Economia Aplicada, v. 19, n. 3, 2015, pp. 429-454

THE TIME-(IN)VARIANT INTERPLAY OF GOVERNMENT SPENDING AND PRIVATE CONSUMPTION IN BRAZIL

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Abstract

This paper analyzes the relationship between government spending and private consumption in Brazil through an application of a VAR with time-varying parameters and stochastic volatility, estimated with Bayesian simulation over the 1996:Q1–2014:Q2 period. The findings reveal that fiscal policy is indeed effective in stimulating GDP and private consumption, which characterizes the presence of positive Keynesian multipliers. However, these positive effects are only sustained on the short-run. Also, stochastic volatility seems to have decreased from 2000 onwards, suggesting that Brazil has steadily improved its macroeconomic stability after the adoption of the inflation-targeting framework and the Fiscal Responsibility Law.

Keywords: Government Spending; Private Consumption; TVP-VAR.

Resumo

O presente estudo analisa a relação entre gasto público e consumo privado no Brasil através de um modelo VAR com parâmetros variantes no tempo e volatilidade estocástica, estimado com simulação bayesiana para o período 1996:T1–2014:T2. Nossos resultados revelam que a política fiscal é de fato efetiva para estimular o PIB e o consumo privado, caracterizando a presença de multiplicadores keynesianos positivos. Porém, tais efeitos positivos apenas são sustentados no curtíssimo-prazo. Além disso, a volatilidade estocástica se reduziu a partir de 2000, revelando um ambiente macroeconômico mais sólido após a adoção do regime de metas para inflação e da Lei de Responsabilidade Fiscal.

Palavras-chave: Gasto Público; Consumo Privado; TVP-VAR.

JEL classification: E62, E32, C32, D78

DOI: http://dx.doi.org/10.1590/1413-8050/ea125573

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Recebido em 24 de outubro de 2013 . Aceito em 31 de março de 2015.

1 Introduction

The depth of the recent global recession has rekindled the debate on the role of discretionary fiscal policy. In order to mitigate the potential economic downturn and ensure the resilience of the financial system, governments around the world have designed unprecedented fiscal stimulus packages. However, due to controversial predictions of neoclassical and Keynesian oriented models, there remains no macroeconomic consensus on the interplay of government spending shocks and private consumption.

Since the seminal paper by Barro (1974), which introduced the concept of *Ricardian Equivalence*, there has been a resurgence in the debate on the possible non-Keynesian effects of fiscal policies. By embodying this feature, the future tax burden of present fiscal stimulus restrains the Keynesian effects on private consumption (Mankiw & Summers 1984, Blanchard 1985). Moreover, models of neoclassical tradition argue that the intertemporal substitution effects on labor supply are not strong enough to offset the negative wealth effects driven by an increase on government spending (see e.g. Barro & King (1984) and Baxter & King (1993)).

By amending the Real Business Cycles (RBC) framework to allow for monopolistic competition and nominal rigidities, macroeconomic modeling departed from price flexibility in order to achieve short-run non-neutrality of money. Regarding the effectiveness of fiscal policy to stimulate private consumption, these so called New Keynesian models formerly presented unexpected non-Keynesian responses (Smets & Wouters 2003, Linnemann & Schabert 2003, Cogan et al. 2010, Cwik & Wieland 2011).

However, empirical evidences - mainly based on vector autoregressions (VAR) — depicted another conclusion. For instance, with a structural VAR approach, Blanchard & Perotti (2002) obtained positive public spending multipliers for output and private consumption with US postwar data. Using the same estimation technique as the latter, Perotti (2002) verified positive multipliers for United Kingdom, Germany, Canada and Australia, despite their downward trend over time. Furthermore, many other papers have used similar approaches[1], including Fatás & Mihov (2001), Ramey (2008), Mountford & Uhlig (2009), Fisher & Peters (2009) and Ilzetzki et al. (2013).

Following Mankiw (2000)[2], Galí et al. (2007) proposed a new feature to the New Keynesian framework in an attempt to counter these theoretical and empirical divergences. By introducing the coexistence of non-Ricardian (*rule-of-thumb*) and intertemporal optimizing households, the authors generated standard Keynesian effects of government spending expansions for the US economy, arguing that the usual negative wealth effect was damped. The studies of Linnemann (2006), Ravn et al. (2006) and Forni et al. (2009) supported the latter results. On the other hand, one should not generalize these findings. Coenen & Straub (2005) showed that the presence of positive public spending multipliers for private consumption is directly related to the share of

[1] Despite the choice of a structural VAR framework, the identification restrictions imposed differ. For instance, Fatás & Mihov (2001) applied the standard recursive approach (Cholesky decomposition) introduced by Sims (1980), while Mountford & Uhlig (2009) used the sign-restrictions scheme. Besides, Blanchard & Perotti (2002) and Perotti (2002) assigned structural restrictions based on fiscal institutional information.

[2] Mankiw (2000) pointed out that non-Ricardian households were a crucial element in order to explain heterogeneity in consumer behavior and, therefore, enhance the transmission channels of fiscal policies in Neoclassical and overlapping generation models.

non-Ricardian households in the population. Moreover, Ratto et al. (2009) and Furceri & Mourougane (2010) highlighted labor market adjustment costs and financial market stress as restrictions to the expected Keynesian effects of fiscal policies, respectively.

Regarding the Brazilian economy, empirical evidences are ambiguous as well as scarce. Silva & Cândido Júnior (2009) evaluated the 1970–2002 period through an application of cointegration in VAR models, concluding that government spending crowds out private consumption in the long-run even though positive government spending shocks initially increase private consumption. Thus, these results advocate against the effectiveness of discretionary fiscal policy as a countercyclical measure since its positive effects would be restricted to the short-run. Silva & Portugal (2010) corroborated the latter non-Keynesian effects of fiscal policy for Brazil through a DSGE model with non-Ricardian and intertemporal optimizing households. The authors argued that the share of Brazilian liquidity constrained households is rather low (nearly 10%), hence unable to offset the negative wealth effect from a government spending shock.

On the other hand, Mendonça et al. (2009) presented crowding in effects of government spending on private consumption over a 1995–2007 sample. Furthermore, while evaluating the period after the introduction of the Real Plan (1994–2012) with VAR models, Peres (2012) also identified standard positive Keynesian responses for the interplay of government spending and private consumption. By analyzing developed and developing economies through a panel error-correction model both uniequational (P-ECM) and multiequational (P-VECM) for 48 countries, Soave & Sakurai (2012) also presented empirical evidences of crowding in effects on consumption in the long-run, especially for the developing ones (including Brazil).

However, the fiscal transmission channels are likely subject to changes over time. Empirical support for the latter proposition comes, for instance, from the study of Kirchner et al. (2010), which showed that the short run government spending multipliers in the Euro area increased from the early 1980s until the late 1980s, but presented a decreasing trend thereafter. Moreover, Pereira & Lopes (2010) argue that fiscal policy has lost its capacity to stimulate output in the US economy from 1965 to 2009, despite positive multipliers. Yet, Brazilian literature has struggled so far to provide results accounting for potential time heterogeneity patterns. To the best of my knowledge, the present paper is the first attempt of evaluating the time-varying interplay of government spending and private consumption for Brazil.

Besides the reforms implemented by the Real Plan in 1994 and the adoption of a floating exchange rate regime along with an inflation-targeting framework in 1999, the establishment of the Brazilian Fiscal Responsibility Law in 2000 as well as the presence of fiscal stimulus packages in face of the 2008 financial crisis might have contributed to shifts in the Brazilian fiscal dynamics. Additionally, given the outburst of consumer credit growth rates in Brazil since 2005 (Freitas 2009, Hansen & Sulla 2013), this recent transition of the share of non-Ricardian households might have also affected the effectiveness of fiscal policy throughout the sample[3].

