Economics Bulletin

Volume 43, Issue 1

Oil price volatility: impacts in the Brazilian economy

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Abstract

In this article, we analyze the impact of oil price volatility on Brazil's macroeconomic variables. The estimation is made using an autoregressive vector model (VAR) for the period from January 2001 to June 2021. The monthly oil price volatility is calculated utilizing the realized volatility of daily oil prices. The study's main finding is that oil price volatility has a negative and statistically significant impact on Brazilian economic growth and investment. Our results suggest that these impacts take four and twelve months, respectively, to dissipate.

The authors are grateful for the research financial support received from Fundação de Amparo à Pesquisa do Rio de Janeiro (Faperj) and Coordenação de Aperfeiçoamento do Pessoal de Nível Superior (Capes).
Citation: Adilson de Oliveira and Susan Schommer and Ledson L. G. da Rosa, (2023) "Oil price volatility: impacts in the Brazilian economy", *Economics Bulletin*, Volume 43, Issue 1, pages 429-440
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Submitted: October 08, 2021. **Published:** March 30, 2023.

1 Introduction

The economic literature preaches that price volatility generates uncertainties that hamper the calculation of investment returns and thus postpone the decision to invest until prices return to relatively stable levels (Majd and Pindyck 1987, Brennan 1990, Gibson and Schwartz 1990, Triantis and Hodder 1990, Aguerrevere 2009). This phenomenon originates in economic cycles that affect the economy's aggregate investment with ensuing social and economic effects (Bernanke 1983).

Price volatility has gained prominence in the past decade in the scope of commodity markets. The transformations that took place in these markets, especially due to the expansion of consumption in emerging countries, caused strong volatility in the prices of these inputs, having a decisive impact on capital accumulation and, consequently, on the pace of economic activity (Cavalcanti *et al*. 2015).

Crude oil is the most intensely consumed commodity in the world, supplying 33.1% of the global primary energy consumption (BP 2020). Oil price shocks influence macroeconomic performance through several channels. Volatility increases economic uncertainties, slows investments and, consequently, reduces aggregate production. In the external sector, the impacts depend on whether the country is an oil importer or exporter.

Until 2008, according to the Petroleum Agency (ANP)[1], Brazil was a net oil importer country. Imports dropped from 145 million barrels in 2000 to 60 million barrels in 2021, while exports grew significantly from 6 million barrels in 2000 to 483 million barrels in 2021[2]. Domestic oil production grew from 450 million barrels in 2000 to 1.06 billion barrels in 2021. The replacement of imported oil with domestic energy sources and the introduction of a price tax (CIDE-fuel - Law 10,336/2001)[3] on its derivatives aimed to reduce imports. As Brazil became an oil exporter, CIDE-fuel was gradually abandoned, with the exception of gasoline[4].

Currently, Brazil is an oil producer and exporter and, since October 2016, has adopted an import price parity policy, that is, domestic prices for its derivatives track international prices plus costs that importers would have. This decision further exposed the Brazilian economy[5], until then it was relatively protected from the volatility of oil prices on the international market with a policy of administered domestic prices.

The literature regarding the impact of oil price volatility in Brazil is very limited. The work of Choi and Kim (2012) analyzes the Brazilian case, but recent changes in the economy in relation to the oil market are not included. Therefore, it is extremely important to analyze the impact of oil price volatility on the Brazilian economy, as well as the policies that mitigate these adverse effects of volatility.

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1 Agência Nacional de Petróleo (ANP) is the Brazilian oil regulator.

2 Imports include oil and condensate and do not include natural gas and natural gas liquids. Exports include only oil.

3 The CIDE-fuel revenues are used to subsidize investments in the production of oil, ethanol and their domestic transport.

4 The objective was not to restrain consumption and but more to protect the ethanol market.

5 In 2018, we had the truck drivers' strike, considered the biggest in the history of the category. It started on May 21 and lasted for 10 days. This strike was associated with the rise in fuel, which was associated with the increase in the dollar and oil in the international market, showing one of the economic effects of this new policy of price parity. This strike caused shortages of food, medicine and oil throughout Brazil.

