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DOCUMENTO DE TRABAJO

Nº 539

REGIME-SWITCHING, STOCHASTIC VOLATILITY, FISCAL POLICY SHOCKS AND MACROECONOMIC FLUCTUATIONS IN PERU

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Octubre, 2024

DOCUMENTO DE TRABAJO 539
http://doi.org/10.18800/2079-8474.0539

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Editado:

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Primera edición – Octubre, 2024

ISSN 2079-8474 (En línea)

Regime-Switching, Stochastic Volatility, Fiscal Policy Shocks and Macroeconomic Fluctuations in Peru*

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Version: October 2, 2024

Abstract

Following Chan and Eisenstat (2018a), we use a family of regime-switching models with time-varying parameters and stochastic volatility (RS-VAR-SV) to analyze the evolution of fiscal shocks impacts on Peru's economic growth from 1995Q1 to 2019Q4. Key findings include: (i) identification of two distinct economic regimes with different macroeconomic fundamentals tied to improvements in fiscal and monetary policy; (ii) enhanced model fit with the inclusion of stochastic volatility; (iii) a positive trend in the size of spending multipliers, though they remain below unity; (iv) during the 2008 Global Financial Crisis, capital expenditure shocks mitigated the decline in economic growth by 2 percentage points, highlighting their counter-cyclical potential. These findings are corroborated by robustness checks, which include changes in priors, variable reordering, adjustments in external and demand variables, and extending the sample to 2022Q4 to encompass the COVID-19 crisis.

JEL Classification: C11, C32, C52, E62, H30.

Keywords: Regime-Switching Models, Fiscal Multipliers, Marginal Likelihood, Cross-Entropy, Bayesian Model Comparison, Peruvian Economy, Stochastic Volatility.

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[*] This document is drawn from the Thesis of Joseph Santisteban at the Faculty of Social Sciences of the Pontificia Universidad Católica del Perú (PUCP). We appreciate the comments from Paul Castillo B. (Central Reserve Bank of Peru and PUCP). The points of view expressed in this document are those of the authors and do not necessarily represent the official position of the Fiscal Council. Any remaining errors are the responsibility of the authors.

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Cambios de Régimen, Volatilidad Estocástica, Choques de Política Fiscal y Fluctuaciones Macroeconómicas en Perú*

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Resumen

Siguiendo a Chan y Eisenstat (2018a), utilizamos una familia de modelos de cambio de régimen con parámetros cambiantes en el tiempo y volatilidad estocástica (RS-VAR-SV) para analizar la evolución de los impactos de los choques fiscales en el crecimiento económico del Perú desde 1995T1 hasta 2019T4. Los hallazgos clave incluyen: (i) identificación de dos regímenes económicos distintos con diferentes fundamentos macroeconómicos vinculados a mejoras en la política fiscal y monetaria; (ii) ajuste mejorado del modelo con la inclusión de volatilidad estocástica; (iii) una tendencia positiva en el tamaño de los multiplicadores del gasto, aunque permanecen por debajo de la unidad; (iv) durante la crisis financiera global de 2008, los choques de gasto de capital mitigaron la caída del crecimiento económico en 2 puntos porcentuales, lo que destaca su potencial contracíclico. Estos hallazgos se corroboran con ejercicios de robustez, que incluyen cambios en los valores previos, reordenamiento de variables, ajustes en variables externas y de demanda, y la extensión de la muestra al cuarto trimestre de 2022 para abarcar la crisis de COVID-19.

Clasificación JEL: C11, C32, C52, E62, H30.

Palabras Clave: Modelo VAR con Cambio de Régimen, Volatilidad Estocástica, Verosimilitud Marginal, Modelos Bayesianos, Política Fiscal, Perú.

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[*] Este documento está basado en la Tesis de Licenciatura de Joseph Santisteban de la Facultad de Ciencias Sociales de la Pontificia Universidad Católica del Perú (PUCP). Apreciamos los comentarios de Paul Castillo B. (Banco Central de Reserva del Perú y PUCP). Los puntos de vista expresados en este documento son de los autores y no necesariamente representan la posición oficial del Consejo Fiscal del Perú. Los errores subsistentes son responsabilidad de los autores.

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1 Introduction

In the last two decades, following the implementation of Peru's first fiscal framework in 1999, fiscal policy has adhered to fiscal rules to preserve the sustainability of public finances. These measures aimed to correct biases in the design of fiscal policy and the public budget. With greater discipline, transparency, institutional strengthening, and predictability of fiscal accounts, the sovereign credit rating has improved; see Fiscal Council (2016).

Analyzing fiscal policy in Peru is particularly interesting because it is a small, open economy dependent on commodity prices with significant institutional weaknesses. Additionally, the country has not always been fiscally solvent and has undergone several reforms, such as the independence of the Central Reserve Bank of Peru (BCRP) and its prohibition from financing the Treasury since 1993; the strengthening of fiscal rules in 2003; and the creation of an autonomous Fiscal Council in 2015 to monitor fiscal sustainability and compliance with fiscal rules, among other duties. In this scenario of increased control over public finances, Peru's fiscal strength has improved. However, the external context has also played an important role through higher tax revenues from mineral resource exploitation, leaving the country significantly vulnerable to changes in commodity prices, as seen since 2012; see Ganiko and Merino (2018) and Urbina and Rodríguez (2023).

Peru's macro-fiscal history has transitioned from a situation with limited fiscal space (from the late 1980s to 2002), due to poor policy decisions (Martinelli and Vega, 2019), to a scenario with greater stability in public finances. In this context, it is reasonable to think that the effect of fiscal policy shocks has not been constant over time. Recent literature has explored these questions through models with time-varying parameters; see Guevara (2018), Jiménez et al. (2023) and Meléndez and Rodríguez (2023). This methodology captures smooth changes in parameters over time. However, the improvement in fiscal accounts was substantial in a relatively short period, so changes in the effects of fiscal policy have not necessarily been smooth. This document aims to analyze the evolution of the effects of fiscal shocks in different states of the economy, not at every point in time. For this purpose, we use a family of regime-switching models with stochastic volatility (RS-VAR-SV), similar to those proposed by Sims and Zha (2006), but implementing the methodology of Chan and Eisenstat (2018a). Additionally, tools such as impulse response functions (IRFs), forecast error variance decomposition (FEVD), historical decomposition (HD), and fiscal multipliers are used to evaluate the impacs of fiscal shocks.

The main results indicate that the best-fitting model incorporates only stochastic volatility. Furthermore, two economic states are identified with a single regime change in 2002, coinciding with the start of a commodity price supercycle, the strengthening of fiscal rules, and the adoption of an inflation targeting (IT) framework. On the fiscal front, the instrument with the greatest capacity to impact output growth is capital expenditure, which, like current expenditure, has improved in effectiveness. However, our results show that despite this progress, spending multipliers do not exceed unity.

The rest of the document is structured as follows. Section 2 reviews the empirical literature both internationally and for Peru. Section 3 presents the RS-VAR-SV model, its variants, and the methodological details of estimation and comparison. Section 4 presents the data, the identification scheme, evidence of changing parameters, the model selection, an analysis of IRFs, FEVDs, HDs, and the fiscal multipliers. Section 5 analyzes the sensitivity of tax revenues to external shocks, and Section 6 presents the robustness analysis. The main conclusions are discussed in Section 7.

