Fiscal Policy and Financial Stress in Brazil: Evidence from threshold-VAR approaches

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Abstract
This article analyzes possible nonlinearities in fiscal and monetary policy responses in Brazil from February 2000 through November 2020. The objective is to verify whether the fiscal and monetary authorities acted countercyclically in times of financial stress. Six models threshold-VAR (TVAR) are estimated to assess the existence of asymmetries in economic policy responses. Periods of financial turmoil were based on the Financial Stress Index (FSI). The results suggest that the fiscal policy, during economic growth, was expansionary in the fiscal impulse, but in a contractionary way in the fiscal rule. The monetary authority, in turn, acted in a countercyclical manner when considering all models.

Keywords: Fiscal Policy, Financial Stress Index, Threshold VAR
JEL classification: C53; E43; G17.

Resumo
Este artigo analisa a presença de não linearidades nas respostas da políticas fiscal e monetária no Brasil entre Fevereiro de 2000 e Novembro de 2020. O objetivo é verificar se as autoridades fiscal e monetária agiram de forma contracíclica em momentos de estresse financeiro. São estimados seis modelos threshold-VAR (TVAR) para avaliar a existência de assimetrias nas respostas da política econômica, sendo que períodos de turbulência financeira foram baseados no Índice de Estresse Financeiro (FSI). Os resultados sugerem que a política fiscal, nas fases de crescimento, agiu de maneira expansionista no impulso fiscal, mas de forma contracionista na regra fiscal. A autoridade monetária, por sua vez, agiu de maneira anticíclica quando considerado todos os modelos.

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1. Introduction
The relationship between economic policies and the financial system has received more attention from economists after the subprime mortgage crisis in 2008. The global pandemic of coronavirus disease 2019 (COVID-19), as well, has resulted in economic disruption and uncertainty, which affect the productive sector and financial markets (Zhang \textit{et al.}, 2020; Bakas & Triantafyllou, 2020; So \textit{et al.}, 2021).

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In turn, governments countercyclical response runs through fiscal and monetary stimulus to overlap economic downturns (Cukierman, 2013; Spilimbergo et al., 2009; Casado et al., 2020), such as cutting interest rates, taxes, and increase spending (Gali, 2020). These policies in pandemic times are crucial because inadequate measures can affect the government’s credibility since financial markets can penalize sovereigns with low fiscal space (Augustin et al., 2021). As a consequence, the government’s financing capacity may be affected.

The government’s inability to sell its bonds and to reducing its liquidity weakens the balance sheet of financial institutions that hold this type of asset. Also, perception of sovereign risk can affect financial stability represented by credit risk and the degree of solvency of banks (Montes et al., 2021). A consequence of falling government bond prices, for instance, is banks may experience a reduction in their ability to lend. In such moments of higher turbulence in the bank sector and financial markets is essential to have an objective measure of this stress, as suggested by Hakkio et al. (2009), since policymakers could take action to mitigate the effect of the economic cycle.

There is a well-known literature on linkage between economy activity, financial markets, financial stability, and financial crisis (Slingenberg & De Haan, 2011; Oet et al., 2015; Monin, 2019; Sandahl et al., 2011; Illing & Liu, 2003; Claessens et al., 2012). In particular, Balakrishnan et al. (2011) use a Financial Stress Index FSI to investigate periods of turbulence in financial markets between advanced economies and emerging economies. At the peak of the 2008 crisis in advanced economies, there was a considerable reaction in emerging economies, with a sharp rise in FSI in these countries. Moriyama (2010) investigate the effects of the global crisis on financial conditions and economic activity in emerging countries. The author points out that increase of economic stress identified by FSI may explain about half of the decline in real GDP growth in these countries.

Researches also present results involving the relationship between economic policies and financial stress. Li & St-Amant (2010) seek to identify linkage among monetary policy, business cycle, and evolution of Canada’s financial sector. They conclude that a contractionary monetary policy has a more significant effect on the product when the economy is in a period of deep financial stress. Park & Mercado Jr (2014), for instance, extends the existing literature on the use of FSI in understanding the channels of financial transmission in emerging market economies. Using FSI of 25 emerging markets from 1992 to 2012, their results suggest regional and nonregional emerging market FSIs significantly increase in domestic financial stress.

Stona et al. (2018) investigate the differences in macroeconomic dynamics during instabilities in the Brazilian financial market from 2000 to 2015. The authors introduced the Brazil Financial Stress Index as a proxy for financial stress and assessed its interaction with real activity, inflation, and monetary policy. Their main results suggest an expansionary monetary policy can worsen the scenario in an adverse situation. Also to Brazil, Wichmann & Portugal (2013) assess the existence of asymmetries in economic policy responses through economic cycles from 2001 to 2010. They suggest the rule is faster and less asymmetric than the other policies, while the monetary policy responds more strongly to positive variations in the output gap.

Although there are studies on economic policy responses in Brazil, we seek to investigate the monetary and fiscal responses in periods of crisis using the FSI as a threshold variable to identify two states of nature: low stress regime (economic growth) and high stress regime (economic downturn) (Afonso et al., 2018; Galvão & Owyang, 2018; Alessandri & Mumtaz, 2017). The main purpose of this research is to assess whether the response of Brazil’s monetary and fiscal policies were contractionary (countercyclical) in moments of growth and expansionary in periods of downturn. To the best of our knowledge, there is a literature gap in this field using threshold vector autoregression methodology threshold-VAR (TVAR) in this framework (Soave, 2020; Evgenidis & Tsagkanos, 2017; Li & St-Amant, 2010). Some questions can emerge to address our research: have the fiscal and monetary authorities different responses depending on the financial markets state? What was this response in the COVID-19 pandemics?

