interesting to notice the profile of the response functions, given the cointegration vector, where an excess of investment relative to long-term equilibrium results in a lower growth rate at a later time, which causes the oscillating profile of the IRFs.

For the average impulses, as presented in Figures 3.11 to 3.14, in general, the following initial conclusions emerge: (i) positive relation between international commodity prices and private investment in machinery and equipment; (ii) the real exchange rate seems to be inversely related to private investment; and (iii) public investment exerted a complementary influence on private investment, that is, it had a crowding in effect on investment in machinery and equipment.

3.2. ANALYSIS OF THE FORECAST ERROR VARIANCE DECOMPOSITION

In order to evaluate the relative importance of each model´s variable shocks over private investment in machinery and equipment, we use the decomposition of variance of the forecast error of this variable, as seen in Table 2. According to our estimates, errors related to the investment itself dominate the forecasting error in the short-term, but from the fourth quarter onwards, changes in commodity prices are the dominant source of investment dynamics.

For Model 1, it can be observed that shocks in the private investment variables (GFCF_ME) account for more than 84% in the variation of this variable in the first quarter. However, this proportion drops to about 26% after 4 quarters and in the long run accounts for less than 5% of the variances. A contrary move occurs with commodity price shocks, which in the long run account for 61% of the variance of private investment in machinery and equipment. Still, shocks to the real exchange rate represent 35.6% of the changes in investment after 24 quarters.

It is worth noting the small influence of public sector investment, for Model 2, on the forecast error of the variables under study, accounting for 4.1% of the variation in machinery and equipment after 24 quarters. In Model 3, which includes exchange rate and public investment in the same model, shows a behavior similar to previous models, emphasizing that although the forecast errors of commodity prices still dominate the investment variance, this relationship decreases considerably when compared to Model 1, standing at 55.5% of private investment variance.

Table 2 – Decomposition of variances

Qtr.	**Model 1**			**Model 2**			**Model 3**			
	$\varepsilon_t^{\text{COMM}}$	$\varepsilon_t^{\text{REER}}$	$\varepsilon_t^{GFCF\_ME}$	$\varepsilon_t^{\text{COMM}}$	$\varepsilon_t^{\text{GFCF\_PA}}$	$\varepsilon_t^{GFCF\_ME}$	$\varepsilon_t^{\text{COMM}}$	$\varepsilon_t^{\text{GFCF\_PA}}$	$\varepsilon_t^{\text{REER}}$	$\varepsilon_t^{GFCF\_ME}$
1	15.8%	0.0%	84.2%	15.5%	5.4%	79.1%	13.6%	11.4%	0.0%	75.0%
4	56.2%	17.1%	26.7%	46.5%	3.9%	49.5%	46.8%	14.3%	6.3%	32.6%

8	60.9%	27.7%	11.4%	52.2%	3.8%	44.0%	52.7%	18.5%	8.5%	20.3%
12	61.1%	31.8%	7.1%	53.9%	4.0%	42.2%	54.2%	20.0%	9.2%	16.6%
18	60.9%	34.4%	4.6%	54.9%	4.0%	41.0%	55.1%	20.9%	9.6%	14.4%
24	60.8%	35.6%	3.6%	55.4%	4.1%	40.5%	55.5%	21.3%	9.8%	13.4%

Source: Elaborated by the authors based on estimation results.

3.3. DISCUSSION OF RESULTS

In all the estimated models we observe a consistent relationship in which commodity price levels have an effect on the real exchange rate, which in turn impact both private investment and public investment. The dynamics behind a positive commodity price shock is intuitive - it acts as an income shock that increases consumer demand for domestic goods, increasing its relative price and appreciating the currency. Increased absorption through consumption creates incentives for the investment goods sector, positively stimulating the demand and price of capital goods, and as domestic goods become relatively more expensive, exports, unlike commodities, fall. This situation creates a procyclical and volatile consumption and investment situation according to Fernandez *et al.* (2018).