2 Literature Review

A key reference in the empirical literature on the capacity of fiscal policy to stimulate economic activity is Blanchard and Perotti (2002), who use an SVAR model with short-term restrictions and find that output responds positively to public expenditure shocks and negatively to tax shocks. Both fiscal instruments have an adverse effect on investment but positively impact on consumption.

Perotti (2005), using the same identification scheme, extends the analysis to OECD countries and evaluates the performance of public spending before and after 1980, arguing that the effectiveness of fiscal policy in stimulating output has weakened over time. Restrepo and Rincón (2006) employ SVAR and SVEC models to evaluate the performance of public spending in Colombia and Chile, respectively, during the period 1990-2005. The results indicate that public spending is more effective in Chile than in Colombia, with differences stemming from distinct management of public finances and macroeconomic stability. Bénassy-Quéré and Cimadomo (2006), using a FAVAR model, analyze the impact of both public spending and taxes on the output of Germany, the UK, and the US. The results indicate that the impact of public spending is positive but weak in the short term and close to zero in the medium term, while the impact of taxes is even weaker.

Mountford and Uhlig (2009) use an SVAR model with a sign identification scheme, where they restrict the sign of all shocks except fiscal ones. The results indicate that fiscal policy positively impacts output and recommend using the fiscal deficit financed with tax cuts. Romer and Romer (2010), using a narrative identification scheme, consider the size, timing, and motivations of tax measures and find that the impact of taxes on output is greater with a narratively constructed series. Mertens and Ravn (2011), Ramey (2011), and Favero and Giavazzi (2011), using the same approach, obtain similar estimates, where the effect of an unanticipated tax cut boosts output and shows persistent effects on consumption and investment. According to Mertens and Ravn (2011), the effect is negative in the short term but then stimulates output.

Starting in 2008, in response to the Global Financial Crisis (GFC), the literature focused on the effects of fiscal policy depending on the position of the economy in the business cycle. Auerbach and Gorodnichenko (2012) employ a smooth transition VAR (ST-VAR) model and find that in periods of recession, the effect of public spending on output is greater than in periods of expansion, with a multiplier effect greater than one. Baum et al. (2012) estimate a Threshold-VAR model for the G-7 economies and find that, on average, fiscal multipliers are larger during periods of recession. Bachmann and Sims (2012) extend this analysis by introducing confidence shocks as a transmission mechanism, which influence the differences in multipliers depending on the state of the economy. Cimadomo and Bénassy-Queré (2012), Blanchard and Leigh (2013), and Candelon and Lieb (2013) find further evidence of regime asymmetries. Using a narrative approach, Owyang et al. (2013) employ new data constructed for the US and Canada, setting the unemployment rate as a threshold to identify economic regimes and find evidence of asymmetries for Canada but not for the US. However, Fazzari et al. (2015) present evidence of asymmetries in the US using a T-VAR model arguing, based on Bayesian criteria, that the nonlinearity of the model is relevant.

The literature has also explored the presence of size asymmetries, where the effects of fiscal policy are expected to vary over the sample period. To obtain time-dependent estimates, Berg (2015) uses a time-varying parameter model with stochastic volatility (TVP-VAR-SV), where the results for Germany suggest that the effectiveness of fiscal policy has diminished over time. For Brazil, Pereira (2015) finds the opposite result and argues that fiscal policy has gained strength due to greater macroeconomic stability. In the case of Romania, Boiciuc (2015) concludes that fiscal policy has a weak influence on output and fiscal multipliers do not show substantial variation over time. Glocker et al. (2019) use an augmented TVP-VAR-SV model with factors for the UK, showing that public spending multipliers vary over time and are mostly explained by cyclical factors.

These estimates are greater than one during periods of recession and lower during expansions.

Regarding the empirical literature for Peru, Mendoza and Melgarejo (2008) use an SVAR model employing the methodology of Blanchard and Perotti (2002) for the periods 1980-1990 and 1990-2006. Based on the results, they argue that fiscal policy has been more effective in the second period due to the strengthening of public finances. Using the same methodology, Rossini et al. (2011) disaggregate public spending into current and capital expenditure, finding evidence that the most effective component of public spending is capital expenditure.

In examining state asymmetries, Sánchez and Galindo (2013), Salinas and Chuquillín (2013), and Vtyurina and Leal (2016) provide important contributions. The first two studies use an ST-VAR model, which suggests that the effect of public spending on output growth is greater during periods of negative output gap. In contrast, Vtyurina and Leal (2016), using a T-VAR model, conclude that capital expenditure is the fiscal instrument with the greatest state asymmetry, being more effective during recessions.

Regarding size asymmetries, Guevara (2018) employs a TVP-VAR-SV model and identifies shocks under sign restrictions, finding that the effectiveness of public spending has decreased since 1999. In contrast, Jiménez et al. (2023), using hybrid TVP-VAR-SV models (Chan and Eisenstat, 2018b), find that spending multipliers have shown an increasing trend over the past two decades, stabilizing near unity in recent years. Similarly, Meléndez Holguín and Rodríguez (2023) explore restricted versions of the TVP-VAR-SV models (Chan and Eisenstat, 2018a) and find that fiscal multipliers do not exceed unity and that their variability is influenced by cyclical factors, although their results show a slight positive trend similar to Jiménez et al. (2023). According to Aguilar and Lahura (2024), spending shocks could be overestimated if the anticipated component of public spending measures is not included, although the effect on output growth would remain positive.[1]

This research contributes to the empirical literature by employing a family of RS-VAR-SV models, as outlined by Chan and Eisenstat (2018a), to analyze regime changes in the effects of fiscal policy shocks on output. Unlike previous studies, this methodology identifies abrupt shifts in outcomes through an unobservable variable that aligns with structural changes in the economy. There is no prior evidence of this methodology being applied in Latin American countries, making these findings significant for understanding the impact of fiscal shocks on output growth.

3 Methodology

3.1 The Econometric Model

Following Chan and Eisenstat (2018a), we use a regime-switching model with stochastic volatility (RS-VAR-SV), similar to Sims and Zha (2006):

$$\mathbf{B}_{0,S_t}\mathbf{y}_t = \boldsymbol{\mu}_{S_t} + \mathbf{B}_{1,S_t}\mathbf{y}_{t-1} + ... + \mathbf{B}_{p,S_t}\mathbf{y}_{t-p} + \boldsymbol{\epsilon}_t, \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_{S_t}), \tag{1}$$

where $\mathbf{y}_t$ is an $n\times 1$ vector of endogenous variables, $\boldsymbol{\mu}_{S_t}$ is an $n\times 1$ vector of intercepts, $\mathbf{B}_{1,S_t}, ..., \mathbf{B}_{p,S_t}$ are $n \times n$ matrices of structural coefficients, $\mathbf{B}_{0,S_t}$ is a lower triangular $n \times n$ matrix of contemporaneous relations with unit values on its diagonal, and $\boldsymbol{\Sigma}_{S_t} = diag(\sigma^2_{1,S_t}, ..., \sigma^2_{n,S_t})$ is an $n \times n$ diagonal

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[1] It is important to consider that we do not incorporate anticipated effects as in Ramey (2011), since there are no public data available for the entire sample on a quarterly basis for Peru. The BCRP has published projections of the annual growth rates of General Government spending since 2002. From 2002 to 2008, three reports have been published annually and, only since 2009, have the reports been published quarterly. Our data set, however, is quarterly beginning in 1995. This discrepancy in the frequency and timing of available data presents a challenge in incorporating the expected effects of fiscal policy. Likewise, the limited data available does not break down total spending into government consumption spending and government investment spending, a division that for us is essential.

matrix containing the variances of the structural shocks. Furthermore, $\mathbf{S}_t \in 1, ..., r$ represents the regime indicator r at time t and follows a Markov process with transition probability defined as $P(\mathbf{S}_t = j \mid \mathbf{S}_{t-1} = i) = p_{ij}$ for $i, j = 1, ..., r$, where p_{ij} indicates the probability of transitioning from state i to j.