Here, we present the effects of oil price volatility on the performance of the Brazilian economy. The study covers the period from January 2001 to June 2021. The uncertainty of real oil prices is measured through its realized volatility and is constructed from the informed daily prices of crude oil. The impact of oil price volatility is investigated using an autoregressive vector (VAR) model with macroeconomic variables. Our main result indicates that oil price volatility had a negative and significant effect on GDP growth. The analysis of the impulse-response function also suggests that oil volatility shocks have impacted GDP for a period of four months.

This article is structured as follows: Section 2 presents a review of the literature on empirical models, Section 3 describes the data and methodology, Section 4 presents the empirical analysis and Section 5 concludes.

2 Brief literature review

The economic literature indicates that it is necessary to use economic instruments to mitigate the harmful effects of price volatility to sustain the pace of economic growth. In the case of oil, changes in the geopolitical composition of supply-demand, on the one hand, and the financialization of the management of its stocks, on the other hand, initiated strong price volatility after the 1970s oil crisis.

Much of the empirical literature uses macroeconomic models to analyze the impact of oil price variation or volatility on economic activity. The seminal work of Hamilton (1983), for the American economy, establishes a negative relationship between the price of oil and real GDP and unemployment[6].

Lee *et al*. (1995) estimated the impact of changes in oil prices on real GDP using a univariate GARCH model to estimate oil price volatility and included this variable in a model with a macroeconomic autoregressive vector (VAR) for the US economy in the period from 1949 to 1992. One of the results shows that the impact on real GDP is more significant in an environment where oil prices have been stable compared to an environment in which oil price movement has been irregular. In addition, positive normalized oil price shocks have a powerful effect on growth, while normalized negative shocks do not[7].

Kumar (2009) uses a VAR macroeconomic model for the Indian economy in the period 1975-2004. The main result was that oil price shocks negatively affect industrial production. Ozturk (2015) analyzed the impact of oil price shocks on Turkey's macroeconomic variables for the period 1990-2011. VAR models and Granger causality tests were applied to determine shocks in the price of oil in the macroeconomic relationship. The results show that positive shocks in the price of oil decrease industrial production, money supply and imports, while negative shocks in the price of oil increase imports.

Rafiq *et al*. (2009) examined the impact of oil price volatility on some of Thailand's macroeconomic indicators. Quarterly oil price volatility is measured using realized volatility. The impact of oil price volatility is investigated using VAR. Granger's causality test, impulse response functions and variance decomposition show that oil price volatility has a significant impact on macroeconomic indicators, such as unemployment and investment, from 1993 to 2006. A VAR model for the post-Asian crisis period (1997-1998) shows that the impact of oil price volatility is transmitted to the budget deficit. The authors report that the floating exchange rate regime introduced after the crisis may be the main contributor to this new impact channel.

6 Hooker (1996) and Hamilton (1996) confirm these results.

7 Mork (1989) and Mork and Olsen (1994) also analyze the effects of positive and negative oil price shocks.

Elder and Serletis (2010) identified that oil price volatility had a negative and statistically significant effect on investment, the consumption of durable goods and the aggregate product of the American economy. They draw attention to the fact that the socioeconomic effects of oil price volatility do not occur in a symmetrical manner. They are more impactful during periods of high prices, being transmitted to society in general through different means due to the role of oil in the economy.

Choi and Kim (2012) analyzed the volatility of commodity prices in real GDP for the G20 countries for the period from January 1991 to April 2012. The authors initially made a univariate GARCH model to estimate the relationship between industrial production and the volatility of three variables: inflation, price of energy commodities (oil) and price of nonenergy commodities. The results showed that, for most countries, the estimated volatility coefficient of energy commodity prices is negative and statistically significant. In the case of Brazil, the coefficient was not statistically significant. The authors also conducted a multivariate analysis using the VAR-GARCH methodology. The results pointed in the same direction as the univariate model. However, the significance of the negative coefficients was only for six countries in the case of the price of the energy commodity. Again, in the case of Brazil, the coefficient was not significant.