The main objective is to estimate the economic cycle responses of Brazilian fiscal policy during
episodes of instability in the domestic financial market. Such events can lead to asymmetric reactions on policymakers. The specific objectives are to verify how the fiscal authority behaves during periods of high turbulence in the financial markets; to investigate the existence of nonlinearities in fiscal and monetary policy caused by financial stress, and to estimate the fiscal and monetary authorities’ responses concerning the economic cycle during periods of financial stress. The outline of the paper is as follows. Section 2 introduces the Financial Stress Index. Section 3 and 4 present the methods for filtering impulse fiscal policy and the threshold-VAR (TVAR), respectively. Section 5 presents the dataset and our empirical findings, and lastly, section 6 concludes.

2. Financial Stress Index

An episode of financial stress can be defined as a period of interruption in financial markets’ normal functioning (Hakkio et al., 2009), such as generated by the uncertainties brought the COVID-19. A period of financial stress has at least one of these features: increased uncertainty about the value of fundamental assets (Zhang et al., 2020; Bakas & Triantafyllou, 2020), increased uncertainty about other investors’ behavior (Bogdan et al., 2021), increased information asymmetry between lenders and borrowers, less willingness to hold risky assets, decreased desire to keep assets less liquid (flight to liquidity), see Davi et al. (2010) for detailed descriptions.

Balakrishnan et al. (2011) developed an index of financial stress for emerging markets based on the existing index of Cardarelli et al. (2009) for developed countries. This index is composed of five variables, namely: “banking-sector beta”, stock market returns, stock market volatility, sovereign debt spreads, and exchange market pressure index EMPI. The $\beta_t$ of the banking-sector is obtained as follows:

$$\beta_{i,t} = \frac{\text{cov}(r_{i,t}^M, r_{i,t}^B)}{\sigma^2_{i,t}},$$

where $r_{i,t}^M$ represents the annual rates of return of the general stock market and $r_{i,t}^B$ the rates of return of the shares of companies in the banking-sector, the covariance and variance were calculated based on a 12-month moving window. When $\beta_t > 1$, it is clear that the banking-sector presents greater volatility than the rest of the market. The return of the stock market consists of the year-on-year change of the stock index multiplied by $-1$. Thus a decline in stock prices implies an increase in stock market stress.

The third variable is the volatility of the stock market. Higher volatility of the stock market can cause an increase in uncertainty and cause an increase in financial stress. Balakrishnan et al. (2011) estimated such volatility using a GARCH specification (1,1) for an auto-regressive process variance with 12 lags. However, we use the Exponentially Weighted Moving Average (EWMA) volatility models, considering the six-month moving average of the square of the stock index’s monthly growth rate.

The fourth variable is the sovereign debt spreads. It is defined by the EMBI+ (Emerging Market Bond Index Plus) and is a proxy for country risk. An increase in EMBI+ implies a perception, on the part of the market, that investing in a particular economy has become riskier, which, in turn, can lead to an increase in financial stress. Lastly, the EMPI+ captures depreciation of exchange rate and declines in international reserves, and is defined for country $i$ in month $t$ as:

$$EMPI_{i,t} = \frac{(\Delta e_{i,t} - \mu_{i,\Delta e})}{\sigma_{i,\Delta e}} - \frac{(\Delta RES_{i,t} - \mu_{i,\Delta RES})}{\sigma_{i,\Delta RES}},$$

where $\Delta e_{i,t}$ and $\Delta RES_{i,t}$ represents changes in the domestic exchange rate and international reserves, respectively, while $\mu_{i,\Delta e}$ and $\sigma_{i,\Delta RES}$ represents the mean and standard deviation of the variable $i$. It is clear that the EMPI+ consists of the sum of variables $\Delta e_{i,t}$ and $\Delta RES_{i,t}$ standardized. Domestic

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1In the final FSI calculation, betas were only considered when their value was greater than one and when the returns of the banking-sector’s shares were less than the returns of the market as a whole.
currency depreciation as reductions in international reserves pressure the foreign exchange market and, as a result, increase financial stress.

To yield the aggregate Financial Stress Index for an individual country the five components are standardized and summed up:

\[
FSI_t = \beta_t + SMR_t + SMV_t + EMBI_t + EMPIt.
\]  

(3)

In order to proceed the evaluation of fiscal policy, next section introduces five methods to filtering the fiscal policy.

3. Methods for Filtering Impulse Fiscal Policy

When analyzing the behavior of economic policy, whether fiscal or monetary, it is important to keep in mind that it has automatic and discretionary components (Tornell & Lane, 1999; Talvi & Vegh, 2005; Ilzetzki, 2011). These components can present different path, so that it is possible that procyclicality is present in only one of the components. For example, there is a possibility that the rule component is countercyclical and the discretionary component is procyclical.

The definition of the rule says that the balance increases (decreases) when the output gap rises (lowers). The fiscal impulse can have a greater degree of asymmetry, predominantly countercyclical in the financial stress regime and procyclical in regimes without stress monetary policy can have countercyclical behavior during regimes with stress (Sorensen et al., 2001; Hercowitz & Strawczynski, 2004; Balassone et al., 2010). The central bank can be more tolerant of the economy’s heating during periods without financial stress, accepting a little more inflation.

3.1. The OECD method

In the methodology used by OECD (Girouard & André, 2006), the cyclically adjusted balance, concerning the potential product, \(B^*\), is defined as follows:

\[
B^* = \frac{[T^* - G^* + X]}{Y^*},
\]

(4)

where \(G^*\) represents the cyclically adjusted current primary government expenditure, \(T^*\) represents the cyclically adjusted component of government revenue, \(X\) represents non-tax revenue minus capital and interest expenditures, and \(Y^*\) represents the level of potential output. Cyclically adjusted components are calculated from current revenue from tax collection \((T)\) and government spending \((G)\).