Equation (1) can be rewritten based on two groups of parameters:

$$\mathbf{y}_t = \widetilde{\mathbf{X}}_t \boldsymbol{\beta}_{S_t} + \mathbf{W}_t \boldsymbol{\gamma}_{S_t} + \boldsymbol{\epsilon}_t, \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_{S_t}) \tag{2}$$

where the first group of parameters $(\boldsymbol{\beta}_{S_t})$ consists of a $k_{\beta,S_t} \times 1$ vector of intercepts and coefficients associated with lagged variables $\boldsymbol{\beta}_{S_t} = vec((\boldsymbol{\mu}_{S_t}, \mathbf{B}_{1,S_t}, ..., \mathbf{B}_{p,S_t})')$ and the second group of parameters $(\boldsymbol{\gamma}_{S_t})$ consists of a $k_{\gamma,S_t} \times 1$ vector that contains the contemporaneous relations between the variables $\boldsymbol{\gamma}_{S_t} = (\boldsymbol{\gamma}_{1,S_t}, ..., \boldsymbol{\gamma}_{k,S_t})'$, representing the elements below the diagonal of $\mathbf{B}_{0,S_t}$. Additionally, $\widetilde{\mathbf{X}}_t = \mathbf{I}_n \otimes (1, \mathbf{y}'_{t-1}, ..., \mathbf{y}'_{t-p})$ contains the lagged variables, and $\mathbf{W}_{\mathrm{t}}$ contains appropriate elements of $-\mathbf{y}_t$.[2] Finally, to jointly estimate the parameters, the model presented in equations (1)-(2) can be rearranged as:

$$\mathbf{y}_t = \mathbf{X}_t \boldsymbol{\theta}_{S_t} + \boldsymbol{\epsilon}_t \qquad \boldsymbol{\epsilon}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_{S_t}), \tag{3}$$

where $\mathbf{X}_t = (\widetilde{\mathbf{X}}_t, \mathbf{W}_t)$ with dimension $n \times k_{S_t}$ and $\boldsymbol{\theta}_{S_t} = (\boldsymbol{\beta}'_{S_t}, \boldsymbol{\gamma}'_{S_t})'$ with dimension $k_\theta = k_\beta + k_\gamma$. The initial conditions are $\boldsymbol{\theta}_{\mathbf{0}} \sim \mathcal{N}(\boldsymbol{a}_{\boldsymbol{\theta}}, \boldsymbol{V}_{\boldsymbol{\theta}})$. Additionally, the elements of the diagonal matrix $\boldsymbol{\Sigma}_{S_t}$ are assumed to be independently distributed as $\sigma^2_{i,S_t} \sim \mathcal{IG}(v_{i,S_t}, S_{i,S_t})$ for $i = 1, ..., n$, where $\mathcal{IG}$ represents the Inverse Gamma distribution.

From the general model, a set of competing models is defined: (i) the RS-VAR-SV-R1 model, which restricts the variability of the parameters in $\boldsymbol{\theta}_{S_t}$ but includes SV; (ii) the RS-VAR-R2 model, with changing parameters $\boldsymbol{\theta}_{S_t}$ but without SV; (iii) the RS-VAR-SV-R3 model, which maintains only changing intercepts $\boldsymbol{\mu}_{S_t}$ and SV; (iv) the RS-VAR-SV-R4 model, which restricts only $\boldsymbol{\gamma}_{S_t}$ but maintains variability in $\boldsymbol{\beta}_{S_t}$ and SV; (v) the RS-VAR-SV-R5 model, which restricts $\boldsymbol{\beta}_{S_t}$ but maintains variability in $\boldsymbol{\gamma}_{S_t}$ and SV; and (vi) the CVAR model, which restricts the variability of all parameters.

3.2 Estimation Algorithm

The posterior parameters are estimated using the Gibbs sampling algorithm, which involves dividing the parameters into blocks and estimating each block separately, updating the information obtained from the other blocks. We use the following notation: $\boldsymbol{\theta} = [\boldsymbol{\theta}'_1, ..., \boldsymbol{\theta}'_j]$, $\boldsymbol{\Sigma} = [\boldsymbol{\Sigma}'_1, ..., \boldsymbol{\Sigma}'_j]$, $\mathbf{y} = [\mathbf{y}'_1, ..., \mathbf{y}'_j]$, $\mathbf{S} = [\mathbf{S}'_1, ..., \mathbf{S}'_j]$ for $j = 1, ..., r$; and $\mathbf{P}$ is the transition probability matrix. The posterior distribution $p(\boldsymbol{\theta}, \boldsymbol{\Sigma}, \mathbf{S}, \mathbf{P} | \mathbf{Y}_T)$ is obtained by sampling from (i) $p(\mathbf{S} | \boldsymbol{\theta}, \boldsymbol{\Sigma}, \mathbf{P}, \mathbf{y})$, (ii) $p(\mathbf{P} | \boldsymbol{\theta}, \boldsymbol{\Sigma}, \mathbf{S}, \mathbf{y})$, (iii) $p(\boldsymbol{\theta} | \boldsymbol{\Sigma}, \mathbf{S}, \mathbf{P}, \mathbf{y})$, and (iv) $p(\boldsymbol{\Sigma} | \boldsymbol{\theta}, \mathbf{S}, \mathbf{P}, \mathbf{y})$, where the draws are obtained from the precision sampling method of Chan and Jeliazkov (2009).

Before implementing the algorithm, following Sims and Zha (2006), an approximate estimation of the peak of the posterior density is used to improve the algorithm's convergence. To implement the Markov chain, $\mathbf{S}^{(0)}$ is set to divide the sample into symmetrical parts according to the number

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[2] For example, for $n = 3$, $\mathbf{W}_t$ has the form

$$\mathbf{W}_t = \begin{bmatrix} 0 & 0 & 0 \\ -y_{1,t} & 0 & 0 \\ 0 & -y_{1,t} & -y_{2,t} \end{bmatrix}$$

where y_{it} is the *ith* element of $\mathbf{y}_t$ for $i = 1, 2$.

of regimes considered. In each subsample, using OLS, $\boldsymbol{\theta}^{(0)}$ and $\boldsymbol{\Sigma}^{(0)}$ are estimated, and for the values of $\mathbf{P}^{(0)}$, $p_{ij} = 0.8$ is set for $i = j$ and $p_{ij} = 1/(r-1)$ for $i \neq j$.