With respect to IRFs, we find that: (i) there is a positive and significant relationship between commodity prices and investment in machinery and equipment; (ii) the real exchange rate has a negative and significant relationship with the investment in machinery and equipment; and (iii) in most simulations, public investment had a complementary influence on private investment, that is, it had a crowding in effect on investment in machinery and equipment. These results are aligned with those obtained by most specialized literature. As an example, Cavalcanti *et al.* (2014), Fernandez *et al.* (2018), Fornero *et al.* (2016), IMF (2015) and dos Santos *et al.* (2016). In Fernandez *et al.* (2018), we find that country-specific commodity prices in the small emerging market economies are procyclical and lead the cycle of production, consumption and investment. In addition, real exchange rates and external risk premium measures are countercyclical.

In dos Santos *et al.* (2016) we find similar results for the negative relationship between investment and real exchange rate. According to the authors, "equally complex and controversial is the negative relationship between the real exchange rate and the GFCF verified in the quarterly data". The transmission channels of would be: (i) cost of investment, reducing the cost of capital goods imports; ii) exchange rate appreciation, which would generate a relaxation of the external constraint, making monetary policy more flexible and, therefore, a greater growth of aggregate demand; and (iii) the balance sheet and wealth effect according to Krugman (1999) and Allen *et al*. (2010), for which a high share of the companies' external indebtedness, with relevant currency mismatches in the composition of their assets and liabilities, in the event of a currency depreciation could negatively affect the balance sheet and/or the profitability of a company.

Aligned with the results found in Fornero *et al.* (2016) and Fernandez *et al.* (2018), commodity price shocks on investment are persistent across all three estimated models. In this sense, the authors understand that, when shocks are persistent, the response of investment and real GDP are amplified. In our estimates, a shock of a standard deviation in commodities results in a persistent growth in the level of private investment of around 6%.

Relative to the shocks in the real exchange rate over private investments, results indicate that there is no negative relationship in contemporary relationships, but there are persistent negative effects, which indicate convergence with a drop in the level of private investment by approximately

2% after 10 quarters, according to results of Model 3.

Shocks of a standard deviation of public investment on private investment result in an average positive impact on the latter. Returning to dos Santos *et al.* (2016), we observe similar results, since these authors find a positive, complementary relationship between private investment and public investment. . In our estimates, a shock of a standard deviation in public investments results in a persistent growth in the level of private investment of around 4%.

The importance of commodity shocks on the dynamics of investment in Brazil is reinforced by the analysis of the decomposition of variation of the forecast error. In this analysis, all results indicated that variations in commodities are the dominant source of private investment dynamics in machinery and equipment, accounting for approximately 53% of the variance of private investment as of the 8th quarter, according to the results of Model 3.

4. CONCLUSION

This study analyzes the impact of shocks in international commodity prices on the level of public investment and on machinery and equipment investment, which is mainly private, for Brazil. We can enlist the main results as: first, a rise in commodity prices causes an expansionary effect on the economy, aligned with previous studies for other commodity exporting countries. In this sense, the higher income from the increase in the exported value, generated through higher commodity prices, increases domestic demand and, therefore, stimulates domestic production. Part of this expansion is caused by the positive and delayed effect on investment in commodity sectors that may overflow into other sectors producing non-tradable goods; second, shocks on the real exchange rate have negative effects on investment. In this case, as the unexpected income is generated by more favorable terms of trade, the response of real domestic production is more moderate than that of domestic demand income. Consistent with the effect of the Dutch disease, the response of domestic supply to the increase in domestic income occurs disproportionately in the sector of non-tradable goods, because the demand for tradable goods can be partially offset by increased imports, leading to a deficit in current transactions. Concomitantly to this process, prices of relatively scarce and non-tradable goods and services increase relative to the prices of tradable goods, and the real exchange rate appreciates; and finally, according to the forecast error variance decomposition, in fact the shocks in commodities have been the fundamental determinants of the investment dynamics in Brazil.