The revenue is adjusted by the ratio between the potential product \((Y^*)\) and the current product \((Y)\) and by the elasticity of the revenue concerning the output gap \((\epsilon_{t,y})\). Spending, on the other hand, is adjusted by the ratio between structural unemployment \((U^*)\) and current unemployment \((U)\) and by the elasticity of current primary expenditure in relation to the ratio between structural unemployment and current \((\epsilon_{g,u})\). Algebraically, we have:

\[
\frac{T^*}{T} = \left(\frac{Y^*}{Y}\right)^{\epsilon_{t,y}},
\]

(5)

\[
\frac{G^*}{G} = \left(\frac{U^*}{U}\right)^{\epsilon_{g,u}}.
\]

(6)

Substituting equations (5) and (6) in (4), the cyclically adjusted balance is obtained, that is

\[
B^* = \frac{\left[T \left(\frac{Y^*}{Y}\right)^{\epsilon_{t,y}} - G \left(\frac{U^*}{U}\right)^{\epsilon_{g,u}} + X\right]}{Y^*}.
\]

(7)

The first difference of \(B^*\) in equation (7) represents the fiscal impulse, that is

\[
FIt^{OECD} = \Delta B^*.
\]

(8)
3.2. The IMF (2006) method

In the IMF (2006) method (IMF, 2006), it is necessary to define cyclically neutral expenses and revenues to obtain the components of rule and discretion through this methodology. As noted by Heller et al. (1986), expenditure is considered to be cyclically neutral when it responds proportionally to increases in potential output. On the other hand, cyclically neutral revenue responds proportionally to variations in the observed product. Algebraically, we can represent these relationships as follows:

\[ G_t^* = \frac{G_0}{Y^p_0} Y^p_t, \]  
\[ T_t^* = \frac{T_0}{Y^p_0} Y_t, \]

where \( G_t \) and \( T_t \) represent government expenditures and revenues, \( Y_t \) represents the product, and \( Y^p_t \) the potential product. It is necessary to choose a base year where the observed product is equal to the potential to calculate the cyclically neutral components \( G_t^* \) and \( T_t^* \). To obtain cyclically adjusted government spending and revenue, one can subtract the cyclically neutral components of spending and revenue, that is \( G_{ca} = G_t - G_t^* \) and \( T_{ca} = T_t - T_t^* \).

The fiscal impulse, that is, the net increase in government spending that does not depend on the cycle of economic growth, is obtained by varying the cyclically adjusted government budget balance (in relation to GDP):

\[ FI_t = \left( \frac{\Delta G_t - \Delta G_t^*}{Y_t} \right) - \left( \frac{\Delta T_t - \Delta T_t^*}{Y_t} \right), \]  
\[ FI_{IMF(2006)}^t = \left[ \Delta \left( \frac{G_t}{Y_t} \right) - \Delta \left( \frac{G^p_0}{Y^p_0} Y^p_t \right) \right] - \left[ \Delta \left( \frac{T_t}{Y_t} \right) - \Delta \left( \frac{T^p_0}{Y^p_0} Y_t \right) \right]. \]

3.3. The Dutch method

Another way to calculate the fiscal impulse, called the Dutch method, is presented by Sidaoui et al. (2003). This method is a variation of the IMF (2006) method, considering that the base period for the calculation is the same as the immediately previous period:

\[ FI_{Dutch}^t = \left[ \Delta \left( \frac{G_t}{Y_t} \right) - \Delta \left( \frac{G_{t-1}}{Y_{t-1}} Y^p_t \right) \right] - \left[ \Delta \left( \frac{T_t}{Y_t} \right) - \Delta \left( \frac{T_{t-1}}{Y_{t-1}} Y_t \right) \right]. \]

According to Chand (1992), an advantage of the Dutch method is that it does not depend on the choice of the base year; that is, the fiscal impulse is determined using the fiscal balance of the immediately preceding period as a reference.

3.4. The IMF (2008) method

The IMF (2008) builds a measure of fiscal impulse based on estimating a set of regressions considering real GDP growth as a proxy for the economic environment. In this methodology, the government balance sheet in period \( t \) can be expressed as a function of discretionary fiscal policy, \( P_t \), and the prevailing economic environment in the period, \( E_t \). Thus \( B_t = B(P_t; E_t) \). The change in the fiscal balance concerning the previous year can be represented as follows

\[ \Delta B_t = B(P_t, E_t) - B(P_{t-1}, E_{t-1}). \]

Adding and subtracting the term \( B(P_t, E_{t-1}) \), which represents what would be the fiscal balance resulting from a policy at time \( t \) if the economic environment remained unchanged between \( t-1 \) and \( t \), we obtain

\[ \Delta B_t = \Delta B_t^E + \Delta B_t^P. \]
The term $\Delta B_t^E$ represents the fiscal effects of changes in the economic environment from $E_{t-1}$ to $E_t$. In this case, there are no discretionary changes in fiscal policy between time $t - 1$ and time $t$, that is, $P$ does not change.

The term $\Delta B_t^P$ captures changes in the balance sheet resulting from changes in discretionary policy. There is a change in fiscal policy, $P$, even though the economic environment remains unchanged.

As the balance sheet is the result of the subtraction between government revenues and expenses, to measure the fiscal impulse, it is necessary to estimate the following equations for these variables

$$T_t = \alpha_R + \beta_R (growth_t) + \gamma_R t + u_t, \quad (16)$$
$$G_t = \alpha_E + \beta_E (growth_t) + \gamma_E t + e_t, \quad (17)$$

where $T$ is revenue as a percentage of GDP, $G$ is government expenditure as a percentage of GDP, $growth$ is real GDP growth, and $t$ represents a time trend. The terms $u$ and $e$ indicate the residuals of the estimation.