[3]While assessing these effects in developed and developing countries under the hypothesis of optimizing and non-optimizing agents, Soave & Sakurai (2012) argued that the share of liquidity constrained households has fluctuated over time and indeed is essential when explaining the

In light of the facts formerly mentioned, a four-variable time-varying parameter (TVP) VAR model is estimated for Brazil, following closely Kirchner et al. (2010). The model includes government spending, GDP, short-term interest rate and private consumption over the period 1996:Q1-2014:Q2. Since structural changes cannot be easily identified prior to estimation and might also be part of a long process, the TVP-VAR stands as a method capable of capturing these time-varying effects in a robust and flexible manner (Nakajima 2011). By allowing for time-variation in the autoregressive parameters and stochastic volatility, it is possible to deal with potential non-linearity during estimation. As the parameters follow a first-order random walk process, the method is able to capture both temporary and permanent shifts. In comparison to Markov-switching models, the random walk specification allows for smooth shifts in contrast to discrete breaks, being more suitable for describing changes in private sector behavior or the learning dynamics of both private agents and policy makers (Primiceri 2005). Moreover, given the potential effects of exogenous shocks over the volatility of macroeconomic aggregates, ignoring conditional heteroskedasticity might lead to spurious movements in time-varying variables and inaccurate inference (Hamilton 2010). Thus, the stochastic volatility specification is included to take this issue into account.

The findings reveal that fiscal policy is indeed effective in stimulating GDP and private consumption, which characterizes the presence of positive Keynesian multipliers. Even though the overall response of the variables to a positive government spending shock seems to be rather similar throughout the sample period, the time-varying techniques indicate some increasing persistence of its effectiveness. Besides, the stochastic volatility decrease from 2000 onwards suggests that Brazil has steadily improved its macroeconomic stability after the adoption of the inflation-targeting framework and the Fiscal Responsibility Law.

The remainder of this paper is organized as follows. Section 2 introduces the vector autoregression (VAR) models and how *time-varying* features were implemented on these models, in order to capture potential changes on macroeconomic behavior over time. Furthermore, it describes the data set and the Bayesian estimation procedure. Section 3 presents the empirical results, highlighting the effectiveness of government spending shocks. A time-invariant comparison through an application of a Bayesian VAR as well as a prior sensitivity analysis are also performed. Finally, section 4 presents the conclusion.

2 Econometric Methodology

2.1 Time-Varying Parameter (TVP) Bayesian Vector Autoregression Model with Stochastic Volatility (SV)

Since Sims (1980), the *vector autoregression* (VAR) *model* has played a prominent role on macroeconometric analysis. Considered a flexible and easy tool for dealing with multivariate time series, it generally consists in a multi-

interaction of government spending and private consumption. Yet, Tagkalakis (2008) emphasized that government spending multipliers on private consumption and real output depend on the stage of the business cycle, granted that recessions tend to raise the effectiveness of discretionary fiscal policy since the fraction of non-Ricardian individuals will consume the extra income generated by a government spending increase.

equation system describing the economic dynamics. A basic structural VAR model can be defined as:

$$Ay_t = F_1 y_{t-1} + \cdots + F_s y_{t-s} + u_t, \quad t = s+1, \ldots, n, \tag{1}$$

where y_t is a $k \times 1$ vector of observed variables; A is a $k \times k$ matrix of contemporaneous relationships; $F_1, \ldots, F_n$ is a $k \times k$ matrix of coefficients; and $u_t \sim N(0, \Sigma\Sigma)$ is a $k \times 1$ structural shock vector, with:

$$\Sigma = \begin{pmatrix} \sigma_1 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_k \end{pmatrix} \tag{2}$$

However, one cannot directly estimate Equation (1) since its structure allows A and F to show an infinite set of different values with exactly the same probability distribution, hence data alone cannot provide the true values of A and F. Therefore, by assuming that the simultaneous relations of the structural shock are identified by a recursive approach, which imposes A to be a lower-triangular matrix with the diagonal elements equal to one, the Equation (1) can be re-specified as a reduced form VAR model:

$$y_t = B_1 y_{t-1} + \cdots + B_s y_{t-s} + A^{-1}\Sigma\varepsilon_t, \quad \varepsilon_t \sim N(0, I_k), \tag{3}$$

where $B_i \equiv A^{-1}F_i$, for $i = 1, \ldots, s$ and:

$$A = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ a_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1} & \cdots & a_{k,k-1} & 1 \end{pmatrix} \tag{4}$$

Defining B as a stacked row of $B_1, \ldots, B_s$ and $X_t \equiv I_k \otimes (y'_{t-1}, \ldots, y'_{t-s})$, where $\otimes$ represents the Kronecker product, the reduced form of Equation (3) can be rewritten as:

$$y_t = X_t\beta + A^{-1}\Sigma\varepsilon_t, \tag{5}$$

Although the parameters β, A and Σ in Equation (5) are time-invariant, these can re-specified to account for time-varying analysis as well. Following Primiceri (2005) and Nakajima (2011), one can rewrite Equation (5) as:

$$y_t = X_t\beta_t + A_t^{-1}\Sigma_t\varepsilon_t, \quad t = s+1, \ldots, n, \tag{6}$$

whose parameters are all time-varying[4]. Let $a_t = (a_{21}, a_{31}, a_{32}, a_{41}, \ldots, a_{k,k-1})'$ be a stacked vector of the lower-triangular elements in A_t and $h_t = (h_{1t}, \ldots, h_{kt})'$

[4]As discussed in Nakajima (2011), time-varying intercepts can also be incorporated in TVP-VAR models by defining $X_t \equiv I_k \otimes (1, y'_{t-1}, \ldots, y'_{t-s})$.

with $h_{jt} = \log \sigma_{jt}^2$, for $j = 1, \ldots, k$ and $t = s+1, \ldots, n$, the parameters in Equation (6) are assumed to follow drift less random walk processes[5], given by:

$$\beta_{t+1} = \beta_t + u_{\beta t}, \quad a_{t+1} = a_t + u_{at}, \quad h_{t+1} = h_t + u_{ht}, \tag{7}$$

$$\begin{pmatrix} \varepsilon_t \\ u_{\beta t} \\ u_{at} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right), \tag{8}$$

for $t = s+1, \ldots, n$, where I is the identity matrix of k dimensions, while Σ_β, Σ_a and Σ_h are positive definite matrices, whose elements are usually called the hyperparameters. As in Nakajima (2011), shocks are assumed uncorrelated among the time-varying parameters and the covariance matrices Σ_β, Σ_a and Σ_h are assumed to be diagonal[6]. Moreover, $\beta_{s+1} \sim N(\mu_{\beta_0}, \Sigma_{\beta_0})$, $a_{s+1} \sim N(\mu_{a_0}, \Sigma_{a_0})$ and $h_{s+1} \sim N(\mu_{h_0}, \Sigma_{h_0})$, which are the initial states of the time-varying parameters.

Since TVP-VAR models with stochastic volatility are non-linear non-Gaussian state-space representations, the Maximum Likelihood (ML) approach cannot provide reliable estimates for the parameters. Also, allowing for time-variation in the parameters of a VAR framework as well as in the error covariance matrix causes serious concerns about over-parameterization (Koop & Korobilis 2010). Therefore, the Bayesian approach using the Markov chain Monte Carlo (MCMC) method is by now fairly standard in dealing with this class of models (e.g. Primiceri (2005) and Nakajima (2011)).

By splitting up the original problem into a number of smaller steps, the Bayesian inference is able to deal with high-dimensional parameter space and potential non-linearities in the likelihood function. Under the assumption of a certain prior probability density, the MCMC algorithm is able to generate the joint posterior distribution of the parameters, given as:

$$p(\theta|y) = \frac{p(\theta)L(y|\theta)}{\int_\theta p(\theta)L(y|\theta)d\theta} \propto p(\theta)L(y|\theta) \tag{9}$$

where $y = \{y_t\}_{t=1}^n$; $\theta = \left\{\beta, a, h, \Sigma_\beta, \Sigma_a, \Sigma_h\right\}$; $p(\theta)$ is the prior density distribution; $p(\theta|y)$ is the posterior density distribution; and $L(y|\theta)$ is the likelihood function. In other words, given y, the MCMC simulation draws samples from $p(\theta|y)$ in order to achieve the values of θ. This drawing process can be described by the following MCMC algorithm[7]:

1. Initialize θ;
2. Sample $\beta \mid a, h, \Sigma_\beta$ and y;
3. Sample $\Sigma_\beta \mid \beta$;

[5] One should note that the volatility states (h_t) evolve as geometric random walks, hence depicting a TVP-VAR model with stochastic volatility (SV) as in Primiceri (2005). By including the time-varying stochastic volatility to the VAR estimation, one can prevent potential biases in the covariance matrix for the disturbances and in the autoregressive coefficients because of the misspecification of the dynamics of the parameters (Nakajima et al. 2009).