The study by Eyden *et al*. (2019) analyzed the impact of oil volatility on the economic growth of 17 member countries of the Organization for Economic Cooperation and Development (OECD) over 144 years (from 1870 to 2013) using panel data. The main finding of the study is that oil price volatility has a negative and statistically significant impact on the economic growth of OECD countries. By allowing the heterogeneity of the volatility coefficient, the oil producing countries (mainly Norway and Canada) stand out, in which the negative impacts of the oil price uncertainty are quite significant.

3 Data and methodology

This work uses monthly data from January 2001 to June 2021 for the Brazilian economy. The choice for selecting this period is because the Brazilian exchange rate regime started to fluctuate in 1999. The model covers five endogenous variables[8] obtained from the Institute of Applied Economic Research (IPEADATA):

a) real GDP growth rate for year-over-year (RGDP)[9], deflated by general price index - domestic availability (IGP-DI - Brazilian acronym)[10];
b) inflation rate (RINF), measured by the IGP-DI;

c) investment growth rate for year-over-year (RINV), calculated by the gross fixed capital formation;

d) first difference to real interest rate (RIR), represented by over Selic (Brazilian federal funds rate) and deflated by IGP-DI;

e) realized volatility of oil (RV)[11], measured by the daily Brent crude oil price FOB and transformed into local prices by the foreign exchange rate (R$/US$).

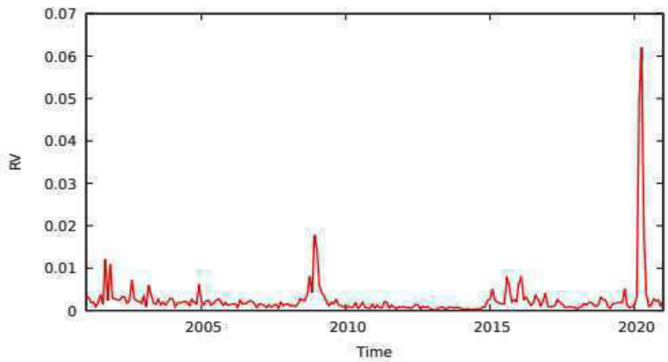
8 Other macroeconomic variables were tested, such as: trade balance as a percentage of GDP; exchange rate and fiscal deficit as a percentage of GDP. For nonstationary variables, we use rates or first difference (see unit root test in Appendix Table A1).
9 GDP was also tested for dollar values. However, the model adjustment was lower than the model estimated in local currency.
10 In Brazil, the IGP-DI is the most used index to deflate variables. It is a hybrid index, which combines wholesale and retail prices.
11 Volatility was also tested, using the GARCH model. However, the adjustment of the model with the realized volatility (RV) was superior.

According to Andersen *et al*. (2004), the realized volatility is the sum of the intra-period square returns, described as follows:

$$RV_t(h) = \sum_{i=1}^{1/h} r_{t-1+ih}^{(h)2}$$

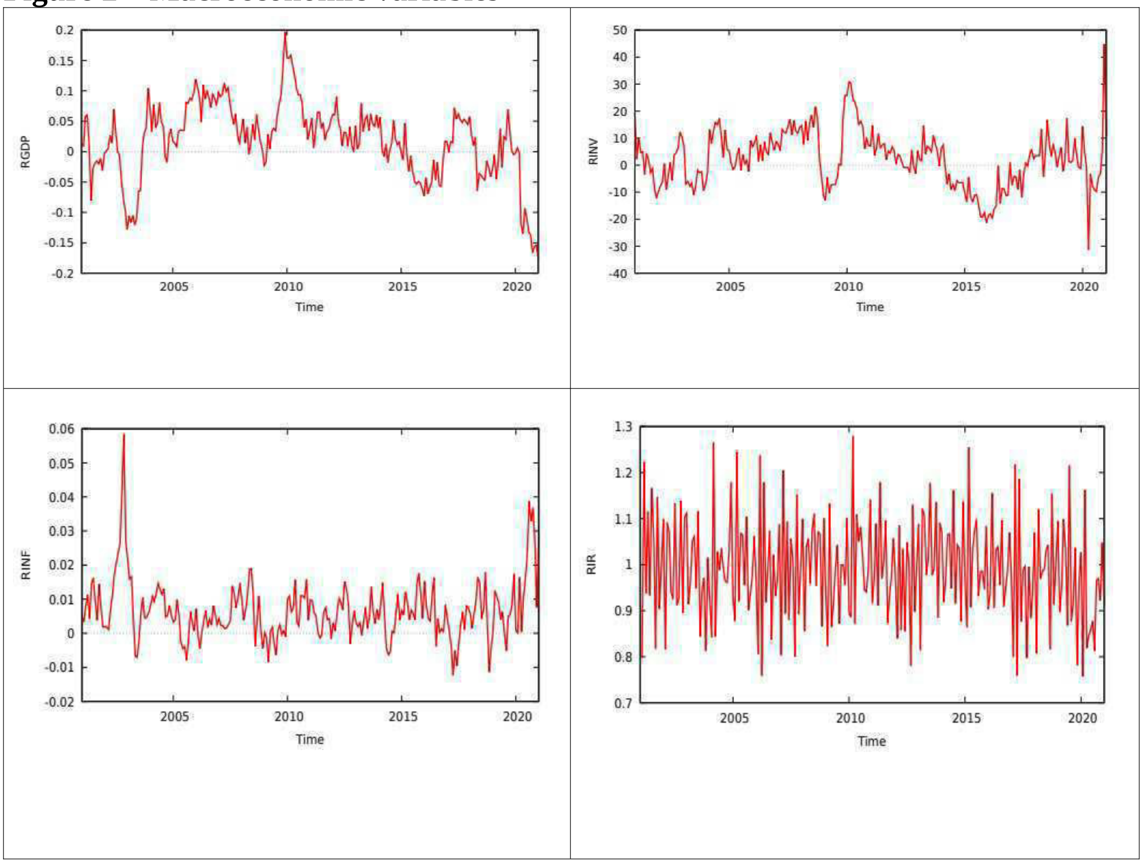
where the return of period h (in this study, this is the daily price of oil return) is given by $r_t^{(h)} = log(S_t) - log(S_{t-h})$ e 1/h, which is a positive integer.

Figure 1 – Realized volatility of oil (RV)



Source: IPEADATA data and author's own calculations

Figure 2 – Macroeconomic variables



Source: IPEADATA data.

A dummy variable was included to capture the effect of the coronavirus pandemic as follows:

D_t=1 for t=03/2020 until 06/2021 and D_t=0 otherwise

In this study, the autoregressive vector (VAR) model with p-lag (p) is estimated as follows:

$$Y_t = \alpha + \sum_{i=1}^{p} \beta_i Y_{t-i} + D_t + u_t$$

where Y_t is an nx1 vector with five endogenous variables, α is the VAR intercept, $\boldsymbol{\beta}_t$ is an nxn matrix of autoregressive coefficients for i = 1,2, ... p, D_t is an exogenous dummy variable and u_t is an nx1 vector that follows a white noise process.

To evaluate the dynamic behavior of the model, impulsive responses (IRs) are used. They provide the reaction of a response variable to a shock of an impulse variable. Furthermore, the analysis of the variance decomposition shows the percentage of the variance of the forecast error that results from each endogenous variable over the forecast horizon.

4 Estimation results

4.1 VAR model

Several tests were carried out to identify the model and investigate the relationship between the variables analyzed. From the results of the information criteria[12], we Model a VAR(3)[13]. Since no root is outside the unit circle and the entire module is less than one, the VAR(3) model is therefore stable. The cumulative sum (CUSUM) test for stability of parameters was also performed. The results indicate that we have no instability problem for the period studied.

Table 1 shows the result of the VAR(3) model with the coefficients and respective robust standard errors in parentheses.

In the RGDP equation, the oil volatility (RV) coefficient for lag 1 was -2.06; for lag 2, the coefficient was positive at 1.02; and for lag 3, it became negative at -0.65 (all statistically significant at 1%). In the aggregate of the three periods, the impact is negative (-1.69). This indicates that an increase in oil price volatility reduces economic growth, as explained above. This volatility creates uncertainty, which can affect investments, production and the external sector.