Thus, cyclically adjusted income and expenditure are given by equations (18) and (19), which in turn show the value of these variables would be if the product’s growth rate did not present variation in relation to time $t - 1$.

$$T_t (growth_{t-1}) = \hat{\alpha}_R + \hat{\beta}_R (growth_{t-1}) + \hat{\gamma}_R t + \hat{u}_t, \quad (18)$$
$$G_t (growth_{t-1}) = \hat{\alpha}_E + \hat{\beta}_E (growth_{t-1}) + \hat{\gamma}_E t + \hat{e}_t. \quad (19)$$

Thus, the difference between equations (18) and (19) consists of the cyclically adjusted fiscal balance, which, when differentiated, provides a measure for the fiscal impulse.

$$FIMF^{(2008)}_t = (\hat{\gamma}_R - \hat{\gamma}_E) + (\hat{u}_t - \hat{u}_{t-1}) - (\hat{e}_t - \hat{e}_{t-1}). \quad (20)$$

### 3.5. The Kalman Filter method

Another way of decomposing fiscal policy, to obtain its automatic component and its discretionary component, can be done considering that the government’s weight to the deviations of the product wrt its potential level varies over time. Therefore, the Kalman filter (Kim et al., 1999; Durbin & Koopman, 2012) is used. Considering that the fiscal policy consists of the variation of the government surplus, $B_t - B_{t-1} = \Delta B_t$, there is:

$$\Delta B_t = \rho_t + \varepsilon_t, \quad (21)$$
$$\rho_t = \beta_t \Delta gap_t, \quad (22)$$
$$\beta_t = \beta_{t-1} + \eta_t. \quad (23)$$

Equation (21) informs that fiscal policy is composed of two components, $\rho_t$ and $\varepsilon_t$. The $\rho_t$ component is a function of changes in the economic cycle (represented by the variation in the output gap, $\Delta gap_t$), as described in equation (22). The regression residues follow a normal distribution and are identical and normally distributed, that is, $\varepsilon_t \sim (0, \sigma^2_\varepsilon)$.

Unlike the OECD, IMF (2006), and IMF (2008) methodologies, here the impact of the economic cycle on fiscal policy is not constant; that is, the $\beta_t$ of equation (23) is time-varying. The underlying intuition is that the tax authority can change the weight given to fluctuations in the output gap over time.
4. Threshold VAR and Nonlinear Impulse Response Functions

The threshold vector autoregression (TVAR\textsuperscript{2}) methodology is a vector autoregression extension that allows dealing with nonlinear relationships. Balke (2000) noted that TVAR is a relatively intuitive and straightforward to capturing nonlinearities generated, for instance, by changes in regimes and asymmetries. A TVAR model with two regimes can be represented as follows:

\[ Y_t = (D^{(1)} + B^{(1)}(L)Y_{t-1}) I_t + (D^{(2)} + B^{(2)}(L)Y_{t-1}) (1 - I_t) + e_t, \]  
(24)

where \( Y_t \) is the vector of endogenous variables, \( I_t \) it is an indicator function that assumes the value 1, when the threshold variable \( c_t \), with \( d \) lags is less than the critical threshold value \( \tau \), and 0, otherwise. The parameter \( d \) is known as the delay parameter. Algebraically we have:

\[ I_t = \begin{cases} 
1, & \text{when } c_{t-d} < \tau \\
0, & \text{when } c_{t-d} > \tau
\end{cases} \]  
(25)

Thus, the model identifies two distinct regimes based on the values of \( c_{t-d} \) and \( \tau \).

The equation (24) can present a nonlinear path throughout the autoregressive system’s complete trajectory. However, by dividing this trajectory into two parts (that is, where it is less than the threshold value and where it is greater than the threshold value), the system has a linear behavior.

Tong (1978) noted there is a possibility that the system space is composed of at least two subspaces. Although such a system is linear in all segments, it will operate in a nonlinear manner if you consider the space as a whole. In autoregressive modeling with threshold effect (TAR), a threshold variable is defined to capture the system’s movement from one space to another, see Tsay (1989).

The asymmetry of the model described by equations (24) and (25), which is captured by the threshold variable, allows the constants vector to switch between regimes.

The threshold variable \( c_t \) can be modeled into the \( Y_t \) vector, allowing the regime change to be endogenously determined by the system. Since the VAR considers all endogenous variables, shocks in any of the vector variables \( Y_t \) can, through their impact on the variable, induce a regime change.

4.1. Econometric Specification

We estimated six TVAR models. They formed by the (\( \Delta \text{gap}_t \)) product gap variation, by inflation (\( \pi_t \)), the variation in the nominal interest rate (\( \Delta i_t \)), and changes in the fiscal policy’s discretion and rule components, that is, the (\( if_t \)) fiscal impulse and the rule tax (\( rf_t \)).

In addition to the dataset, the cyclical and discretionary components of fiscal policy were in the estimations, as defined by the OECD, IMF (2006), and IMF (2008) methodologies, and by the Dutch versions and Kalman filter method (see section 3).

The TVAR model in equation (26) can be estimated as follow:

\[ X_t = \left( A_0^{(1)} + A_0^{(1)}(L)X_{t-1} \right) I_t + \left( A_0^{(2)} + A_1^{(2)}(L)X_{t-1} \right) (1 - I_t) + e_t, \]  
(26)

where \( X_t \) is the endogenous variables vector (\( \Delta \text{gap}_t, \pi_t, \Delta i_t, if_t, rf_t \)), \( A_0^{(s)} \) is the regime vector’s constants \( s = \{1, 2\} \), \( A^{(s)}(L) \) is the coefficients matrix, and \( e_t \) is the error vector, as follow:

\textsuperscript{2}Examples of vector autoregression analysis considering the threshold effect can be found in Afonso et al. (2018), Calza & Sousa (2005), Atanasova (2003), Balke (2000), Galbraith (1996), and McCallum (1991).
\[ X_t = \begin{bmatrix} \Delta \text{gap}_t \\ \pi_t \\ \Delta \text{n}_t \\ i_t \\ r_t \end{bmatrix}, \quad A_0^{(s)} = \begin{bmatrix} A_{10}^{(s)} \\ A_{20}^{(s)} \\ A_{30}^{(s)} \\ A_{40}^{(s)} \\ A_{50}^{(s)} \end{bmatrix}, \quad A^{(s)}(L) = \begin{bmatrix} A_{11}(L) & A_{12}(L) & \cdots & A_{15}(L) \\ A_{21}(L) & A_{22}(L) & \cdots & A_{25}(L) \\ \vdots & \vdots & \ddots & \vdots \\ A_{31}(L) & A_{32}(L) & \cdots & A_{35}(L) \end{bmatrix}, \quad e_t = \begin{bmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \\ e_{4t} \\ e_{5t} \end{bmatrix}. \]

The indicator function \( I_t \) takes is 1 when the economy is under a stress regime in the financial markets and 0, otherwise. \( I_t \) is similar to equation (25):

\[ I_t = \begin{cases} 1, & \text{when } f s i_{t-d} > \tau \\ 0, & \text{when } f s i_{t-d} \leq \tau \end{cases} \]

4.2. Nonlinear impulse response functions

Once the estimation of the TVAR is accomplished, the next step consists of analyzing the impulse response functions. In standard linear VARs, the response to a shock is computed assuming that a shock only hits the economy at a particular point in time but neither before nor during the forecasting horizon. Linear VARs are thus history-independent, and reactions to shocks are strictly proportional to the shock itself. However, these convenient properties do not hold within the class of nonlinear models, so Koop et al. (1996) developed a computation of Generalized Impulse Response Functions (GIRF).

In a threshold VARs, the reaction of an endogenous variable to a shock depends on the history, the state of the economy, the size of the shock under analysis at time 0, and the size and the sign of all the shocks hitting the economy within the period of interest. The GIRFs approach relies on the simulation of data depending on which regime the system is in at the time the shock hits the economy (the history \( \Omega_{t-1} \) up to point \( t \)). The advantage of GIRFs is not only that it allows for the analysis of regime-dependent responses, but also that effects of shocks of different sizes and directions can be analyzed. Due to this history- and shock-dependence, GIRFs lend themselves as an appropriate framework to explore the above-mentioned dimensions of nonlinearity such as regime-dependencies, asymmetries (positive vs. negative shocks), and shock nonlinearity (small vs. large shocks).

\[ \text{GIRF} = E [X_{t+m} | \varepsilon_t, \varepsilon_{t+1} = 0, \ldots, \varepsilon_{t+m} = 0, \Omega_{t-1}] - E [X_{t+m} | \varepsilon_t = 0, \varepsilon_{t+1} = 0, \ldots, \varepsilon_{t+m} = 0, \Omega_{t-1}], \]

where \( X_{t+m} \) is a vector of variables at horizon \( k \), \( \Omega_{t-1} \) is the information set available before the time of shock \( t \). This implies that there is no restriction regarding the symmetry of the shocks in terms of their sizes because the effects of a \( \varepsilon_t \) shock depend on the magnitude of the current and subsequent shocks. Moreover, in the high stress regime, the size of the fiscal shock matters since a small shock is less likely to induce a change in the regime. Likewise, the impulse responses depend also on the entire history of the variables that affect the persistence of the different regimes. Therefore, to get complete information about the dynamics of the model, the impulse responses have to be simulated for various sizes and the signs of the shocks. The algorithm proceeds as follows.

The general idea is to simulate the model for any possible starting point over the time horizon of interest by feeding the system with bootstrapped shocks and repeating the exercise by adding a new shock of a specific size (1 or 2 times the standard deviation of the fundamental shock in the linear model). The procedure is done hundreds of times with a newly generated series of bootstrapped residuals. Finally, the responses to shocks specific to a particular regime are recovered by averaging the simulation results.
5. Data and Empirical Results

5.1. Data

We use monthly time series data for the period between February 2010 throughout November 2020. We obtained most of the series through the Time Series Management System of the Central Bank of Brazil (BACEN)\(^3\). The variables and their respective sources are specified below:

- **Domestic product (y):** we use the gross domestic product from the Central Bank (BACEN code: 4380).
- **Primary surplus (B):** represented by the primary result of the central government (in R$ million), as availability by the National Treasury of Brazil\(^4\).
- **Government spending (G):** equivalent to the total federal government expenditure (in R$ million)(BACEN code: 7547).
- **Government revenue (T):** consists of total federal government revenue (in R$ million)(BACEN code: 7544).
- **Domestic interest rate (i):** represented by the annualized Over-Selic rate accumulated in the month, released by the Central Bank (BACEN code: 4189).
- **Inflation rate (π):** represented by the national broad consumer price index (IPCA), measured in monthly variation and calculated by The Brazilian Institute of Geography and Statistics (BACEN code: 433).
- **Financial Stress Index (FSI):** time series from January 2010 to December 2020, calculated by the authors.
- **Ibovespa (IBOV):** measures the performance of the domestic capital market.
- **The Financials Index (IFNC):** is compiled as a weighted average of a theoretical portfolio of stocks: measures companies’ performance in financial sector.
- **The (EMBI+):** measured in base points and released by JPMorgan.
- **Exchange rate average quotation of the US dollar (sale) published by the Central Bank (BACEN code: 3698).**
- **International reserves consist of international funds under the liquidity concept (in US$ million), published by the Central Bank (BACEN code: 3546).**

5.2. Empirical Findings

We present the results of the benchmark TVAR model (henceforth mainstream) and five TVAR models that include the fiscal impulse methods - OECD, IMF (2006), Dutch, IMF (2008), and Kalman filter. These methods are described in Section 3. Our results are from 2000 February through November 2020, time interval that includes data related to COVID-19. Table 1 presents statistics on the dataset and Figure 1 presents their path over time, respectively. In the Financial Stress Index, values above zero are considered High Stress Regime, and below zero are considered Low Stress Regime. According to the threshold variable, we have 59.3% of observations in Low Stress Regime and 40.7% in High Stress Regime.