[6] Nakajima (2011) argues that the diagonal assumption for Σ_β, Σ_a and Σ_h does not affect sensitively the results when compared to the non-diagonal assumption.

[7] For technical details, see Nakajima et al. (2009).

4. Sample $a \mid \beta, h, \Sigma_a$ and y;
5. Sample $\Sigma_a \mid a$;
6. Sample $h \mid \beta, a, \Sigma_h$ and y;
7. Sample $\Sigma_h \mid h$;
8. Return to 2.

Regarding the choice of priors, this paper sets rather diffuse and uninformative priors, following the study of Nakajima (2011)[8]:

$$(\Sigma_\beta)_i^{-2} \sim G(25, 0.01I), \quad (\Sigma_a)_i^{-2} \sim G(4, 0.01), \quad (\Sigma_h)_i^{-2} \sim G(4, 0.01) \tag{10}$$

where $(\Sigma_\beta)_i^{-2}$, $(\Sigma_a)_i^{-2}$ and $(\Sigma_h)_i^{-2}$ represents the i-th diagonal element of the matrices and G is the Gamma distribution. In addition, flat priors were set to the initial states of the time-varying parameters, such that $\mu_{\beta_0} = \mu_{a_0} = \mu_{h_0} = 0$ and $\Sigma_{\beta_0} = \Sigma_{a_0} = \Sigma_{h_0} = 10 \times I$. Also, following the Akaike information criterion (AIC) and the Schwarz information criterion (SBC), applied to a time-invariant VAR, the TVP-VAR is estimated based on two lags[9].

As for the identification procedure, establishing the simultaneous relations of the structural shocks is not a trivial task. Following Kirchner et al. (2010), this paper resorts to a recursive identification framework for fiscal policy[10]. Based on the seminal work of Blanchard & Perotti (2002), the contemporaneous interactions between government spending and the macroeconomic environment can be completely assigned to the working of automatic stabilizers, hence discretionary fiscal policy would not respond within the same quarter to macroeconomic shocks due to political decision-lags. Government spending shocks are identified as predetermined in a system with output, interest rate and private consumption, being ordered first in a Cholesky-type variance-covariance decomposition scheme[11]. One should notice that the latter identification procedure is commonly adopted by the literature on fiscal policy (Perotti 2002, 2007, Caldara & Kamps 2008, Ramey 2008, Kirchner et al. 2010).

2.2 Data Description

In order to evaluate the time-variation and the potential effects of Brazilian fiscal policy, we use quarterly data from 1996:Q1 until 2014:Q2, which corresponds to the period after the introduction of the Real Plan (1994) and the adoption of the inflation-targeting regime (1999). Furthermore, by using quarterly data, we exclude the possibility of fiscal policy discretionary response to macroeconomic shocks within the quarter. The VAR specification includes

[8] In order to evaluate the robustness of the chosen priors, a sensitivity analysis discussion is carried out in Subsection 3.3.

[9] These results are available upon request from the author.

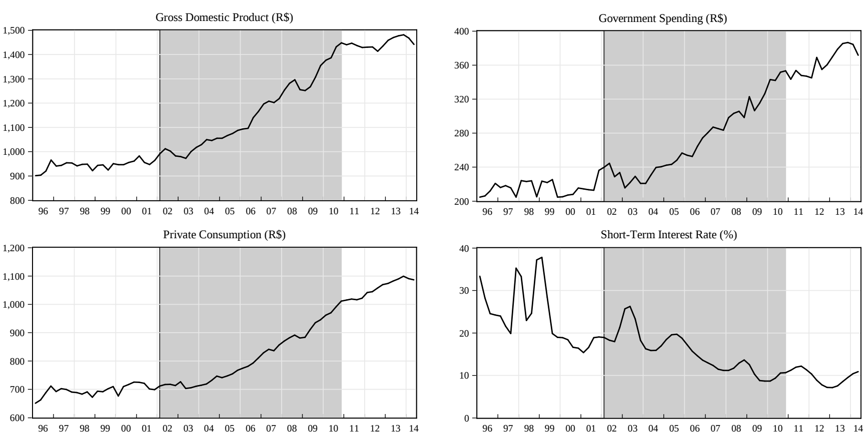
[10] Even though the TVP-VAR models allow for time-varying features, the identification scheme is assumed to be time-invariant over the sample.

[11] Although the present identification scheme can be arguable (as is often the case in a Cholesky ordering), the data frequency grants a sufficient degree of flexibility. Moreover, for the purposes of identifying just the dynamic effects of government spending shocks, it is not necessary to take into account the ordering of the other variables (Fatás & Mihov 2001, Blanchard & Perotti 2002, Ramey 2008, Kirchner et al. 2010, Bachmann & Sims 2011).

government spending (measured as government final consumption expenditure)[12], private consumption (measured as private final consumption expenditure), GDP (measured as factor prices) and short-term interest rate (measured as Brazilian Central Bank's overnight call rate). The time series were downloaded from the Brazilian Institute of Geography and Statistics (IBGE) and the Brazilian Central Bank (BCB).

Government spending, private consumption and GDP were first realized by the Extended National Consumer Price Index (IPCA), whose base is 1996:Q1, and then seasonally adjusted, applying the X-12-ARIMA method. Moreover, the latter data series enter the analysis in the form of their respective real *per capita*[13] values. The short-term interest rate is expressed in nominal, annual terms.

Figure 1 and Figure 2 present the Brazilian data used in the model specification. In general, the time series present contrasting patterns, which can be seen as a first indication that a time-varying parameter model might be the suitable choice. For instance, one can identify two seemingly distinctive sub-sample periods: from 1996 to the end of 2002, and from 2003 onwards.



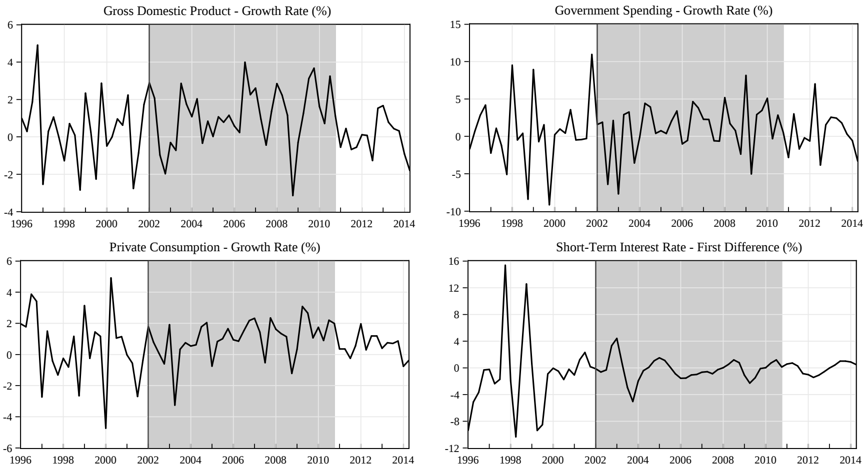
Notes: Shaded area corresponds to Luiz Inácio "Lula" da Silva 1st and 2nd terms as president; government spending (GS), private consumption (PC) and GDP are all expressed in real *per capita* terms and seasonally adjusted; short-term interest rate is measured in nominal, annual terms.
Sources: Brazilian Institute of Geography and Statistics (IBGE) and Brazilian Central Bank (BCB).

Figura 1: Brazilian Data (1996:Q1–2014:Q2)

Based on standard unit root tests, namely, the Augmented Dickey-Fuller (ADF) (Dickey & Fuller 1981) test, the Phillips-Perron (PP) (**?**) test and the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) (Kwiatkowski et al. 1992) test, the data series were found to be non-stationary in general, hence converted to their corresponding growth rate[14]. The test statistics and the specification for the deterministic terms are presented in Table (1).

[12] The government final consumption expenditure time series sums up expenditures from central administration agencies and decentralized entities (independent agencies, foundations and funds) at federal, state and municipal spheres. It also considers parastatal entities, such as the S System and Federal Councils.

[13] In order to achieve quarterly data for population, a cubic spline interpolation to the annual



Notes: Shaded area corresponds to Luiz Inácio "Lula" da Silva 1st and 2nd terms as president; government spending growth rate (gGS), private consumption growth rate (gPC) and GDP growth rate (gGDP) are all measured as the percent rate of increase in their respective real *per capita* values.
Sources: Compiled by the authors.