This result is in line with the findings in several G20 countries in the work of Choi and Kim (2012), although these authors do not find the coefficient significant for Brazil. The difference can be explained by three reasons. The first is due to the methodologies used (VAR-GARCH used in the study by Choi and Kim); the second is because the same endogenous variables were used for all G20 countries, neglecting the particularities of each country. The last one refers to the period of analysis, because after 2012 there were many changes in the Brazilian economy related to the oil market.

In the work of Rafiq *et al*. (2009), a VAR (1) was estimated, and the main result is that the volatility of oil prices (RV) has a negative impact on Thailand's economic growth, which is consistent with our findings for the Brazilian case.

Still in the RGDP equation, the variation in inflation and real interest rate contribute negatively to GDP, as expected.

In the RINF equation, oil volatility was not significant. This result is in line with expectations, as we assume that only increases and decreases in oil prices impact inflation. The

12 See Table A.2 Appendix A.

13 To test the robustness of the model, some variations were made both for the number of lags (6, 4 and 2) and for the period under study (excluding the coronavirus pandemic period). The coefficients of the variables remained with the same sign and magnitude in relation to the VAR(3) model with the total sample.

RINF is basically self-explanatory. The dummy variable for the coronavirus pandemic was positive and significant at 10%. This suggests that we had an increase in inflation on the supply side. Although this dummy variable is only significant in the RINF and RINV equations, using the Wald test for omission of an exogenous variable, we reject the null hypothesis that the regression parameters are zero for the dummy variable[14].

Table 1 - Results of the VAR(3) model

	RGDP	RINF	RINV	RIR	RV
RGDP(-1)	0.690 (0.075)***	−0.061 (0.021)***	0.149 (0.232)	0.005 (0.306)	0.013 (0.014)
RGDP(-2)	0.048 (0.097)	0.058 (0.022)***	−0.038 (0.302)	−0.355 (0.364)	0.001 (0.016)
RGDP(-3)	0.080 (0.077)	0.012 (0.016)	0.161 (0.249)	0.188 (0.377)	−0.003 (0.012)
RINF(-1)	−0.615 (0.208)***	0.636 (0.098)***	0.007 (0.672)	−1.748 (0.826)**	−0.019 (0.053)
RINF(-2)	−0.549 (0.262)**	−0.129 (0.073)*	1.870 (1.122)*	3.561 (1.082)***	−0.106 (0.102)
RINF(-3)	−0.124 (0.245)	0.124 (0.078)	−0.455 (0.774)	−1.145 (1.038)	0.127 (0.096)
RINV(-1)	−0.032 (0.032)	0.026 (0.011)**	0.372 (0.092)***	0.061 (0.120)	−0.004 (0.005)
RINV(-2)	0.023 (0.039)	−0.016 (0.011)	0.144 (0.139343)	−0.246 (0.167)	−0.003 (0.007)
RINV(-3)	0.025 (0.032)	−0.015 (0.008)*	0.225 (0.144)	0.334 (0.188)*	0.003 (0.005)
RIR(-1)	−0.053 (0.023)**	−0.003 (0.004)	−0.027 (0.067)	−0.481 (0.072)***	−0.004 (0.004)
RIR(-2)	−0.019 (0.020)	−0.0002 (0.005)	−0.041 (0.054)	0.193 (0.092)**	−0.002 (0.003)
RIR(-3)	−0.002 (0.019)	−0.002 (0.005)	−0.031 (0.043)	0.395 (0.060)***	0.002 (0.002)
RV(-1)	−2.064 (0.270)***	−0.046 (0.135)	−5.342 (1.609)***	−1.504 (1.146)	0.753 (0.144)***
RV(-2)	1.024 (0.372)***	−0.015 (0.155)	3.093 (2.486)	−4.280 (1.170)***	−0.415 (0.245)*
RV(-3)	−0.648 (0.219)***	0.064 (0.106)	−2.651 (1.241)**	−0.581 (1.013)	0.040 (0.103)
Dummy	−0.004 (0.010)	0.006 (0.003)*	0.090 (0.045)**	0.045 (0.056)	0.007 (0.006)
Constant	0.072 (0.042)*	0.012 (0.011)	0.357 (0.091)***	0.748 (0.219)***	0.008 (0.010)

Note: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The investment (RINV) is self-explanatory and explained by the volatility of oil (RV). An increase in volatility at lags 1 and 3 reduces investment, as expected (the net value is -7.99). These results are in line with Rafiq *et al*. (2009), who found a significant relationship between investment and oil volatility.