For step (i), following Kim and Nelson (1999), Sims et al. (2008), and Bianchi and Melosi (2017), $\boldsymbol{\omega}_{t|t} = \frac{\boldsymbol{\omega}_{t|t-1} \odot \boldsymbol{\eta}_t}{1\prime(\boldsymbol{\omega}_{t|t-1} \odot \boldsymbol{\eta}_t)}$ is used as the algorithm to calculate the filtered and smoothed probabilities, where $\boldsymbol{\omega}_{t+1|t} = \mathbf{P}\boldsymbol{\omega}_{t|t}$; $\boldsymbol{\omega}_{t|t}$ represents the filtered probabilities and $\boldsymbol{\eta}_t$ is the jth element of the conditional density $(\mathbf{y}_t|\mathbf{S}_t = j, \mathbf{y}_{t-1}; \mathbf{P}, \boldsymbol{\theta}_{S_t}, \boldsymbol{\Sigma}_{S_t})$. For recursive calculation, an initial probability of 1/3 is assumed, and $\boldsymbol{\omega}_{t|T} = \boldsymbol{\omega}_{t|t} \odot [\mathbf{P}^{'}(\boldsymbol{\omega}_{t+1|T}(\div)\boldsymbol{\omega}_{t+1|t})]$ is used as the algorithm for smoothed probabilities. The operators $\odot$ and $(\div)$ denote element-wise multiplication and division, respectively.

For step (ii), a Dirichlet distribution is used for the transition probabilities following Chib (1996), which are independent of $\mathbf{y}$ and other model parameters. In each row, $\boldsymbol{P}(i,:) \sim Dir(\boldsymbol{\alpha}_0 + \boldsymbol{\xi}_{ij})$, where $\boldsymbol{\alpha}_0$ is the prior value and $\boldsymbol{\xi}_{ij}$ denotes the number of transitions from state i to state j.

For step (iii), following Chan and Eisenstat (2018a), we have: $(\boldsymbol{\theta}_j|\mathbf{y}, \boldsymbol{\Sigma}, \mathbf{S}, \mathbf{P}) \sim \mathcal{N}(\hat{\boldsymbol{\theta}}_j, \mathbf{K}_{j\theta}{}^{-1})$, where the mean of the normal distribution is $\hat{\boldsymbol{\theta}}_j = \mathbf{K}_{j\theta}{}^{-1}(\boldsymbol{V}_\theta{}^{-1}\boldsymbol{a}_\theta + \boldsymbol{X}_j^{'}\boldsymbol{\Sigma}_j^{-1}\mathbf{X}_j)$ and the variance is $\mathbf{K}_{j\theta} = \mathbf{V}_\theta{}^{-1} + \boldsymbol{X}_j^{'}\boldsymbol{\Sigma}_j^{-1}\mathbf{X}_j$ for $j = 1, ..., r$. The values for $\boldsymbol{a}_\theta$ and $\boldsymbol{V}_\theta$ are defined in Section 4.2.

Finally, for step (iv) is implemented using the conditional distribution of the diagonal elements of $\boldsymbol{\Sigma}_j$ for $j = 1, ..., r$: $(\sigma_j{}^2|\mathbf{y}, \boldsymbol{\theta}, \mathbf{S}, \mathbf{P}) \sim \mathcal{IG}(\boldsymbol{\upsilon}_0 + \frac{T}{2}, \mathbf{S}_0 + \frac{1}{2}\sum_{t=1}^{T}(\mathbf{y}_{jt} - \mathbf{X}_{jt}\boldsymbol{\theta}_j)^2)$, where $\mathcal{IG}$ represents the Inverse Gamma distribution. Steps (i) to (iv) are repeated N times, where N is the sum of burn-in samples and the number of iterations. The values for $\boldsymbol{\upsilon}_0$ and $\mathbf{S}_0$ are defined in Section 4.2. For further details on the estimation algorithm, see Chan and Eisenstat (2018a).

3.3 Comparison Criterion

Following Chan and Eisenstat (2018a), we define the marginal likelihood of model M_m as $p(\mathbf{y}|M_m) = \int p(\mathbf{y}|\boldsymbol{\theta}_m, M_m)p(\boldsymbol{\theta}_m, M_m)d\boldsymbol{\theta}_m$ and use the Bayes Factor (BF) as a measure to compare models, which is defined as the ratio of the marginal likelihoods of two competing models $BF_{ij} = \frac{p(y|M_i)}{p(y|M_j)}$ for $m = i, j$. To estimate the marginal likelihood more efficiently, we use the method of Chan and Eisenstat (2015) based on the importance sampling approach with an estimator based on the integrated likelihood, defined as the conditional density of the data given all latent states:

$$\widehat{p}_{IS}(\mathbf{y}) = \frac{1}{N}\sum_{n=1}^{N}\frac{p(\mathbf{y}|\boldsymbol{\theta}_n)\,p(\boldsymbol{\theta}_n)}{g(\boldsymbol{\theta}_n)}, \tag{4}$$

where $\boldsymbol{\theta}_1, ..., \boldsymbol{\theta}_N$ are independent draws obtained from the importance density $g(.)$, which is optimally chosen through the cross-entropy method. The estimator $\widehat{p}_{IS}(\mathbf{y})$ is consistent and unbiased, and is designed to have minimal variance. If g^* denotes the optimal importance density and $g^* = g(\boldsymbol{\theta}) = p(\boldsymbol{\theta}|\mathbf{y}) = p(\mathbf{y}|\boldsymbol{\theta})p(\boldsymbol{\theta})/p(\mathbf{y})$ is the posterior density, we obtain:

$$\widehat{p}_{IS}(\mathbf{y}) = \frac{1}{N}\sum_{n=1}^{N}\frac{p(\mathbf{y}|\boldsymbol{\theta}_n)\,p(\boldsymbol{\theta}_n)}{g(\boldsymbol{\theta}_n)} = \frac{1}{N}\sum_{n=1}^{N}\frac{p(\mathbf{y}|\boldsymbol{\theta}_n)\,p(\boldsymbol{\theta}_n)}{p(\mathbf{y}|\boldsymbol{\theta})p(\boldsymbol{\theta})/p(\mathbf{y})} = p(\mathbf{y}). \tag{5}$$

To choose g^*, a parametric family $\mathscr{F} = f(\boldsymbol{\theta}; \mathbf{v})$ standardized by the vector $\mathbf{v}$ is used, from which the importance density $f(\boldsymbol{\theta}; \mathbf{v}^*) \in \mathscr{F}$ closest to g^* is obtained. The objective is to find $\mathbf{v}_{ce}^*$ such that the distance between the optimal density and the chosen density $f(\boldsymbol{\theta}; \mathbf{v})$ is minimized:

$$\mathbf{v}_{ce}^* = \arg\min_{\{\mathbf{v}\}}(\int g^*(\boldsymbol{\theta})\log g^*(\boldsymbol{\theta})\,d\boldsymbol{\theta} - p(\mathbf{y})^{-1}\int p(\mathbf{y}|\boldsymbol{\theta})\,p(\boldsymbol{\theta})\log f(\boldsymbol{\theta}, \mathbf{v})\,d\boldsymbol{\theta}). \tag{6}$$

This exercise is equivalent to maximizing the second part, given that the first part does not depend on $\mathbf{v}$. Then, the estimator corresponding to the second part of equation (6) is:

$$\widehat{\mathbf{v}}_{ce}^{*} = \arg\max_{\{\mathbf{v}\}} \frac{1}{L} \sum_{l=1}^{L} \log f\left(\theta_r, \mathbf{v}\right), \tag{7}$$

where $\boldsymbol{\theta}_1, ..., \boldsymbol{\theta}_L$ are draws obtained from the posterior. In summary, the algorithm consists of obtaining these draws from the posterior density $g^*(\boldsymbol{\theta}) = p(\boldsymbol{\theta}|\mathbf{y}) \propto p(\mathbf{y}|\boldsymbol{\theta})p(\boldsymbol{\theta})$ and solving (6), then generating a random sample $\boldsymbol{\theta}_1, ..., \boldsymbol{\theta}_N$ from $f(.; \mathbf{v}_{ce}^*)$ and estimating the marginal likelihood using the proposed estimator in (4).