Figura 2: Brazilian Data - Growth Rates (1996:Q1–2014:Q2)

Tabela 1: Unit Root Tests

Data	Deterministic Terms	ADF	PP	KPSS
GS	Intercept	0.3970	0.2949	1.0782*
GS	Intercept, Trend	− 1.8527	− 2.0222	0.2692*
GDP	Intercept	− 0.1978	0.0981	1.0954*
GDP	Intercept, Trend	− 1.9091	− 1.7937	0.2429*
STIR	Intercept	− 2.6573**	− 2.4620	1.0225*
STIR	Intercept, Trend	− 3.6169**	− 3.7647**	0.0573
PC	Intercept	1.0470	0.1366	1.0599*
PC	Intercept, Trend	− 1.9418	− 1.6456	0.2796*
GS Growth	Intercept	−11.2337*	−12.3167*	0.1689
GDP Growth	Intercept	− 7.3389*	− 7.3007*	0.1333
ΔSTIR	Intercept	− 5.5441*	−10.4223*	0.3407
PC Growth	Intercept	− 9.1748*	− 9.1758*	0.2135

*, ** and *** indicate that the null hypothesis is rejected at the 1%, 5% and 10% significance level.
For the ADF test, the lag length selection was based on the Schwarz info criterion. The Bartlett kernel and the Newey-West Bandwidth were applied to the spectral estimation of PP and KPSS tests. The terms "GS", "STIR" and "PC" refer to government spending, short-term interest rate and private consumption, respectively.

3 Estimation Results

In order to compute the posterior estimates, we draw $M = 50,000$ samples after the initial 5,000 samples were discarded in the burn-in period. Figure (3) presents the sample autocorrelation function, the sample paths and the posterior densities for selected parameters. In general, the sampling method efficiently produces uncorrelated samples, since the sample paths look stable and the sample autocorrelations drop stably.

Table (2) provides the estimates for posterior means, standard deviations, the 95% credible intervals, the convergence diagnostics (CD)[15], and the inefficiency factors[16] of Geweke (1992). According to the CD statistics obtained, one should observe that the null hypothesis of the convergence to the posterior distribution is not rejected for the parameters at the 10% significance level. Moreover, the sampling for the parameters and state variables is efficient since the inefficiency factors are rather low.

Tabela 2: Estimation Results of Selected Parameters in the TVP-VAR model

Parameter	Mean	Std. Dev.	95% Interval	CD	Inefficiency
$(\Sigma_\beta)_1$	0.0203	0.0021	[0.0167;0.0248]	0.327	3.91
$(\Sigma_\beta)_2$	0.0203	0.0021	[0.0167;0.0248]	0.245	3.55
$(\Sigma_a)_1$	0.0501	0.0127	[0.0322;0.0807]	0.478	21.06
$(\Sigma_a)_2$	0.0481	0.0114	[0.0316;0.0757]	0.764	19.48
$(\Sigma_h)_1$	0.0612	0.0189	[0.0360;0.1075]	0.933	32.72
$(\Sigma_h)_2$	0.0597	0.0176	[0.0357;0.1044]	0.607	31.51

Notes: The term "Std. Dev." refers to the standard deviation.

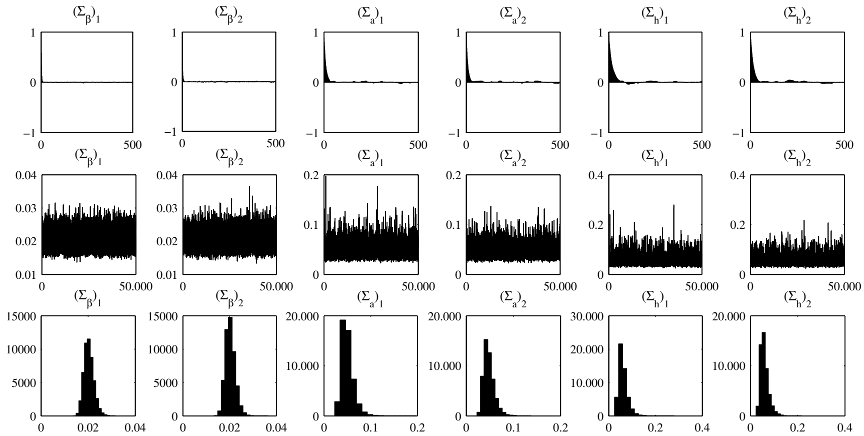
Figure (4) plots the posterior estimates of stochastic volatility of the structural shock, $\sigma_t^2 = \exp(h_{it})$, on four variables, based on the posterior mean, and the one-standard-deviation intervals. Regarding the time-varying volatility of the government spending growth rate, the period from 1996–2002 displays a

data available was applied(source: IBGE).

[14]Regarding the short-term interest rate (STIR), solely the usual difference operator was applied to the series. One should note that the results for the short-term interest rate in its level are divergent among themselves. Since the tests depicted stationarity for its first difference, the model was therefore estimated using the STIR as a I(1) process. However, as a robustness check, the model was also estimated with STIR being a I(0) process. The results were not considered qualitatively different from the ones presented in this paper. These results are available upon request from the author.

[15]Following Geweke (1992), the CD statistics can be obtained by $CD = (\bar{x}_0 - \bar{x}_1)/\sqrt{\hat{\sigma}_0^2/n_0 + \hat{\sigma}_1^2/n_1}$, where n_0 and n_1 are respectively the first and the last n draws, $\bar{x}_j = (1/n_j)\sum_{i=m_j}^{m_j+n_j-1} x^{(i)}$, $x^{(i)}$ is the i-th draw, and $\sqrt{\hat{\sigma}_j^2/n_j}$ is the standard error of $\bar{x}_j$, for $j = 0,1$. If the sequence of the MCMC sampling is stationary, then it converges in distribution to a standard normal. Based on Nakajima et al. (2009), we set $m_0 = 1$, $n_0 = 5,000$, $m_1 = 25,001$ and $n_1 = 25,000$, while the $\hat{\sigma}_j^2$ is obtained using a Parzen window with bandwidth $B_m = 500$.

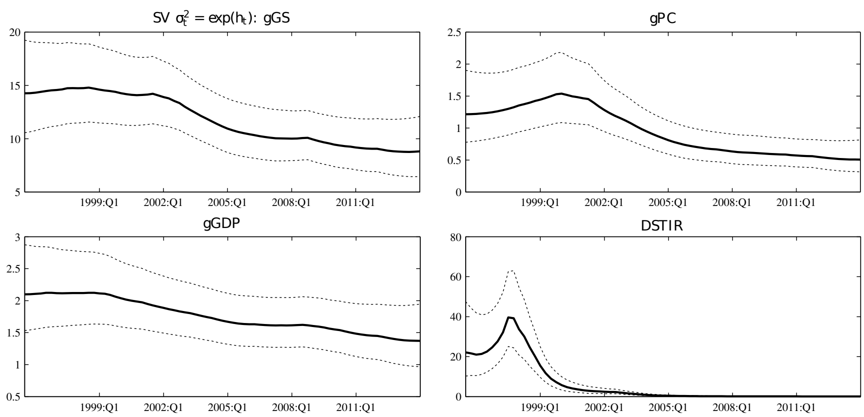
[16]The inefficiency factor is defined as $1 + 2\sum_{s=1}^{B_m} \rho_s$, with ρ_s being the sample autocorrelation at lag s. This factor measures how well the MCMC chain mixes. Besides, when the inefficiency factor is equal to k, we need to draw k times as many MCMC samples as uncorrelated samples. For instance, the inefficiency factor for $(\Sigma_\beta)_1$ is 4.18, which implies that we obtain about $50,000/4.18 = 11,961$ uncorrelated samples.



Notes: Sample autocorrelations (top), sample paths (middle) and posterior densities (bottom).

Figura 3: Estimation Results of Selected Parameters in the TVP-VAR model

higher volatility level as compared to the period from 2002 onwards. The dampening behavior, and later stability, is in agreement with the establishment of the Brazilian Fiscal Responsibility Law (FRL) in 2000, which imposed limits to government budget in order to achieve the solvency of the public debt.