14 Wald test: Chi-square(5) = 33.6301, p-value 2.8207e-06

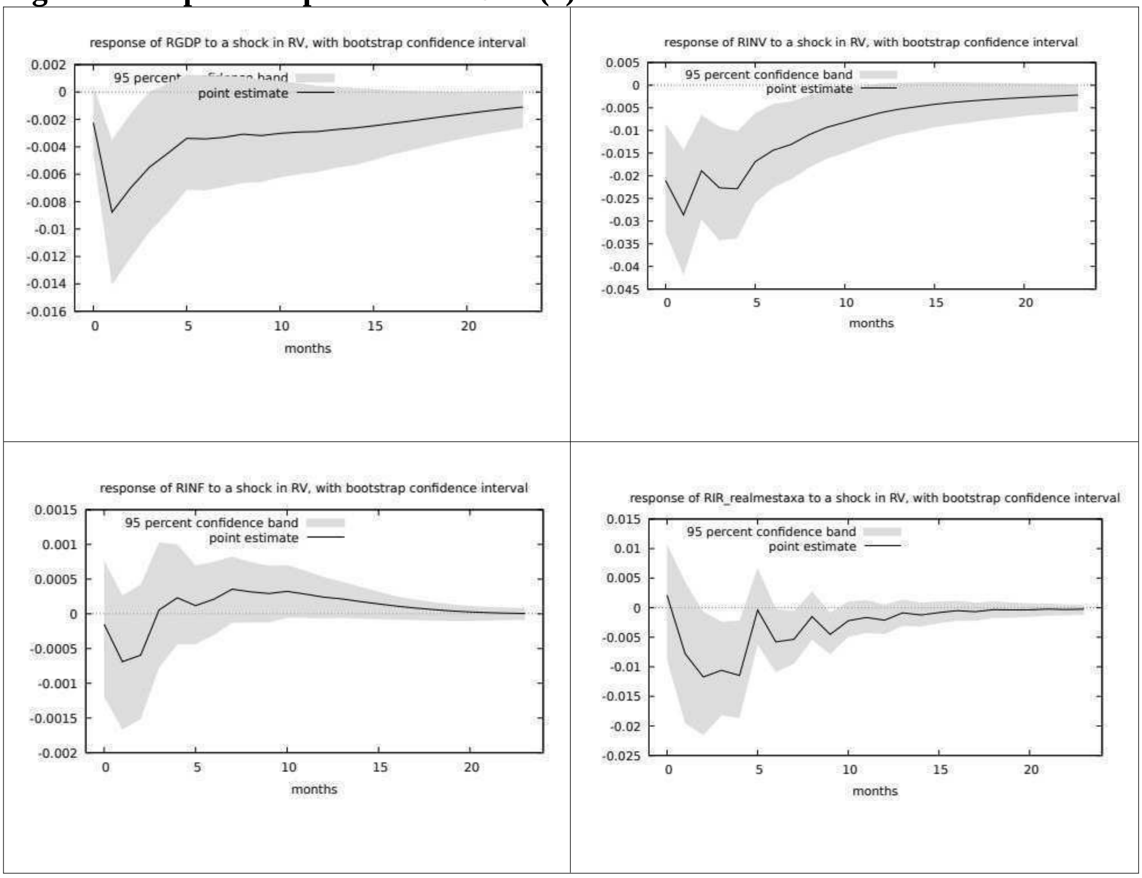
In the real interest rate equation (RIR), in addition to it being self-explanatory, it is also explained by the inflation and RV. Finally, in the RV equation, the only significant variable is itself in lags 1 and 2.

Next, we will analyze the impulse response function and variance decomposition. The order of variables follows economic theory and is as follows: RV → RIR → RINV → RINF → RDGP. It should be noted that there is no great difference in changing the order of presentation of the variables in question.