We tested the presence of nonlinearities in the six models defined in the previous section. These results are reported in Table 2. The Maximum likelihood Ratio (LR) test suggests the existence of nonlinearities in all tested cases, according to the p-values. According to the Bayesian information (BIC) criterion, the threshold variable lag and the lags included in the models was one. Given that indication, we estimated the model to obtain the GIRFs and their associated confidence intervals.

\(^3\)https://www3.bcb.gov.br/sgspub
Figure 1: Main Time Series (2000 - 2020)

Note: This figure shows the main time series used from February 2000 through November 2020. In the Financial Stress Index, values above zero are considered High Stress Regime, and below zero are regarded as Low Stress Regime. Shaded ranges are relative to FSI periods above zero. In these cases, we consider High Stress Regime or economic downturn. One can see nine periods of financial stress in which the last one was due to COVID-19.

Table 1: Stationarity Tests

<table>
<thead>
<tr>
<th>Time Series</th>
<th>ADF</th>
<th>KPSS (4L)</th>
<th>KPSS (12L)</th>
<th>PP (4L)</th>
<th>PP (12L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Gap</td>
<td>-4.449</td>
<td>0.048</td>
<td>0.036</td>
<td>-5.987</td>
<td>-5.872</td>
</tr>
<tr>
<td>IPCA</td>
<td>-5.601</td>
<td>0.444</td>
<td>0.321</td>
<td>-7.670</td>
<td>-7.474</td>
</tr>
<tr>
<td>SELIC</td>
<td>-5.764</td>
<td>0.064</td>
<td>0.066</td>
<td>-5.445</td>
<td>-4.448</td>
</tr>
<tr>
<td>Balance</td>
<td>-4.357</td>
<td>0.445</td>
<td>0.383</td>
<td>-9.579</td>
<td>-9.502</td>
</tr>
<tr>
<td>FSI</td>
<td>-3.173</td>
<td>1.233</td>
<td>0.639</td>
<td>-3.499</td>
<td>-3.035</td>
</tr>
<tr>
<td>Impulse (OECD)</td>
<td>-4.035</td>
<td>0.398</td>
<td>0.338</td>
<td>-9.819</td>
<td>-9.869</td>
</tr>
<tr>
<td>Impulse (IMF, 2006)</td>
<td>-2.697</td>
<td>0.520</td>
<td>0.421</td>
<td>-9.628</td>
<td>-9.755</td>
</tr>
<tr>
<td>Impulse Dutch</td>
<td>-4.404</td>
<td>0.422</td>
<td>0.341</td>
<td>-15.33</td>
<td>-15.52</td>
</tr>
<tr>
<td>Impulse IMF (2008)</td>
<td>-3.431</td>
<td>0.376</td>
<td>0.335</td>
<td>-12.47</td>
<td>-12.55</td>
</tr>
<tr>
<td>Impulse Kalman</td>
<td>-5.492</td>
<td>0.281</td>
<td>0.293</td>
<td>-17.11</td>
<td>-17.17</td>
</tr>
</tbody>
</table>

Note: This table reports the stationarity tests of time series used in our models until now. The tests are Augmented Dickey–Fuller test (ADF), Kwiatkowski–Phillips–Schmidt–Shin tests (KPSS), and Phillips-Perron tests (PP). All entries are least 90% of statistical significance. The variables IPCA, SELIC, Balance, and FSI represent the inflation rate, the realized interest rate, the primary surplus, and the Financial Stress Index, respectively. The Output gap, interest rate, and Balance are in first difference.
Table 2: TVAR Lag Selection and LR Linearity Tests

Panel A: TVAR Lag Selection

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2967.48</td>
<td>-3854.63</td>
<td>-5397.54</td>
<td>-3520.83</td>
<td>-3717.31</td>
<td>-3432.98</td>
</tr>
<tr>
<td>2</td>
<td>2805.52</td>
<td>-3596.53</td>
<td>-5139.86</td>
<td>-3274.91</td>
<td>-3453.29</td>
<td>-3190.22</td>
</tr>
<tr>
<td>3</td>
<td>2631.22</td>
<td>-3326.57</td>
<td>-4869.88</td>
<td>-3025.66</td>
<td>-3184.16</td>
<td>-2932.60</td>
</tr>
<tr>
<td>4</td>
<td>2421.30</td>
<td>-3038.85</td>
<td>-4568.23</td>
<td>-2747.67</td>
<td>-2900.44</td>
<td>-2668.71</td>
</tr>
</tbody>
</table>

Panel B: LR Linearity Tests

<table>
<thead>
<tr>
<th>LR Test</th>
<th>47.525</th>
<th>60.623</th>
<th>51.970</th>
<th>86.080</th>
<th>57.418</th>
<th>56.685</th>
</tr>
</thead>
<tbody>
<tr>
<td>p-value</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note: Panel (A) reports the TVAR lag selection based on Bayesian information criterion (BIC), in which bold entries represent the chosen model. Panel (B) reports LR Linearity Tests. The null hypothesis is of model linearity.

In Table 2 (Panel A), we present results of Bayesian information criteria to select the TVAR lags. Also, a formal test was performed to confirm the nonlinearity of fiscal and monetary responses. The LR test shown in Table 2 (Panel B) indicated that modelling with regime-switching is the most appropriate, as the null hypothesis of linearity was rejected. This result may justify the use of the TVAR model.

To clarify the possible policy sets, we have summarized them in Table 3. The fiscal (impulse) rule is the expansion or contraction of government spending that (not) depends on the economic cycle. During growth (downturn) periods, the government should act countercyclically by adopting a contractionary (expansionist) fiscal policy.