These results, only recently debated in the Brazilian academic environment, show the dynamics of investment and economic growth are strongly subject to external agents. Results for exchange rate shocks also play an interesting role in the current economic debate in Brazil. On one hand, according to the causal mechanisms mentioned here, a shock in commodity prices end up causing an appreciation of the exchange rate, since part of the higher domestic demand could be supplied by the importation of tradable goods, in line with the process of the Dutch disease cited by Bresser-Pereira (2008, 2010). On the other hand, the effect of the appreciation of the exchange rate is that it increases private investment, either by the lower cost of imports, by the softening of monetary policy or by the balance sheet effect of companies. In this case, clearly there are winning and losing sectors within this process that the aggregate analysis developed here ends up masking. A possible path of research could study the determinants of investment in a sectoral way, trying to show how different sectors respond to these transmission mechanisms.

In such way, we observe that the obtained results emphasize the external influence on investment dynamics in Brazil, and its correlation with the known "chicken flights" of the Brazilian economy appear naturally. In that sense, Gruss (2014) warned that the end of the commodity price boom would have a significant impact on the growth of Latin American and Caribbean (LAC) commodity-exporting countries. Even more interesting is to observe the author's recommendations at that time: "With the economic slowdown linked to the end of the commodity super cycle, the use

of demand stimulators to maintain growth at the recently observed high rates would not be justified and could lead to problematic macroeconomic imbalances." He also suggested that policymakers in these economies should work to weaken the link between commodity prices and economic activity in order to avoid the expansion and recession dynamic often associated with past commodity cycles.

In this sense, a recommendation that emerges from this research is that if a fiscal policy is conducted with a countercyclical fiscal rule, it can help reducing commodity shocks. On the other hand, in the absence of a fiscal rule or in the existence of pro-cyclical rules, governments can amplify the effect of the business cycle originated from shocks on the commodity terms of trade. Economic reforms with the goal of constructing mechanisms that act as a cushion for these cycles and that help the growth of the potential GDP could be extremely useful to countries like Brazil, minimizing the occurrence of the "chicken flights" associated to the expansion and recession dynamics originated from the commodity cycles. The Chilean model should be a reference to policymakers, where a formal countercyclical fiscal structure was adopted, determined by natural resource revenues, and a stabilization fund was created to minimize the volatility of public expenditure.

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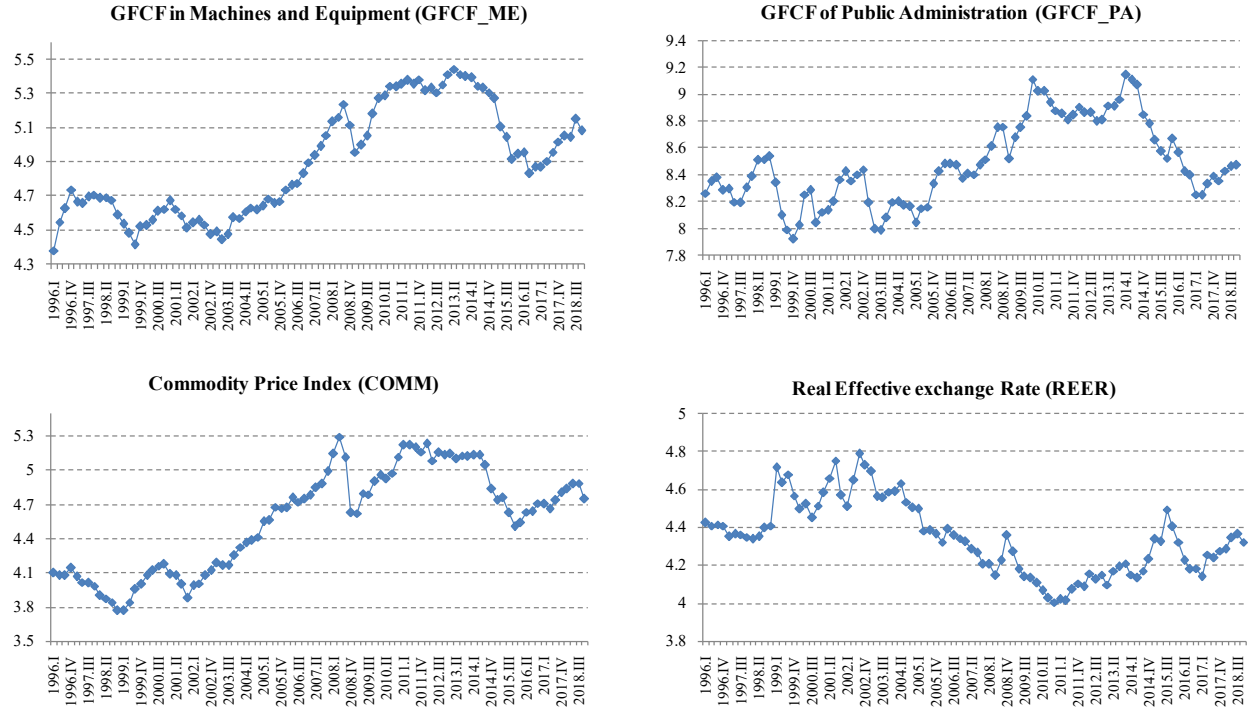
APPENDIX