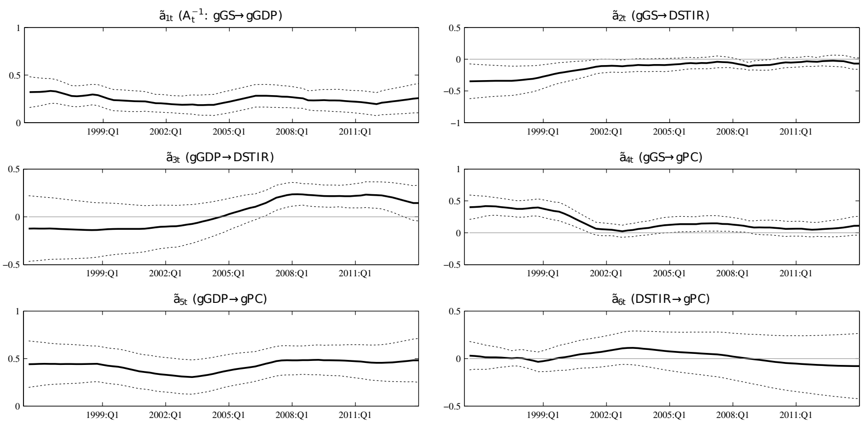
Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura 4: Posterior Estimates for Stochastic Volatility

The time-varying volatility of the GDP growth rate shows a similar pattern, although smoother and on a lower level. It should be noted that the downward path reflects the absence of external restrictions to growth as well as the solid conduct of macroeconomic policies, even in the presence of the 2008 global economic crisis. On the other hand, the stochastic volatility of the private consumption growth rate spikes in the last quarter of 1999, then decreasing from 2000 onwards. The latter decrease is in line with the recent credit expansions which increase the liquidity of Brazilian households and, therefore, have smoothed their intertemporal consumption (Steter 2013).

In mid-1999, less than six months after moving to a floating exchange rate system, Brazil adopted an inflation-targeting framework for monetary policy. The short-term interest rate thus became the Brazilian Central Bank's main instrument to manage inflation. Moreover, since the Brazilian government established a sustained fiscal austerity, the Monetary Policy Committee (Copom) decided in favor of a downward bias, as public debt is indexed to the short-term interest rate. Therefore, the estimated time-varying volatility for its first difference drops sharply until 2000, reaching values close to zero towards the rest of the sample. This result further corroborates the empirical evidences of a smoothing behavior for the short-term interest rates during the inflation-targeting regime.

But how have the simultaneous relations among the variables changed over time? Based on the recursive identification from the lower triangular matrix A_t, one can obtain the posterior estimates of the free elements in A_t^{-1}, denoted $\tilde{a}_{it}$. In other words, these free elements depict the size of the simultaneous effect of other variables to one unit of the structural shock[17], presented in Figure (5).



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura 5: Posterior Estimates for Simultaneous Relations

The simultaneous relations of the short-term interest rate in its first differences to the government spending growth rate shock ($\tilde{a}_{2t}$: $g_{GS} \rightarrow$ DSTIR) are negative and vary over time, going from near -0.3 in 1996 to almost zero in 2014. Similarly, the simultaneous relations of the private consumption growth rate to the short-term interest rate in its first differences ($\tilde{a}_{6t}$: DSTIR $\rightarrow g_{PC}$) are negative throughout the sample, but more constant than the latter. Furthermore, the estimated results suggest that these relationships are insignificantly different from zero since the probability bands include the zero line.

[17] With exception of the short-term interest rate in its first difference, the variables presented positive time-varying intercepts, though almost constant throughout the whole sample. These results are available upon request from the author.

Both simultaneous relations of the GDP growth rates to the government spending growth rate shock ($\tilde{a}_{1t}$: $g_{GS} \rightarrow g_{GDP}$) and the private consumption growth rates to the GDP growth rate shock ($\tilde{a}_{5t}$: $g_{GDP} \rightarrow g_{PC}$) stay positive and rather constant over the sample period. Also, with respect to the simultaneous relations of the private consumption growth rates to the government spending growth rate shock ($\tilde{a}_{4t}$: $g_{GS} \rightarrow g_{PC}$), these are positive and rather volatile between 1996 and 2003, following a downward trend. From Lula's election onwards, the relations remains almost constant.

Even though the simultaneous relation of the short-term interest rate in its first differences to the GDP growth rate shock ($\tilde{a}_{3t}$: $g_{GDP} \rightarrow$ DSTIR) is insignificantly different from zero until 2007, changes in the GDP growth seems to positively affect the interest rate thereafter, with the positive relation spiking in mid-2010. This might imply that the interest rate dynamics has become more responsive to the business cycle fluctuations after the recent global financial crisis.

3.1 (In)Effectiveness of Government Spending Shocks

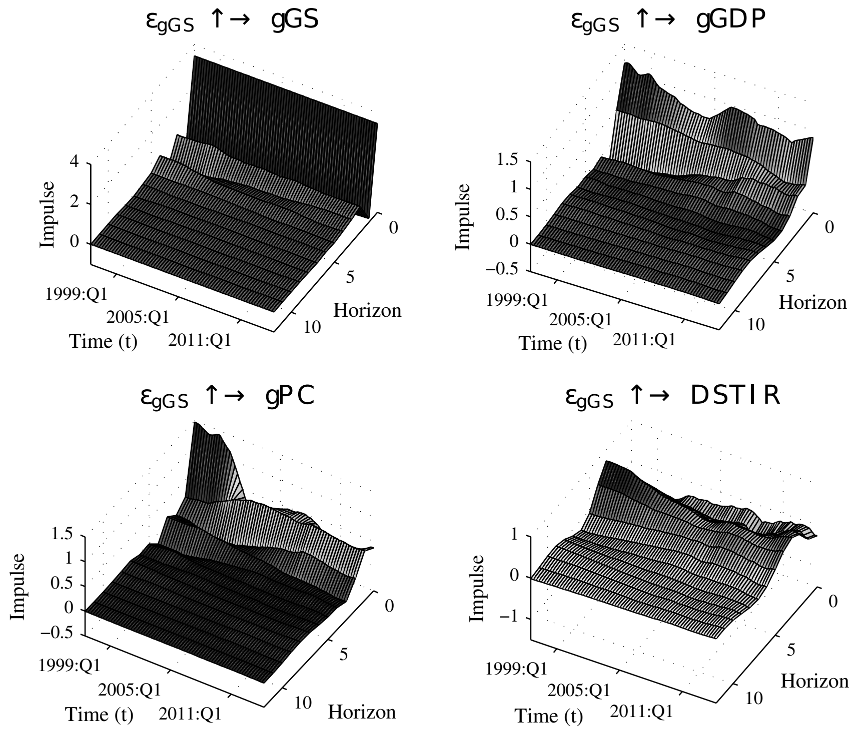
Since the time-varying VAR framework is able to compute state-dependent impulse responses at each individual quarter, potential changes on the macroeconomic dynamics can be evaluated over the sample period. As proposed by Nakajima (2011), these impulse responses are calculated after fixing an initial shock size equal to the time-series average of stochastic volatility over the sample period, using the simultaneous relations at each point in time, in order to achieve comparability over time.

Figure (6) reports the estimated time-varying impulse responses for the variables to a positive government spending growth rate shock[18]. The results show that the recovery of the government spending growth rate to its initial level was more volatile at the beginning of the sample, even though the overall response is rather similar throughout the entire period.

Regarding the short-term interest rate, the effects of spending shocks are negative at first, turning positive after the second quarter until reaching the initial level on the fifth quarter onwards. Kirchner et al. (2010), addressing the effects of fiscal stimulus with an estimated TVP-VAR for the Euro Area, found similar results. One possible explanation for this behavior is the Brazilian government's commitment to the fiscal debt solvency, mainly since the FRL in 2000. Furthermore, the effects of spending shocks on the interest rate have lost persistence over time.

But how effective is discretionary fiscal policy in stimulating economic activity? We can immediately observe that the spending shocks increase private consumption and the GDP growth rates, which is in line with other Brazilian studies (e.g. Mendonça et al. (2009), Carvalho & Valli (2010) and Peres (2012)). As discussed in Reis et al. (1998), and later corroborated in Gomes (2004), nearly 80% of Brazilian households are non-Ricardian and thus consume their income period by period. Consequently, the positive estimated effects of Brazil's fiscal stimulus arises from the fact that the *rule-of-thumb* consumption, to an extent sufficient, compensates the potential negative effects from Ricardian agents. Also, the initial impulse responses are larger at the beginning of the sample, whereas the shock persistence seems to have decreased after Lula's

[18] The accumulated time-varying impulse responses are presented in Appendix Apêndice A.