4 Results

4.1 Data

The models are estimated using quarterly data on seven variables: the growth of the export price index (p_t^*), the growth of general government current expenditure (gc_t), the growth of general government capital expenditure (gk_t), the growth of central government tax revenues (tr_t), the growth of real GDP (y_t), inflation (π_t), and the reference interest rate (i_t). Similar to Salinas and Chuquillín (2013), BCRP (2012), MEF (2015), Fiscal Council (2018), Jiménez et al. (2023), and Meléndez Holguín and Rodríguez (2023), it is considered relevant to disaggregate public spending following the findings of Castro Fernández and Hernández de Cos (2006) and Heppke-Falk et al. (2010) on the differences in the persistence and magnitude of individual current and capital expenditure shocks. The series used are obtained from the BCRP database for the period 1995Q1-2019Q4. Additionally, fiscal variables are deflated using the consumer price index and seasonally adjusted using the Census X-13 filter.

The first column of Figure 1 presents all the variables in levels. For fiscal variables, there is a positive trend throughout the sample, and from 2002 onwards, a change in the trend of the series is observed, reflecting a more stable economy along with a favorable external context (panel (a)), which translates into higher revenues and thus greater fiscal space. Mendoza Bellido and Anastacio Clemente (2022) highlight that fiscal instruments have gained greater relevance in recent decades. Similarly, monetary variables have shown a change in 2002 associated with the adoption of the IT framework, which provided greater price stability to the Peruvian economy.

The second column of Figure 1 shows the variables in annual growth rates, revealing the following stylized facts. First, there is a difference in the volatility of public spending components, with gk_t being more volatile than gc_t, which remains more stable throughout the sample. Second, tr_t follows a similar pattern to the external variable (p_t^*), as highlighted by Ganiko and Montoro (2018), because the volatility of p_t^* is transmitted to the volatility of tr_t through the collection of revenues associated with natural resources; see Urbina and Rodríguez (2023). Third, there has been lower volatility in π_t in recent years, which has helped reduce nominal distortions in the economy. Finally, spending variables show slightly procyclical behavior, especially before the GFC; however, the fiscal position is less defined afterward.

4.2 Priors

The priors for estimating $\boldsymbol{\theta}$ follow a Gaussian distribution $\boldsymbol{\theta} \sim \mathcal{N}(\mathbf{a}_\theta, \mathbf{V}_\theta)$ with $\mathbf{a}_\theta = 0$ y $\mathbf{V}_\theta = 10 \times I_{k_\theta}$, while the priors for estimating the variance follow an Inverse Gamma distribution $\boldsymbol{\Sigma}_j = diag(\sigma_{ij}^2, ..., \sigma_{nj}^2)$ for $i = 1, ..., n$ y $j = 1, ..., r$; where $\sigma_i^2 \sim \mathcal{IG}(\mathbf{v}_0, \mathbf{S}_0)$ with $\mathbf{v}_0 = 5$ and $\mathbf{S}_0 = (\mathbf{v}_0 - 1) \times \mathbf{I}_n$. For the transition probabilities, a Dirichlet distribution $\mathbf{P} \sim Dir(\boldsymbol{\alpha}_0, \boldsymbol{\phi}_{ij})$ is used, depending on the parameter $\boldsymbol{\alpha}_0 = 2 \times \mathbf{I}_r$. In the other models, the following priors are used: $\boldsymbol{\beta} \sim \mathcal{N}(\mathbf{a}_\beta, \mathbf{V}_\beta)$ with $\mathbf{a}_\beta = 0$ and $\mathbf{V}_\beta = 10 \times \mathbf{I}_{k_\beta}$; $\boldsymbol{\gamma} \sim \mathcal{N}(\mathbf{a}_\gamma, \mathbf{V}_\gamma)$ with $\mathbf{a}_\gamma = 0$ and $\mathbf{V}_\gamma = 10 \times \mathbf{I}_\gamma$; y $\boldsymbol{\mu}$ con $\mathbf{a}_\mu = 0, \mathbf{V}_\mu = 10 \times \mathbf{I}_n$. These additional specifications are used in the RS-VAR-SV-R3, RS-VAR-SV-R4, and RS-VAR-SV-R5 models.

4.3 Identification Scheme

The models have been estimated using a recursive identification scheme and a single lag chosen based on the AIC and BIC information criteria. The ordering of the model variables, from the most exogenous to the most endogenous, is as follows: $\mathbf{y}_t = (p_t^*, gk_t, gc_t, y_t, tr_t, \pi_t, i_t)'$.

This ordering positions p_t^* as the most exogenous variable in the model, with all domestic variables responding contemporaneously to shocks in p_t^*. This reflects the condition of a small open economy characterizing Peru. For expenditure variables, following Blanchard and Perotti (2002), we assume a lag in their response to movements in y_t due to governmental constraints associated with the public budget. Tax revenues (tr_t) respond contemporaneously to shocks in p_t^* and y_t because tax collection is closely tied to commodity prices and economic growth. Furthermore, this ordering ensures that changes in tax measures do not contemporaneously affect y_t due to implementation lags after new taxes are announced.

Regarding monetary variables (π_t and i_t), both respond contemporaneously to the rest of the variables in the model, with i_t being the most endogenous variable, as it is assumed that the monetary authority follows a behavior responding to a Taylor rule.

4.4 Evidence of Time-Varying Parameters

As preliminary evidence, following the procedure used in Bijterbosch and Falagiarda (2015) and Guevara (2018), we present the Cogley and Sargent (2005) test, the Kolmogorov-Smirnov (K-S) test, and the t-test. The first statistic compares the trace of the prior variance matrix with the percentiles of the posterior variance matrix. The remaining statistics evaluate by subsamples whether the parameters can be obtained from the same continuous distribution in the case of the Kolmogorov-Smirnov test or from distributions with the same mean in the case of the t-test.

Table 1 presents the results of the three tests, individually evaluating the presence of time-varying parameters in the matrix of contemporaneous relations ($\boldsymbol{\gamma}_t$), the matrix of lagged coefficients and intercepts ($\boldsymbol{\beta}_\mathrm{t}$), and the variance of the innovations ($\mathbf{h}_\mathrm{t}$). Two specific periods have been selected to compare the variability of the parameters (1995Q1-2004Q4 and 2005Q1-2019Q4).

The Cogley and Sargent (2005) test indicates that the trace of the prior variance matrix is close to the median percentile of the posterior variances, suggesting little variation in the parameters. However, the results of the K-S test and the t-test show the opposite, indicating that 71% and 82% of the parameters of $\boldsymbol{\gamma}_t$ and $\boldsymbol{\beta}_\mathrm{t}$ vary between the subperiods, while the variance of the innovations shows total variation, suggesting the inclusion of the stochastic volatility component in the model specification. Both statistical tests indicate that around 81% of the model parameters (68 out of 84 parameters) show time variability, supporting the use of time-varying models, like the findings of Guevara (2018), Meléndez Holguín and Rodríguez (2023), and Jiménez et al. (2023).