Table 3: Set of Possibles Regimes and Policies

<table>
<thead>
<tr>
<th>Regimes</th>
<th>Low Stress (0) / Growth</th>
<th>High Stress (1) / Downturn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policies</td>
<td>Countercyclical</td>
<td>Procyclical</td>
</tr>
<tr>
<td></td>
<td>Countercyclical</td>
<td>Procyclical</td>
</tr>
<tr>
<td>Expected</td>
<td>Contractionary</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Expansionary</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nonconventional</td>
<td>-</td>
<td>Expansionary</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>Contractionary</td>
</tr>
</tbody>
</table>

Note: This table reports a summary of possible regimes and policies. It is expected from economic policy contractionary response in growth, and expansionary in downturn, representing a countercyclical policy. The opposite is applicable to procyclical policy.

In GIRFs results, a negative (positive) response to an output gap shock means that fiscal or monetary policy was countercyclical (procyclical). Also, the definition of asymmetry used here is related to the dependence of fiscal policy on the business cycle.

The first set of results was the TVAR mainstream, reported in Figure 2. The results of TVAR mainstream suggest that fiscal policy was countercyclical both in times of growth and in times of crisis. In the growth phase of the economic cycle (low-stress regime), the balance response to a shock in the output gap was statistically significant only at the beginning of the period. On the other hand, at times of downturn in the economic cycle (high-stress regime), the fiscal response to a shock in the gap had more statistical significance than the low-stress regime. Overall, this result is in line with what is expected from the countercyclical fiscal policy: expansionary in crises and contractionary in growth.

The monetary policy response to shocks in the output gap was countercyclical in both regimes. In
Figure 2: Generalized Impulse Response Functions of the TVAR Mainstream. Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

Note: This figure shows the generalized impulse response functions (GIRF) of the TVAR Mainstream. Confidence bands (95%) obtained from the empirical distribution of simulated GIRFs assuming normality. These results suggest the policies were countercyclical in all regimes.

the high financial stress regime, the monetary authority’s response was statistically significant in more periods than the low-stress regime, which had no significant periods. This set of results suggests that monetary policy was expansionary at the time of financial stress.

The OECD TVAR results are reported in Figure 3. In the TVAR OECD model, the results show that the fiscal impulse was countercyclical only in the low-stress regime. That is, in periods of economic growth, the impulse response was contractionary. On the other hand, monetary policy was countercyclical only in the high-stress regime. In other words, it was expansionary in times of crisis.

Despite the countercyclical responses, the confidence intervals contain zero, so the results do not present statistical significance. In summary, the results of the TVAR OECD model show, in part, what would be expected from monetary and fiscal policy.

The IMF (2006) results suggest a procyclical path to fiscal impulse - see Figure 4. From the point of view of fiscal impulse, the results are opposite to the results of the TVAR OECD. The results of the TVAR IMF method suggest that the fiscal impulse was procyclical in both regimes. In contrast, in the low-stress regime, which corresponds to the growth cycle phase, the fiscal impulse had more significant periods. Overall, this result reveals that the fiscal impulse was expansionary during the growth phase of the cycle. On the other hand, the fiscal impulse was contractionary in the contraction phase of the cycle but with less significant periods.

On the other hand, the fiscal rule was only significant in the economic contraction cycle, which shows the expansionary response in crises. Similarly, monetary policy had similar behavior. That is, it was expansionary in economic contraction cycles. Overall, this method suggests asymmetries in the direction of fiscal policy, where the fiscal impulse was procyclical in both phases of the cycle, and the fiscal rule was countercyclical only in the high financial stress regime.

The Dutch method results are presented in Figure 5. The TVAR Dutch method had similar results to the TVAR IMF (2006). However, the fiscal impulse responses were faster than the previous method, according to the confidence intervals. In general, monetary policy behaved similarly to the previous
Figure 3: Generalized Impulse Response Functions of the TVAR OECD.
Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

Note: This figure shows the generalized impulse response functions (GIRF) of the TVAR OECD. Confidence bands (95%) obtained from the empirical distribution of simulated GIRFs assuming normality. These results suggest the policies were countercyclical in all regimes. These results suggest the policies were countercyclical.

Figure 4: Generalized Impulse Response Functions of the TVAR IMF (2006).
Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

Note: This figure shows the generalized impulse response functions (GIRF) of the TVAR IMF (2006). Confidence bands (95%) obtained from the empirical distribution of simulated GIRFs assuming normality. These results suggest the impulse fiscal response was procyclical in both regimes, while the fiscal rule and monetary responses were countercyclical.
method. That is, the monetary authority acted in an expansionary manner during the contraction phases of the cycle.

Figure 5: Generalized Impulse Response Functions of the TVAR Dutch. Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

The main result of this method comes from the fiscal impulse that was procyclical in both regimes. In the low-stress regime, which corresponds to the growth phase of the cycle, the impulse had more significant periods. Therefore, the fiscal impulse was expansionary in the growth phase and contractionary in the crisis phase.

The IMF (2008) method are presented in Figure 6. In line with the OECD method, the fiscal policy results in the IMF(2008) method was countercyclical. In both regimes, the responses were countercyclical. In periods of growth (downturn), the fiscal authority adopted a contractionary (expansionist) policy. The difference between this method and the OECD method is that it had significant periods in the fiscal rule in the low-stress regime. Overall, the results point to a countercyclical behavior but with slight changes in speed and duration.

The Kalman filter method are presented and in Figure 7. Finally, the fiscal impulse showed a significant result in the low-stress regime and the SELIC response to a gap shock in the high-stress regime in the Kalman filter method. In this model, the results show that there were procyclical responses to the fiscal impulse. Concerning the rule, a significant result emerged in the low-stress regime. Therefore, the fiscal authority acted in a countercyclical manner in the growth phase of the cycle. In Table 4, we summarized all the impulse-response results.