Figure A.1: Deflated and seasonally adjusted level series



Source: (i) GFCF in machinery and equipment, 1995 = 100, Institute of Applied Economic Research (IPEA); (ii) GFCF of public administrations: before 2010 according to the methodology of dos Santos *et al.* (2012), and after 2010, published by National Treasury Secretariat; (iii) Commodities index: IMF's International Financial Statistics and the World Economic Outlook, All Commodity Price Index, 2005 = 100; and (iv) Real Effective Exchange Rate, June/1994 = 100, published by Central Bank of Brazil.

Table A.1 - Unit Root Test (ADF) – 1996:Q1 – 2018:Q4

Variables	W/o tendency	W tendency
In level		
Commodities	-1.84	-2.14
REER	- 1.93	-2.48
GFCF_PA	-1.98	-2.19
GFCF_ME	-1.35	-1.49
In first difference		
ΔCommodities	-7.29***	-7.28***
Δ REER	-6.94***	-6.90***
Δ GFCF_PA	-5.60***	-5.93***
Δ GFCF_ME.	-4.90***	-4.86***

Source: Elaborated by the authors based on estimation results. Notes: The null hypothesis for the ADF test is that the series has unit root. To define the number of lags for the ADF test was used the Akaike Info Criterion (AIC).. The critical values are: a) no trend: 1% = -3.51; 5% = -2.89; 10% = -2.51; and b) with a tendency: 1% = -4,04; 5% = -3.45; 10% = -3.15.. *** Rejection of the null hypothesis at the 1% level; ** Rejection of the null hypothesis at the 5% level. * Rejection of the null hypothesis at the 10% level.

Table A.2 – Diagnostics tests

	Model 1	Model 2	Model 3
Jarque-Beramultivariado:H0: normality			
Statistic	6.05	2.04	8.35
p-value	0.42	0.56	0.40
Test for autocorrelation–Portmanteau: H0: absence of autocorrelation			
Statistic	198.12	144.63	259.12
p-value	0.17	0.12	0.19
Heteroscedasticity test - ARCH-LM multivariado: H0: homocedastic			
Statistic	158.87*	194.16	524.92
p-value	0.08	0.22	0.21

Source: Elaborated by the authors based on estimation results.

Table A.3 - β's – coefficient of the cointegration vectors

	Model 1	Model 2	Model 3
GFCF_ME	1.00 (NA)	1.00 (NA)	1.00 (NA)
GFCF_PA	-	-1.50*** (-8.15)	-0.67*** (-7.47)
REER	0.80*** (4.76)	-	-0.03 (-0.18)
COMM	-0.51*** (-5.46)	0.52*** (3.06)	-0.30*** (-4.46)
Trend	0.00** (1.95)	-0.01*** (-3.16)	-

Constant	-	-	2.27* (1.66)

Models	Stationary linear combinations
Model 1:	$GFCF\_ME_t = -0.80 * REER_t + 0.51 * COMM_t - 0.002 * trend + ec_t$
Model 2:	$GFCF\_ME_t = +1.50 * GFCF\_PA_t - 0.52 * COMM_t + 0.01 * trend + ec_t$
Model 3:	$GFCF\_ME_t = 0.67 * GFCF\_PA_t + 0{,}03 * REER_t + 0{,}03 * COMM_t - 2.27 + ec_t$

Source: Elaborated by the authors based on estimation results. *P-values* in parentheses.