4.5 Model Selection

Table 2 presents the log-marginal likelihoods (log ML_{CE}) of the models with up to four regimes, including the CVAR model for comparison purposes. The estimations were performed with $N = 11000$ simulations for 10 parallel chains, discarding the first 1000. This results in a total of 100000 simulations per model, from which 1 out of every 10 is selected, yielding a total of 10000 simulations used to calculate the $\log ML_{CE}$.

An important topic is the relevance of including regime-switching parameters. When comparing the model with full variation (RS-VAR-SV) against the model with constant parameters (CVAR), the latter performs better with a BF of 1.1×10^{51}. This suggests two possible conclusions: either the methodology does not provide significant gains in fitting the data used, or the over-parameterization of the model negatively affects its performance. For further discussion, see Chan et al. (2012), Nakajima and West (2013), and Belmonte et al. (2014). Comparing the restricted models with the RS-VAR-SV and CVAR models, we find that as the time variation of the VAR model coefficients is restricted, performance improves. Although the comparison criterion does not penalize for the number of parameters, there is a loss in model fit due to specification error. Thus, the model that performs best relative to the others completely restricts coefficient variability but includes stochastic volatility (RS-VAR-SV-R1). Compared to the RS-VAR-SV and CVAR models, it achieves BFs of 2.2×10^{56} and 6.4×10^{4}, respectively, making it the selected model according to $\log ML_{CE}$.

Additionally, the introduction of SV improves model specification, and similar to the results of Chávez and Rodríguez (2023) and Alvarado et al. (2023), it is suggested that the primary source of nonlinearity in the model lies in the time variation of variances. Cléaud et al. (2017) emphasize that the variance of shocks affecting the economy evolves more over time than the autoregressive parameters. Comparing the model with variation in all parameters but without SV (RS-VAR-R2) with the RS-VAR-SV-R1 model, the latter is much more suitable with a BF of 7.7×10^{14}, indicating that changes in the occurrence of unexpected shocks are more relevant than changes in the parameters associated with different transmission mechanisms in the model.

Another important point is the number of regimes included. Comparing the same models with two or more regimes based on the log-marginal likelihood, the most suitable specification includes only two regimes. As the number of regimes increases, the goodness of fit decreases.

4.6 State Probabilities

Figure 2 presents the evolution of estimated transition probabilities for the models with two regimes. Specifically, for the RS-VAR-SV-R1 and RS-VAR-SV-R3 models, there is a single regime change in 2002Q1, dividing the first regime (1995Q1-2002Q1) from the second regime (2002Q2-2019Q4). On average, the first regime lasts 11 quarters, while the second regime is more persistent, lasting approximately 32 quarters. The probability of remaining in the first regime is $p_{11} = 0.908$, while the probability of transitioning from the first to the second regime is $p_{12} = 0.092$. For the second regime, the probability of staying in it is $p_{22} = 0.969$, and the probability of moving from the second regime back to the first is $p_{21} = 0.031$.

The regime change in 2002Q1 coincides with five significant events for the Peruvian economy: (i) the adoption of an IT framework; (ii) the strengthening of the Fiscal Responsibility and Transparency Law (FRTL); (iii) Peru's reintegration into external capital markets after more than 70 years, increasing the government's financing sources; (iv) a shift in the composition of government revenues and expenditures;[3] and (v) the beginning of a commodity price supercycle. This combination of events likely triggered the observed regime change, marking different macroeconomic periods for the Peruvian economy, with stronger macro-fiscal fundamentals in the second regime, set within a more favorable macroeconomic context compared to the years preceding the regime

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[3] Santa María et al. (2009) indicate that, under a favorable external context (higher revenues associated with natural resources), significant modifications were made, such as improving the level, composition, and payment profile of external public debt, as well as efforts to reduce the rigidity of public spending and enhance the decentralization of expenditure related to public investment.

change, as highlighted by Mendoza Bellido and Anastacio Clemente (2021).

From this section onward, the discussion will focus on the results of the three top-ranked models: the RS-VAR-SV-R1 model ($r = 2$), the CVAR model, and the RS-VAR-SV-R3 model ($r = 2$), with priority given to the first.

4.7 Relative Volatilities

Table 3 presents the volatilities associated with the second regime in the models that include SV, normalized to the first regime. Based on the results from the RS-VAR-SV-R1 and RS-VAR-SV-R3 models, the volatility of p_t^* in the second regime is more than four times higher than in the first regime. This finding is consistent with Rodríguez et al. (2024), who observe that the volatility of the external variable has increased since 2000, peaking during the 2008 GFC. The increase in p_t^* volatility is linked to the commodity supercycle characterized by high commodity prices, which directly impact tax revenues through income from natural resources. Consequently, similar to Urbina and Rodríguez (2023), the volatility of tr_t has increased in the second regime (ranging from 88% to 130% depending on the model) in response to external shocks.

Regarding public spending components, there have been reductions in their respective volatilities, approximately 12% for gk_t and between 14% and 29% for gc_t. The implementation of new fiscal rules introduced a more controlled environment for managing public finances; however, gk_t remains the most volatile component of public spending compared to gc_t. This is mainly because gk_t includes public investment by local and subnational governments, which have volatile execution rates for the allocated budget.[4] Additionally, in response to unexpected movements in tr_t, the adjustment variable is typically gk_t rather than gc_t, which is tied to rigid expenditures (payroll, debt interest payments, etc.). On the monetary side, the volatilities of π_t and i_t have shown significant reductions in the second regime, around 60% and 97% of what is observed in the first regime, respectively. This "great moderation" in the volatility of monetary variables is related to the adoption of the IT framework, which established greater price stability without nominal distortions, thereby contributing to more stable output growth; see Castillo et al. (2016), Pérez Rojo and Rodríguez (2024) and Portilla et al. (2022).

Finally, despite the increase in external volatility, the moderation in the volatility of internal variables has led to greater stability in y_t for the second regime, with volatility representing 25% of that in the first regime. The increased stability of monetary and fiscal policy in recent years has created a more favorable environment for economic growth, as highlighted by Mendoza Bellido and Anastacio Clemente (2021).

4.8 Impulse Response Functions (IRF)

Figure 3 presents the IRFs of y_t to fiscal shocks, differentiating the results by the two identified regimes. The results have been normalized to present the response of y_t to 1% fiscal shocks. The results from the RS-VAR-SV-R1, RS-VAR-SV-R3, and CVAR models are theoretically consistent. An increase in public spending, whether through current or capital expenditure, positively impacts y_t, while higher tax burdens have the opposite effect.[5]

The differences among the competing models lie in the magnitude and persistence of the shocks. The RS-VAR-SV-R1 model's results are less persistent than its competitors but exhibit a larger

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[4] Jiménez et al. (2018) indicate that between 2003 and 2017, local public investment grew at an average real rate of 15%, showing levels of over 60% and declines of 25%.

[5] For an extensive review of the literature on fiscal shocks and output growth, see Hemming et al. (2001), Kell et al. (2002), Capet (2004), and Kopcke, Tootell, and Triest (2006).

magnitude for all fiscal shocks (except for gc_t in the second regime). Unlike the CVAR and RS-VAR-SV-R3 models, these results are consistent with previous literature regarding the persistence and magnitude of spending shocks; see Jiménez et al. (2023) and Meléndez Holguín and Rodríguez (2023).