In general, the results suggest the fiscal impulse was mostly procyclical in the low-stress regime, while the fiscal rule was countercyclical. In other words, these results suggest that in the growth phases, fiscal policy was expansionary in impulse but contractionary as a rule. Still, in this regime, monetary policy did not show significant results.

In the high-stress regime, the monetary authority was countercyclical in all models. The fiscal impulse was procyclical in two of the five models, while the fiscal rule was countercyclical in two of the five models. In this regime, the models showed more non-significant results. However, the procyclical result was greater than the countercyclical concerning the impulse. Therefore, fiscal policy was contractionary.
Figure 6: Generalized Impulse Response Functions of the TVAR IMF (2008).
Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

Note: This figure shows the generalized impulse response functions (GIRF) of the TVAR IMF (2008). Confidence bands (95%) obtained from the empirical distribution of simulated GIRFs assuming normality. These results suggest the policies were countercyclical.

Figure 7: Generalized Impulse Response Functions of the TVAR Kalman.
Response of the Fiscal Balance and Interest Rate (SELIC) to One Unit Shock of Output Gap

Note: This figure shows the generalized impulse response functions (GIRF) of the TVAR Kalman. Confidence bands (95%) obtained from the empirical distribution of simulated GIRFs assuming normality. These results suggest the impulse fiscal response was procyclical in both regimes, while the fiscal rule and monetary responses were countercyclical.
Table 4: Summary of Generalized Impulse Response Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Regime</th>
<th>Low Stress (0)</th>
<th>High Stress (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Impulse</td>
<td>Rule</td>
</tr>
<tr>
<td>OECD</td>
<td>Counter</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IMF (2006)</td>
<td>Pro</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dutch</td>
<td>Counter</td>
<td>-</td>
<td>Counter</td>
</tr>
<tr>
<td>IMF (2008)</td>
<td>Counter</td>
<td>-</td>
<td>Counter</td>
</tr>
<tr>
<td>Kalman</td>
<td>Pro</td>
<td>Counter</td>
<td>-</td>
</tr>
<tr>
<td>Procyclical</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Countercyclical</td>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>No Significance</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: This table reports a summary of Generalized Impulse Response results of all models with fiscal impulse. Low Stress Regime (0) means low financial stress and High Stress Regime (1) means high financial stress, both are related to economic growth and crisis, respectively.

in impulse and expansionary as a rule in crisis phases. Monetary policy, in turn, acted in an expansionary manner. It is noteworthy that each model responds with different reaction speeds and durations.

6. Concluding Remarks

Our research aims to analyze the monetary and fiscal responses in periods of financial stress using the Financial Stress Index (FSI) as a threshold variable to identify two states of nature: low stress regime (economic growth) and high stress regime (economic downturn).

The empirical results come from the benchmark threshold-VAR (TVAR) model and five TVAR models that include the fiscal impulse methods - OECD, IMF (2006), Dutch, IMF (2008), and Kalman filter. These methods are described in Section 3. Our results are from 2000 February through November 2020, which includes data of the ongoing economic disruption caused by COVID-19, marked by unprecedented and sharp fiscal interventions designed to attenuate the economic downturn.

The main results suggest that in the growth phases, fiscal policy was expansionary in impulse but contractionary as a rule. In the downturn cycle, the monetary authority was countercyclical in all models. The fiscal impulse was procyclical in two of the five models, while the fiscal rule was countercyclical in two of the five models. In this regime, the models showed more non-significant results. This analysis is necessary since growth and crisis periods can lead to asymmetric responses of policymakers. Overall, the evidence suggests that the government had a procyclical record.

References


Baum, Anja, & Koester, Gerrit. 2011. The impact of fiscal policy on economic activity over the business cycle-evidence from a threshold VAR analysis.


Calza, Alessandro, & Sousa, João. 2005. Output and inflation responses to credit shocks: are there threshold effects in the euro area? *Available at SSRN 704555*.


GiroUARD, Nathalie, & André, Christophe. 2006. Measuring cyclically-adjusted budget balances for OECD countries. *Available at SSRN 2005002*.


Appendix A. Algorithm for Generalized Impulse Response Function

We follow Baum & Koester (2011) algorithm to estimate the generalized impulse response function (GIRF) specific to each regime (High Stress and Low Stress) with $R$ observations.

1. pick a history $\Omega^r_{t-1}$;
2. pick a sequence of shocks by bootstrapping the residuals of the TVAR taking into account the different variance-covariance matrix characterizing each regime;
3. given the history $\Omega^r_{t-1}$, the estimated TVAR coefficients and bootstrapped residuals, simulate the evolution of the model over the period of interest;
4. repeat the previous exercise by adding a new shock at time 0;
5. repeat $B$ times the steps from 2 to 4 ;
6. compute the average difference between the shocked path on the non-shocked one;
7. repeat steps from 1 to 6 over all the possible starting points;
8. compute the average GIRF associated with a particular regime with $R$ observations as:

$$y_{t+m}(\varepsilon_0) = \frac{1}{R} \sum_{r=1}^{R} \frac{y_{t+m}(\Omega^r_{t-1} | \varepsilon_0, E^*_{t+m}) - y_{t+m}(\Omega^r_{t-1} | \varepsilon^*_t, E^*_{t+m})}{B}$$

Once GIRFs are obtained, we apply the algorithm in Schmidt (2013) to compute the related confidence bands:

1. Generate artificial data recursively using the coefficients and residuals from the TVAR;
2. Use recursive data to recalculate TVAR coefficients as well as residuals;
3. Use the empirical data and the coefficients and residuals in 2 and calculate the GIRFs as described above;
4. Repeat steps 1-3 $S$ times to generate an empirical GIRF distribution and obtain confidence intervals for the desired significance.

We used $B=500$, $R=500$, and $S=1000$. All of the calculations were carried out using R programming language and package \texttt{tsDyn}, see (R Core Team, 2021; Fabio Di Narzo \textit{et al.}, 2009).