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported.

Figura 6: Time-Varying Impulse Responses

election at the end of 2002. As for the GDP growth rate results, the initial effectiveness of the fiscal stimulus decreased throughout the sample. On the other hand, the results further suggest that the effects on GDP have gained persistence from 2005 onwards.

Even though the time-varying responses maintained a similar pattern from mid-1996 until late-2014, the results suggest that the government spending shocks could be indeed considered effective in promoting economic activity, but are only sustained on the short-run since positive effects are on average visible only until the horizon of four quarters. Silva & Cândido Júnior (2009) argue that this limited efficacy in stimulating macroeconomic aggregates through fiscal policy is a common feature among Latin America countries. Still, the time-varying techniques indicate some increasing persistence of the latter shocks effectiveness. In general, the results are in line with the recent Brazilian literature on fiscal policy (Mendonça et al. 2009, Peres 2012, Soave & Sakurai 2012).

3.2 Time-Invariant Comparison: A BVAR Approach

Modeling the relationship among macroeconomic variables has been a recurring challenge for economists. From the Lucas (1976) critique, empirical research has relied upon time-varying models in an attempt to overcome parameter uncertainty over time (Hamilton 1989, Canova 1993, Cogley & Sargent

2005, Primiceri 2005, Koop et al. 2009).

While the previous empirical approach highlighted that the time-varying interplay of government spending and private consumption can be considered relevant for Brazilian data, the sample spams for a relatively short period (1996:Q1–2014:Q2). Given that the Brazilian economy has undergone few structural changes throughout these years, such as the abandonment of the crawling peg exchange rate regime on January 15, 1999 and the IT framework implementation in June of the same year, we now turn the attention to the impulse responses of a time-invariant Bayesian VAR (BVAR) for government spending shocks as a comparison to the TVP-VAR model.

Define a reduced-form VAR model as:

$$Y_t = X_t A + \varepsilon_t \qquad \varepsilon_t \sim N(0, \Sigma) \tag{11}$$

where $A = (a_0, A_1, \ldots, A_p)^{'}$ and $X_t = (X_1, \ldots, X_T)^{'}$. Through some matrix algebra, Equation (11) can be rewritten in the form of:

$$y_t = Z_t \alpha + \varepsilon_t \tag{12}$$

with $Z_t = (I_M \otimes X_t)$ and $\alpha = vec(A)$.

The likelihood function can be obtained by the sampling density, $p(y|\alpha, \Sigma)$. We impose a diffuse (or Jeffreys') prior for α and Σ, so that:

$$p(\alpha, \Sigma) \propto |\Sigma|^{-(M+1)/2} \tag{13}$$

Viewed as a function of the parameters, this problem can be split into two parts: (i) a normal distribution for α given Σ; and (ii) an inverse-Wishart distribution for Σ. That is:

$$\alpha|\Sigma, y \sim N(\hat{\alpha}, \Sigma) \tag{14}$$

and

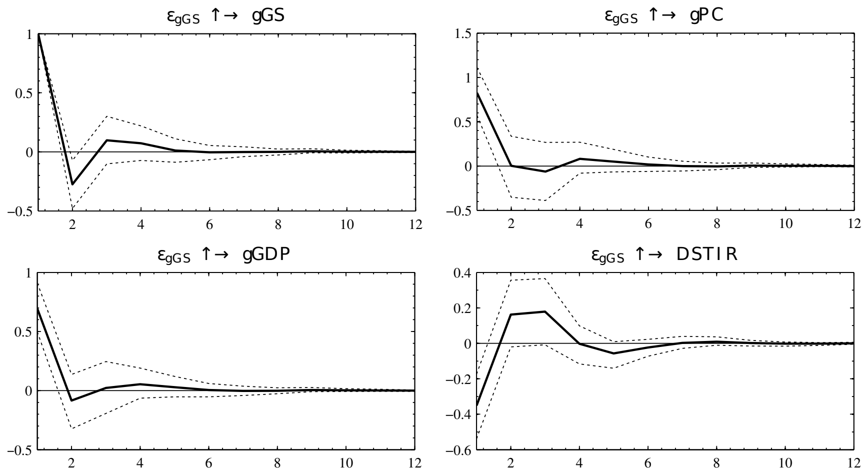
$$\Sigma|y \sim IW(\widehat{S}, T-K) \tag{15}$$

where $\widehat{A} = (X^{'}X)^{-1}(X^{'}Y)$ is the OLS estimate of A, $\hat{\alpha} = vec(\widehat{A})$ is a vector which stacks all the VAR coefficients (and the intercepts), $\widehat{S} = (Y - X\widehat{A})^{'}(Y - X\widehat{A})$ is the sum of squared errors of the VAR, and $\widehat{\Sigma} = \widehat{S}/(T-K)$ is the OLS estimate of Σ.

According to the results in Figure (7), the recovery of the government spending to its initial level requires around five quarters. Despite some volatile behavior between 1994–2005 on Figure (6), the time-invariant dynamics is rather similar. To a lesser extent, the effects of spending shocks on private consumption also resembles the time-varying ones.

As to the effectiveness of discretionary fiscal policy on stimulating GDP growth, we observe positive response of output to an increase in the government spending. Even though corroborating the results previously obtained, the time-varying impulse responses revealed a growing shock persistence from the end of 2002 onwards. Hence, by applying a time-invariant BVAR model, one would underestimate the government capability to promote economic activity in the recent years.

In terms of monetary policy, positive government spending shocks lead to a contemporaneous decrease of the short-term interest rate, increasing from



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura 7: Time-Invariant Impulse Responses of Government Spending Shocks

thereafter until reaching its initial level after 18 months. However, according to Figure (6), the intensity with which STIR decreases is not constant over time, and neither is the shock persistence. The shortcomings of the time-invariant analysis are threefold: (i) it underestimates the positive response after the second quarter in the first half of the sample period; (ii) it does not capture the gradual decrease of STIR response after 2000s, and (iii) it displays a smaller shock persistence for the recent years.

Overall, despite the time-invariant impulse responses closely following the pattern of their time-varying counterparts, BVAR usually underestimates the magnitude of these responses as well as the shock persistence, especially in the last years. That is, the TVP-VAR should thus be considered an appropriate method to overcome the issues concerning parameter uncertainty. Still, regardless of time features, the estimated impulse responses seem to be sustained only on the short-run.

3.3 Prior Sensitivity Analysis: Model Robustness

In order to address any potential divergence on the results due to prior specification, we specify alternative priors for the TVP-VAR model. Therefore, we re-estimate it based on two different sets of diffuse and uninformative priors. The first prior set has an alternative value for the mean of parameters $(\Sigma_\beta)_i^{-2}$, $(\Sigma_a)_i^{-2}$ and $(\Sigma_h)_i^{-2}$, while the second set of priors focuses on the variance of these terms[19]:

[19] One should notice that by imposing a more flexible prior for the covariance matrix of A, the Bayesian estimation process was not able to achieve the inverse matrix of A due to singularity. Therefore, in order to avoid implausible behaviors of the time-varying contemporaneous relationships parameters, $(\Sigma_a)_i^{-2}$ is specified as in Section 2.1. See Koop & Korobilis (2010) for a discussion on the methodology for the TVP-VAR model, including the issues about the prior specifications.

$$\text{(I)} \quad (\Sigma_\beta)_i^{-2} \sim G(40, 0.01I), \quad (\Sigma_a)_i^{-2} \sim G(10, 0.01), \quad (\Sigma_h)_i^{-2} \sim G(10, 0.01)$$

$$\text{(II)} \quad (\Sigma_\beta)_i^{-2} \sim G(25, 0.02I), \quad (\Sigma_a)_i^{-2} \sim G(4, 0.01), \quad (\Sigma_h)_i^{-2} \sim G(4, 0.02)$$

The posterior estimates were obtained by drawing $M = 50,000$ samples after the initial 5,000 samples were discarded in the burn-in period. The complete results can be found in Appendix Apêndice A. In general, both alternative specifications led to similar results in comparison to the chosen priors in Section 2.1. As Figure A.2 and Figure A.3 show that the sample paths look stable and the sample autocorrelations drop stably, the sampling method efficiently generates uncorrelated samples. These results are corroborated by Table A.1 and Table A.2 since the CD statistics imply that the null hypothesis of convergence to the posterior distribution is not rejected at the 10% significance level for both alternative prior sets. Moreover, the Inefficiency factors are rather low on both specifications.