Moreover, comparing the first and second regimes of the RS-VAR-SV-R1 model, the IRFs indicate an increase in the response of y_t to spending shocks, but this is not observed for tr_t, shocks, which remain unchanged between regimes. Additionally, the CVAR model's results are similar to the IRF of the first regime (except for the initial impact) but are lower than the IRF of the second regime. In the specific case of tr_t shocks, the RS-VAR-SV-R1 and RS-VAR-SV-R3 models achieve better identification of the shock in both regimes, unlike the CVAR model, which finds an insignificant effect. The following subsections focus on discussing the selected model based on the results in Figure 3.

4.8.1 Current Expenditure Shock (gc_t)

The response of y_t to a gc_t shock is positive in both regimes, with a greater impact in the second regime. A 1% expansion in gc_t increases y_t by 0.13% in the first regime and by 0.19% in the second regime, both peaking after two quarters and remaining statistically significant until the fourth quarter. The increase in the magnitude of the gc_t shock coincides with the findings of Meléndez Holguín and Rodríguez (2023), who found that before 2000, the impact of the gc_t shock was smaller, which can be explained by a procyclical fiscal policy that affected spending effectiveness; see Mendoza and Melgarejo (2006).

4.8.2 Capital Expenditure Shock (gk_t)

The impact of the gk_t shock on y_t remains positive in both regimes and, similar to the gc_t shock, is greater in the second regime. A 1% increase in gk_t generates a 0.20% rise in y_t in the first regime and a 0.38% rise in the second regime. The maximum response of y_t to the gk_t shock occurs initially and dissipates by the seventh quarter. The results show an increased impact of the gk_t shock after the regime change in 2002, consistent with the findings of Jiménez et al. (2023), who observed a growing trend in the response of y_t to gk_t shocks since the 2000s. The differences between the regimes are related to the distinct macro-fiscal fundamentals characterizing each regime. As documented by Santa María et al. (2009), before the regime change, capital expenditure acted as an adjustment variable to meet fiscal consolidation targets, prioritizing fiscal balance over its effectiveness in stimulating economic growth.

4.8.3 Tax Shock (tr_t)

For the tr_t shock, the IRF of y_t responds negatively in both regimes. A 1% increase in tr_t results in a 0.12% decline in y_t in the first regime and a 0.17% decline in the second regime. The maximum impact of the tr_t shock occurs after one year and loses significance after the seventh quarter. Unlike previous literature (Mendoza and Melgarejo, 2008; Sánchez and Galindo, 2013; Guevara, 2018), the impact of the tr_t shock in the RS-VAR-SV-R1 model is better identified and has a greater magnitude than previously found.

The results can be summarized as follows: (i) the impact on y_t is greater with gk_t, which has a larger magnitude than gc_t and tr_t; (ii) The tr_t shock is the least effective, suggesting fiscal policy design should focus on expenditure variables; and (iii) the impact of fiscal shocks has increased in the second regime, especially the gk_t shock, followed by gc_t and tr_t in terms of importance.

4.9 Forecast Error Variance Decomposition (FEVD)

Figure 4 presents the FEVD of y_t for the two regimes in the RS-VAR-SV-R1 and RS-VAR-SV-R3 models, as well as the CVAR model. A response horizon of 20 quarters is shown, where the FEVD is decomposed into p_t^*, gk_t, gc_t, tr_t,y_t, π_t, and i_t shocks.

Based on the results from the RS-VAR-SV-R1 model, y_t shocks account for about 25% of fluctuations in the first regime, which decreases by 22 percentage points in the second regime, reflecting greater stability in economic growth in recent years. The shocks from π_t and i_t follow a similar pattern, jointly accounting for nearly 15% of uncertainty in the first regime but contributing less than 1% in the second regime. This result is related to the adoption of the IT framework, which provided greater predictability to monetary policy managed by the BCRP in a more credible environment; see Portilla et al. (2022).

The combined influence of y_t, π_t, and i_t shocks diminishes in the second regime in contrast to p_t^* shocks, which increased their contribution by 14 percentage points, from explaining about 3% in the first regime to representing 17% of variability in the second regime. Chávez and Rodríguez (2023) highlight that the rise in external shock uncertainty coincides with Peru's greater trade integration with China and the start of the commodity price supercycle. As export prices rise, p_t^* shocks become more significant and a growing source of uncertainty. These results align with findings by Fernández et al. (2020), Rodríguez et al. (2023, 2024) and Guevara et al. (2024).

Regarding fiscal variables, the contribution of gc_t and tr_t shocks has remained stable at around 7% in both regimes. Salinas and Chuquilín (2013) emphasize that various studies agree that the effects of gc_t and tr_t shocks are not persistent and have limited relevance in explaining output variance; see De Castro and Hernández de Cos (2006). Current expenditure growth, documented by Santa María et al. (2009), has followed a stable upward trend since the fiscal consolidation in the 1990s, with rigid expenses related to wages, public debt interest payments, purchases of goods and services, among others, which do not introduce significant uncertainty in output. Additionally, tax revenue in Peru, besides being influenced by external volatility, faces a high level of informality, so tax measures have a reduced effect on output and, therefore, generate little uncertainty. These results are consistent with those of Guevara (2018) and Jiménez et al. (2023).

Regarding gk_t shocks, the results show that it is the main determinant of uncertainty in the FEVD of y_t in both regimes. In the first regime, gk_t shocks account for 52% of variability, while in the second regime, this figure increases by 20 percentage points, and together with p_t^* shocks, explain nearly 90% of total uncertainty. Jiménez et al. (2023) find similar evidence indicating that in the last decade, gk_t shocks have been the most relevant in explaining the FEVD of y_t, with a contribution of nearly 58%. Factors explaining this result include what the Fiscal Council (2016) refers to as "fiscal bias", related to the discretion of applied policies, the political cycle, and the temporal inconsistency in fiscal policy design, among others. Additionally, the execution rate of public investment in local and subnational governments is volatile, reducing the predictability of capital expenditure; see Jiménez et al. (2018). Rojas and Vasallo (2018) indicate that, at the government level, the fiscal impulse of subnational government spending has been procyclical, while national government spending has been countercyclical. Furthermore, public budget formulation considers a fiscal deficit target, which, in the face of unexpected revenue declines, creates an incentive to use capital expenditure as an adjustment variable to meet the budgetary target. Furthermore, Guevara (2018) notes that spending shocks generate more uncertainty in the medium and long term.

4.10 Historical Decomposition (HD)

Figure 5 presents the HD of y_t following the methodology proposed by Wong (2017), aiming to quantify the individual contribution of each shock over time.

During the period 1995-2002, corresponding to the first regime, the average y_t growth rate was 2.9%, in a context where efforts were being made to reduce the instability of monetary and fiscal policy, combined with unfavorable external conditions for the Peruvian economy. In contrast, between 2003 and 2011, excluding the GFC episode, the average y_t growth rate was 6.3%, that is, 3.4 percentage points higher. The growth difference between the two periods is mainly explained by a more favorable external context and fewer nominal distortions from monetary policy. Especially, p_t^* shocks are the main driver of the y_t increase, contributing approximately 1 percentage point of additional growth. Without the external impulse, the average y_t growth would have been 5.3% for the period 2002-2011. Regarding π_t and i_t, shocks, both contributed negatively to y_t dynamics during 1995-2001, as a result of fiscal dominance. However, after the introduction of the IT framework in 2002, the contribution of π_t and i_t shocks ceased to be contractionary and, up to 2011, they contributed positively to y_t by 0.5 and 0.9 percentage points of additional growth, respectively.