Table A.4 - α's – Speed of adjustment

	Model 1	Model 2	Model 3
GFCF_ME	-0.24***	0.06***	-0.03
	(-5.85)	(2.63)	(-0.52)
GFCF_PA	-	0.23***	0.51***
		(5.99)	(4.79)
REER	-0.03	-	0.13*
	(-0.51)		(1.82)
COMM	-0.05	-0.00*	-0.06
	(-0.65)	(-0.06)	(-0.71)

Source: Elaborated by the authors based on estimation results. *P-values* in parentheses.

Table A.5 - Matrices of contemporary impacts (B) and long-term (ΞB)

Matrices	Model 1: COMM, REER and GFCF_ME	Model 2: COMM, GFCF_PA and gfcf_me	Model 3: COMM, REER, GFCF_PA and GFCF_ME
$B =$	$\begin{bmatrix} 0.08^{***} & 0 & 0 \\ -0.02^{***} & 0.06^{***} & 0 \\ 0.02^{***} & 0.00 & 0.04^{***} \end{bmatrix}$	$\begin{bmatrix} 0.08^{***} & 0 & 0 \\ 0.01 & 0.08^{***} & 0 \\ 0.02^{***} & 0.01^{**} & 0.04^{***} \end{bmatrix}$	$\begin{bmatrix} 0.08^{***} & 0 & 0 & 0 \\ 0.01 & 0.09^{***} & 0 & 0 \\ -0.02^{***} & -0.01 & 0.06^{***} & 0 \\ 0.02^{***} & 0.02^{***} & 0.00 & 0.04^{***} \end{bmatrix}$
$\Xi B =$	$\begin{bmatrix} 0.11^{***} & -0.01 & 0.00 \\ -0.03^{*} & 0.05^{***} & -0.01 \\ 0.08^{***} & -0.06^{**} & 0.01 \end{bmatrix}$	$\begin{bmatrix} 0.11^{***} & 0.01 & -0.01 \\ 0.06^{***} & 0.02 & 0.06^{***} \\ 0.06^{***} & 0.02 & 0.05^{***} \end{bmatrix}$	$\begin{bmatrix} 0.12^{***} & 0.01 & -0.02 & -0.02 \\ 0.03^{*} & 0.06^{***} & 0.01 & 0.06^{***} \\ -0.03^{**} & 0.01 & 0.07^{***} & -0.00 \\ 0.06^{***} & 0.04^{***} & -0.02^{*} & 0.03^{*} \end{bmatrix}$

Source: Elaborated by the authors based on the results of the estimation. The order of the variables in the matrices follows the order of the variables described in the title of each of the models. The t-values were calculated by bootstrapping based on 2000 simulations. *** p<0.01, ** p<0.05, * p<0.1.

Table A.6 – Over-identification tests of the models

Hypotheses	LR test for Model 1	LR test for Model 2	LR test for Model 3
H1: Exchange rate has no contemporary effects on private investment	0.0004 (0.9851)	-	0.8393 (0.360)
H2: Commodity price has no persistent effect on the exchange rate	19.924 (0.0000)	-	19.857 (0.000)
H3: Commodity price has no persistent effect on private investment	83.385 (0.0000)	75.703 (0.000)	77.679 (0.000)
H4: Commodity price has no persistent effect on public investment	-	61.675 (0.000)	12.620 (0.000)
H5: Public investment has no persistent effect on private investment	-	9.186 (0.002)	70.364 (0.000)

Source: Elaborated by the authors based on estimation results. Likelihood ratio test, with chi-square distribution (1). P-values in parentheses.