The obtained results robustly confirm the downward trend of the stochastic volatility in the sample period, thus reaffirming the stable macroeconomic profile in the recent years. Posterior estimates for simultaneous relations also displayed a robust behavior in comparison to the baseline TVP-VAR model. Ergo, the robustness tests evolve consistently with the previous results.

4 Conclusions

In this paper we presented empirical evidences of the relationship between government spending and private consumption in Brazil. We estimated a vector autoregression model with drifting coefficients and stochastic volatility for Brazil over the period 1996:Q1–2014:Q2.

The findings suggest that the effectiveness of spending shocks in stimulating economic activity has increased since 2007, depicting positive Keynesian multipliers. The estimated time-varying impulse responses of GDP growth rate also shows higher persistence in the recent years. However, these positive effects are only sustained on the short-run. Regarding private consumption, the results further suggest a *crowding-in* effect, despite the decrease of the initial positive response over the sample. In general, the latter results are in line with the recent literature on fiscal policy (Mendonça et al. 2009, Peres 2012, Soave & Sakurai 2012). Moreover, we document that the estimated effects of government spending growth rate shocks on private consumption growth rate seem rather time-invariant during this period.

By comparing time-invariant impulse responses of a Bayesian VAR (BVAR) with their time-varying counterpart, we were further able to provide empirical evidences that parameter uncertainty might be overcome with a TVP-VAR specification. Additionally, robustness analysis confirmed the downward trend of the stochastic volatility in the period, thus reaffirming that Brazil has steadily improved its macroeconomic stability in the recent years.

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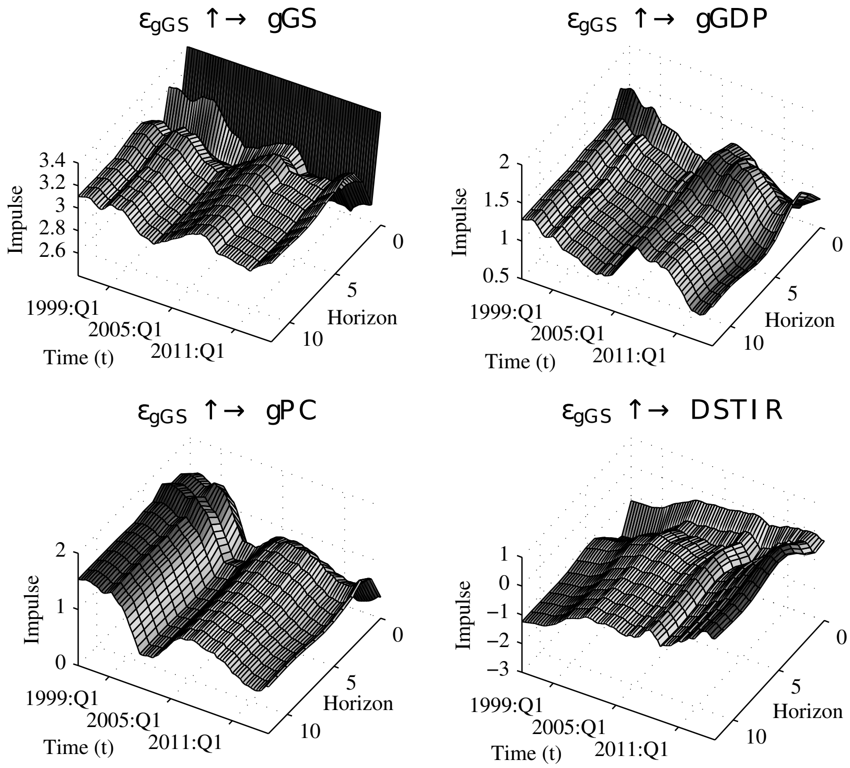
Apêndice A Supplementary Figures and Tables



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported.

Figura A.1: Accumulated Time-Varying Impulse Responses

Tabela A.1: Estimation Results of Selected Parameters in the TVP-VAR model – First Prior Set – Robustness Check

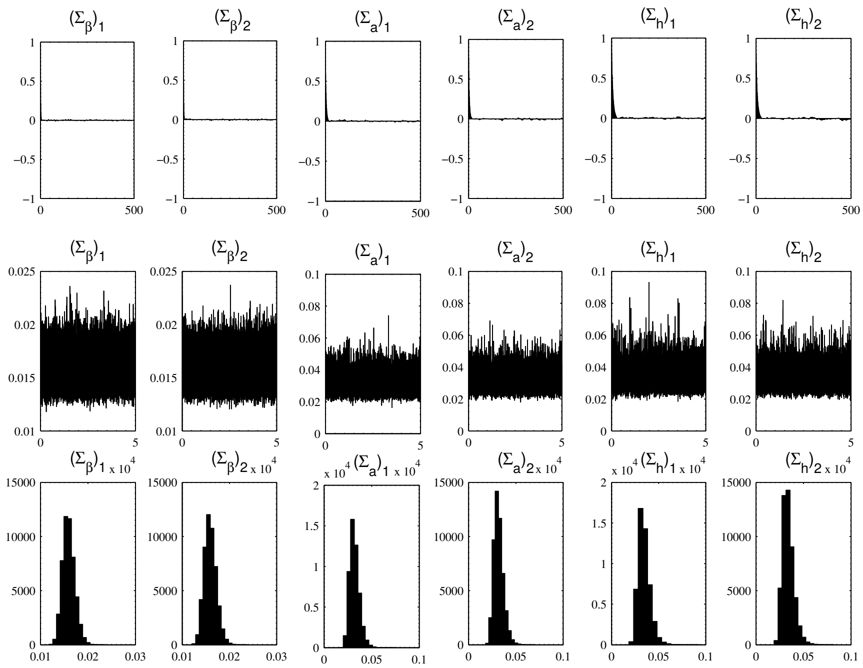
Parameter	Mean	Std. Dev.	95% Interval	CD	Inefficiency
$(\Sigma_\beta)_1$	0.0159	0.0013	[0.0137;0.0187]	0.407	2.78
$(\Sigma_\beta)_2$	0.0159	0.0013	[0.0137;0.0187]	0.422	2.78
$(\Sigma_a)_1$	0.0319	0.0051	[0.0238;0.0436]	0.829	9.24
$(\Sigma_a)_2$	0.0319	0.0051	[0.0238;0.0435]	0.496	7.38
$(\Sigma_h)_1$	0.0345	0.0063	[0.0249;0.0488]	0.675	14.74
$(\Sigma_h)_2$	0.0339	0.0060	[0.0247;0.0479]	0.932	12.89

Notes: The term "Std. Dev." refers to the standard deviation.

Tabela A.2: Estimation Results of Selected Parameters in the TVP-VAR model – Second Prior Set – Robustness Check

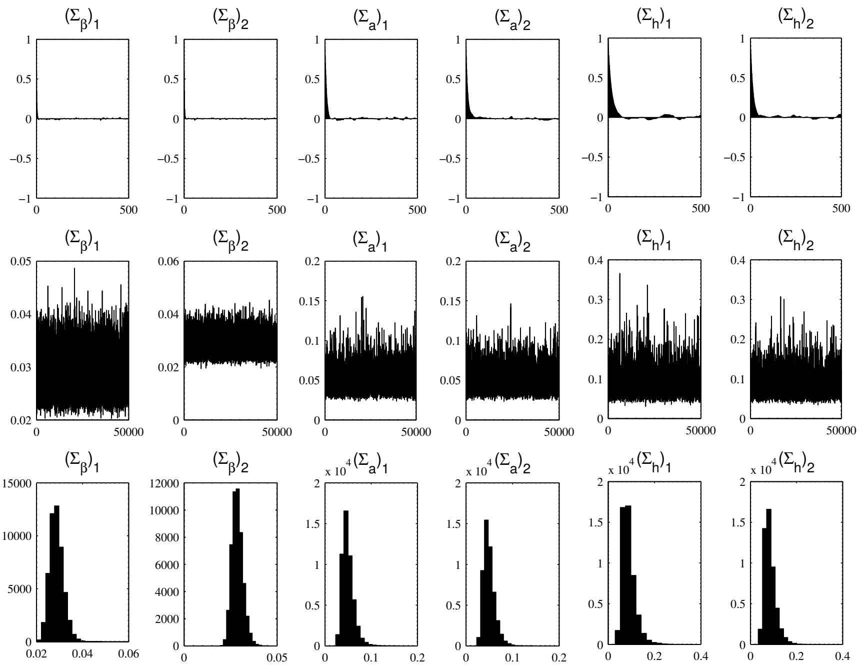
Parameter	Mean	Std. Dev.	95% Interval	CD	Inefficiency
$(\Sigma_\beta)_1$	0.0287	0.0029	[0.0237;0.0349]	0.459	3.45
$(\Sigma_\beta)_2$	0.0287	0.0030	[0.0236;0.0352]	0.106	4.60
$(\Sigma_a)_1$	0.0498	0.0124	[0.0322;0.0800]	0.716	17.38
$(\Sigma_a)_2$	0.0494	0.0121	[0.0321;0.0791]	0.581	14.57
$(\Sigma_h)_1$	0.0895	0.0297	[0.0516;0.1627]	0.603	36.33
$(\Sigma_h)_2$	0.0832	0.0243	[0.0497;0.1428]	0.114	33.30

Notes: The term "Std. Dev." refers to the standard deviation.