4.2 Impulse response functions

The VAR system has five variables, resulting in a total of 25 pulses generated. As the main objective of the article is to examine the impact of oil price volatility on the other variables, we will only show the oil shock (impulse) and the response given in the four variables.

Figure 3 - Impulse response of the VAR(3) model



In the first Figure (3 left top), we have the impact of the RV shock on RGDP, which is negative and becomes more expressive in the second month. After the fifth month, it remains negative, but it is not relevant in terms of significance.

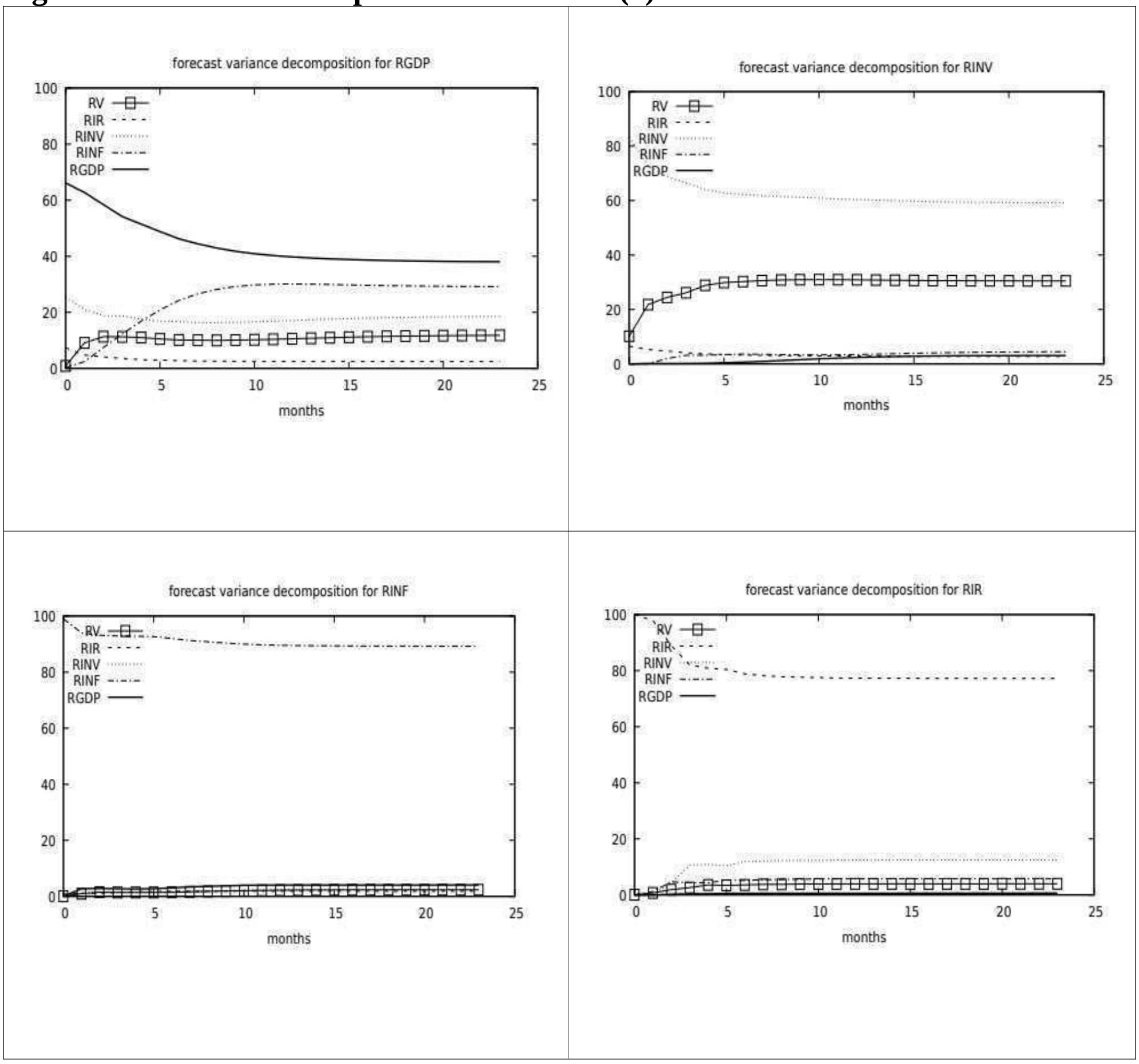
The investment response to an RV shock is significant and quite long, lasting 12 months (Figure 3 right top). This result is in line with the findings in Rafiq *et al*. (2009), in which oil price volatility explains a significant part of investment innovations over a longer time horizon.