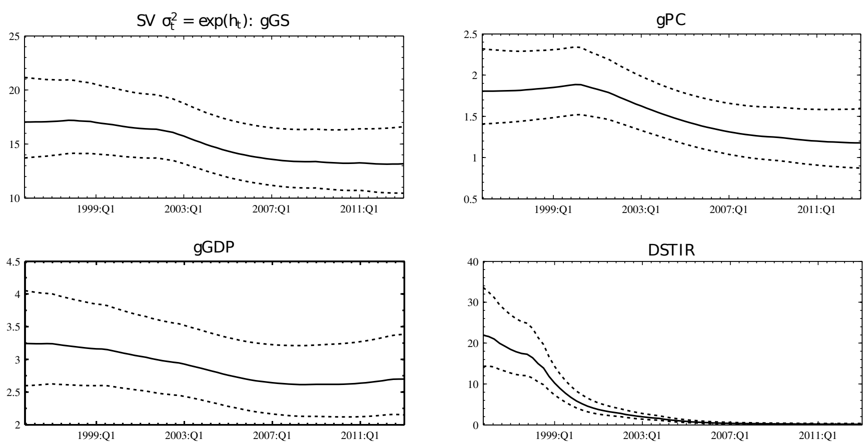
Notes: Sample autocorrelations (top), sample paths (middle) and posterior densities (bottom).

Figura A.2: Estimation Results of Selected Parameters in the TVP-VAR model – First Prior Set – Robustness Check



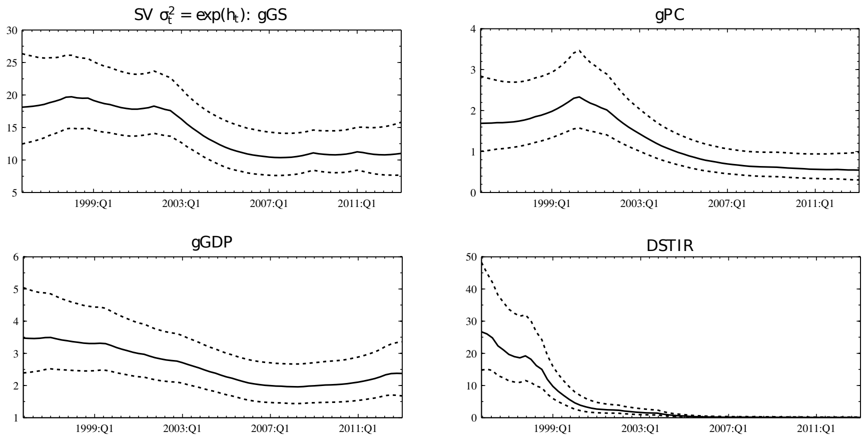
Notes: Sample autocorrelations (top), sample paths (middle) and posterior densities (bottom).

Figura A.3: Estimation Results of Selected Parameters in the TVP-VAR model – Second Prior Set – Robustness Check



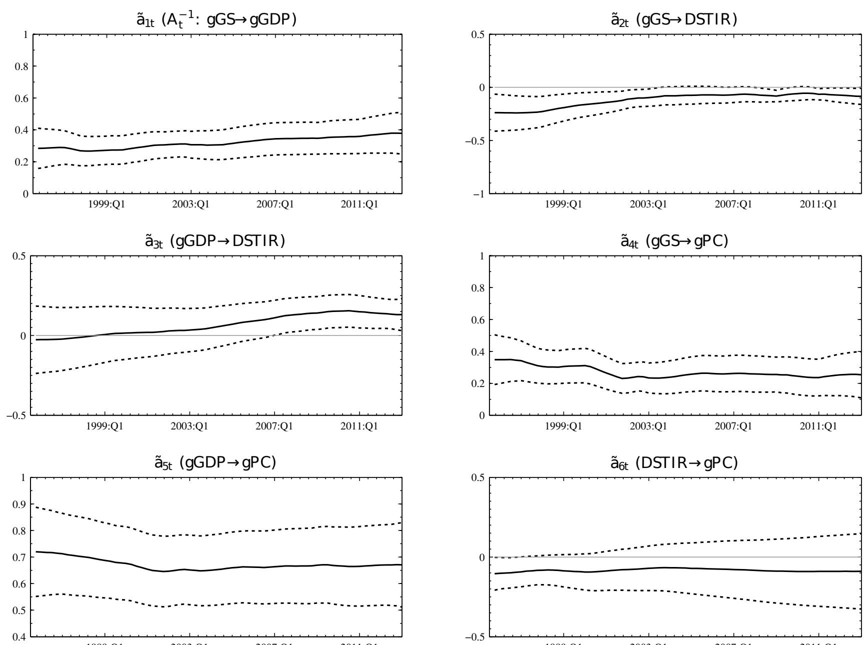
Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura A.4: Posterior Estimates for Stochastic Volatility – First Prior Set – Robustness Check



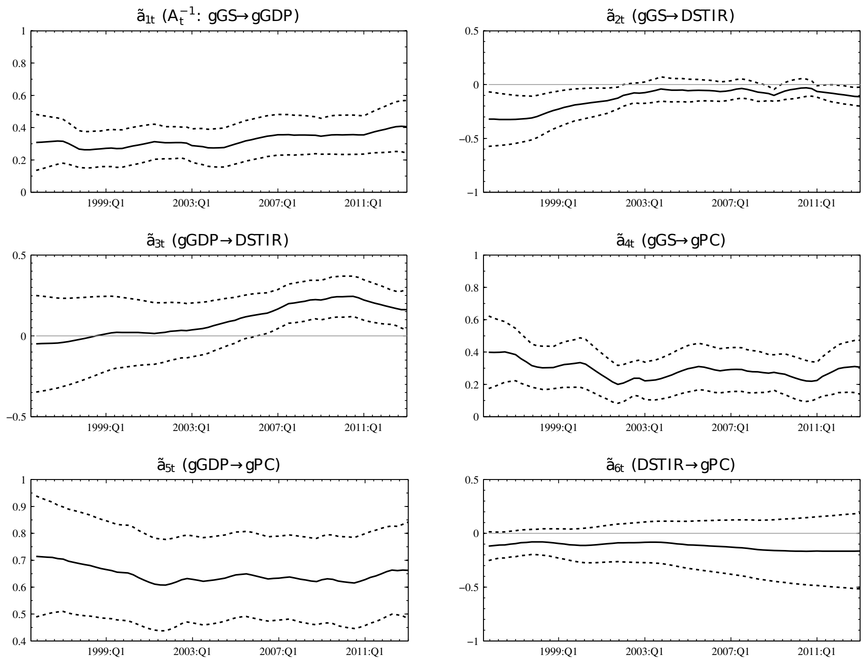
Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura A.5: Posterior Estimates for Stochastic Volatility – Second Prior Set – Robustness Check



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura A.6: Posterior Estimates for Simultaneous Relations – First Prior Set – Robustness Check



Notes: The terms gGS, gPC and gGDP refer to government spending, private consumption and GDP growth rates, respectively. DSTIR is the short-term interest rate in its first difference. Only median responses are reported. Posterior mean (solid line) and 95% credible intervals (dotted line).

Figura A.7: Posterior Estimates for Simultaneous Relations – Second Prior Set – Robustness Check