The shock of the RV in the RINF (Figure 3 left bottom) was not significant, as expected. Regarding the interest rate, the impact is negative and significant for the third and fourth months (Figure 3 right bottom).

4.3 Decomposition of variance

In the estimated model for RGDP, we have the percentage of the variance in the forecast error results, over 24 months from the forecast horizon, with the variable itself 38%, the RINF 29%, the RINV 18%, the RV 12% and the RIR 3% (Figure 4 left top). It should be noted that for investment, oil volatility contributes 31% of the variance of the forecast error (Figure 4 right top). For the RINF and RIR models, the percentage of the variable itself is high, being approximately 90% and 80%, respectively (Figure 4 left and right bottom).

Figure 4- Variance decomposition of the VAR(3) model



5 Conclusion

Here, we have investigated the consequences of oil price volatility on real economic growth, as measured by the growth of the Brazilian real GDP for the period of January 2001 to June 2021. We use a VAR(3), considering five endogenous variables: the realized volatility of the world oil price, real GDP, investment, inflation and real interest rate. A dummy for the 2020 coronavirus pandemic crisis was also included.

Our results show that the empirical results of the VAR(3) estimates are consistent with the perception that real oil price volatility is negatively associated with aggregate economic activity.

The impulse responses showed that the realized volatility has an impact on real growth, which is the most significant in the second month of the time series. The impact remains negative after the fifth month but loses significance. The effect of oil volatility on investment was negative and quite significant, persisting for twelve months.

In Brazil, the introduction of CIDE-fuels in 2001, which encouraged domestic oil production and the use of alternative sources of fuel (ethanol), contributed to the country's shift from an oil importer to an exporter. However, these measures were not enough to mitigate the macroeconomic effects of oil price volatility. To mitigate the harmful economic effects of oil price volatility, especially during peak periods, an additional mechanism will be needed.

Upon becoming an oil producer-exporter, royalty income will increase. This situation offers an opportunity to create this additional mechanism, allocating a portion of this revenue increase to a fund to mitigate the high volatility of the price of a barrel of oil in the international market. At the same time, the portion of the Union's oil resulting from the sharing contracts can be traded with domestic refineries with a similar price ceiling, functioning as a hedge for undesirable levels of this volatility. These two mechanisms, if well adjusted and managed, will make it possible to avoid the negative impacts of oil volatility on investment and economic growth.

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Appendix A

Table A.1 - ADF unit root test for the study variables

Level					First Difference*				
Variable	Lag**	Statistic	P-value	Integration order	Variable	Lag**	Statistic	P-value	Integration order
GDP	14	-1.53	0.52	I(1)	RGDP	3	-3.49	0.01	I(0)
INF	15	1.96	0.99	I(1)	RINF	2	-6.59	8.21E-05	I(0)
IR	24	0.33	0.78	I(1)	RIR	23	-2.89	0.04	I(0)
INV	16	-1.45	0.56	I(1)	RINV	15	-3.10	0.03	I(0)
RV	4	-5.95	1.57E-07	I(0)	RRV	1	-6.42	1.12E-08	I(0)

* The first difference was calculated by the rate of change. ** The criterion for the selection of the lags was the BIC.

Table A.2 – VAR lag selection

lags	**AIC**	**BIC**	**HQC**
1	-24.445	-23.936*	-24.240
2	-24.748	-23.875	-24.396
3	-24.979*	- 23.742	-24.481*
4	-24.973	-23.373	-24.329
5	-24.973	-23.009	-24.181
6	-24.944	-22.617	-24.006

Note: The asterisks below indicate the best (that is, minimized) values of the respective information criteria, AIC = Akaike criterion, BIC = Schwarz Bayesian criterion and HQC = Hannan-Quinn criterion.