Regarding fiscal policy, during the period 1995-2001, the joint contribution of fiscal shocks (gk_t, gc_t, and tr_t) is negative and close to zero despite the economy being in a low-growth scenario. This behavior is explained by austere spending policies and a greater need to generate revenues for fiscal consolidation. Between 2002 and 2011, excluding the GFC quarters, fiscal shocks show a positive and near-zero contribution, even in a context of greater fiscal space and a more favorable external environment, indicating prudent fiscal policy during economic boom periods.

A specific case within the analysis period is the GFC, where fiscal policy assumed a countercyclical stance in response to the economic downturn. The average y_t growth rate dropped from 8.8% in 2008 to 1.1% in 2009. In particular, p_t^* shocks account for about 45% of the growth loss, and together with y_t shocks, they explain 85% of the total decline, jointly contributing to a 6.6 percentage point reduction in y_t. In this scenario, the Ministry of Economy and Finance (MEF) responded with a Fiscal Stimulus Plan, documented in Santa María et al. (2009), focusing on public investment. On average, during 2008Q4-2009Q4, gk_t shocks contributed 2 percentage points to y_t and tr_t shocks contributed 0.8 percentage points, aligning with increased infrastructure spending and measures to boost private consumption. Regarding current expenditure, although the MEF also implemented measures to increase current expenditure, gc_t shocks were, on average, negative, contributing -0.6 percentage points to y_t. Overall, fiscal variables positively contributed 2.2 percentage points to y_t, without which the 2009 GDP growth rate would have been negative (-1.1 percentage points).

For the period 2012-2019, economic growth shows less dynamism, averaging a 3.9% growth rate, which is 2.4 percentage points lower than the supercycle of commodity prices (2002-2011). The lower levels in mineral prices mean that p_t^* shocks explain 65% of the growth rate decline observed in 2012-2019 compared to the supercycle period. Had the external context remained favorable, the average y_t growth would have been 5.4% (1.5 percentage points higher than observed). Additionally, gk_t shocks accounted for 33% of the growth decline (approximately -0.8 percentage points) due to reduced public investment by both subnational and national governments, as documented by Jiménez et al. (2018). Meanwhile, gc_t and tr_t shocks positively contributed to y_t, jointly mitigating the decline in economic growth between 2002-2011 and 2012-2019 by 0.39 percentage points (0.20 percentage points from gc_t and 0.19 percentage points from tr_t), explained by a greater contribution from gc_t shocks as mentioned by Jiménez et al. (2023), increased measures to prevent tax evasion documented by Ganiko and Merino (2018), and tax reductions in areas affected by the 2017 El Niño phenomenon.

4.11 Fiscal Multipliers

The calculation of fiscal multipliers is obtained using the following formula:

$$m_{r,H} = \frac{\Sigma_{h=0}^{H} \frac{\partial \Delta y_{r,t+h}}{\partial \epsilon_{r,t}^{\Delta g_{r,t}}}}{\Sigma_{h=0}^{H} \frac{\partial \Delta g_{r,t+h}}{\partial \epsilon_{r,t}^{\Delta g_{r,t}}}} \times \frac{\bar{y}_r}{\bar{g}_r},$$

where $m_{r,H}$ is the fiscal multiplier for regime r over H horizons. Additionally, $\frac{\partial \Delta y_{r,t+h}}{\partial \epsilon_{r,t}^{\Delta g_{r,t}}}$ is the IRF of y_t in period $t+h$ to a fiscal shock in regime r, $\frac{\partial \Delta g_{r,t+h}}{\partial \epsilon_{r,t}^{\Delta g_{r,t}}}$ is the IRF of the fiscal instrument ($\Delta g_{r,t} = \Delta gc_{r,t}, \Delta gk_{r,t}, \Delta tr_{r,t}$) in period $t+h$ to a shock on itself in regime r, and $\frac{\bar{y}_r}{\bar{g}_r}$ is the inverse of the average weight of the fiscal variable on output in each regime. Table 4 presents the one-year multipliers from the RS-VAR-SV-R1 model and some additional multipliers calculated in the literature using different methodologies.

The gc_t multiplier is positive in both regimes. In the first regime, the gc_t multiplier is 0.35, reaching a maximum value of 0.61. In the second regime, the multiplier increases to 0.53, with a maximum value of 0.85. This increase in the multiplier size may be related to a less procyclical spending behavior in recent years following the regime change, as mentioned in Mendoza and Melgarejo (2008) and Rojas and Vasallo (2018).

For the gk_t multipliers, positive values are also found in both regimes. In the first regime, the gk_t multiplier is 0.55, with a maximum value of 0.73, while in the second regime, the multiplier is 0.66, with a maximum value of 0.93. Mendoza and Melgarejo (2008) argue that there has been an increase in the potency of public spending since the 1990s due to an improvement in the country's macro-fiscal fundamentals.

Regarding the tax multipliers, significant negative values are found in both regimes. The tr_t multiplier is -0.33 in the first regime, with a minimum value of -0.60, and -0.30 in the second regime, with a minimum value of -0.65. Unlike the results for spending variables, the tr_t multipliers do not show a significant change between the two regimes. This may be related to the limited effectiveness of tr_t as a fiscal instrument due to informality and tax evasion in the Peruvian economy, as mentioned by Sánchez and Galindo (2013), and the dependence on the external context discussed by Urbina and Rodríguez (2023).

Contrary to most previous literature (Sánchez and Galindo, 2013; STCF, 2018; BCRP, 2012, 2015, among others), the spending multipliers estimated by the RS-VAR-SV-R1 model are more conservative and below unity. However, studies by Vtyurina and Leal (2016) and Meléndez Holguín and Rodríguez (2023) align with this finding, presenting spending multipliers below unity. One factor that may attenuate the size of the multipliers is the greater trade openness highlighted by Chávez and Rodríguez (2023), as part of the effects of fiscal policy can be redirected towards imported goods and services. Guevara (2018) finds that a higher proportion of exports and imports as a percentage of output reduces spending multipliers for Peru. Additionally, our multipliers are similar to those found by Jiménez et al. (2023) for a model that keeps the equations of gc_t and y_t constant and acts as an average of their results. The authors find that in 1995, the gk_t multipliers were 0.5 and ended near unity by 2019, with an increasing trend. For tax multipliers, the absolute values of the RS-VAR-SV-R1 model are higher than those in previous literature, whose multipliers are close to zero and even positive (Guevara, 2018); however, the consensus that tax multipliers are lower than spending multipliers remains.

The main results of this section can be summarized as follows. First, the size of the gk_t multiplier is greater than the gc_t and tr_t multipliers. Salinas and Chuquillín (2013) highlight that increases in the tax rate or current expenditure do not effectively impact output. According to Vtyurina and Leal (2016), this is because current expenditure is usually associated with transfers and bonuses, which, like tax measures, are intermediated by household savings before effectively stimulating economic activity.

Second, although the fiscal multipliers do not exceed unity, they are higher in the second regime. Comparing the second regime to the first, a 1 sol increase in current expenditure leads to an additional product increase of 0.18 cents (0.35 in the first regime and 0.53 in the second). Similarly, a 1 sol increase in capital expenditure results in an additional product increase of 0.11 cents (0.55 in the first regime and 0.66 in the second). This supports the conclusions of Mendoza and Melgarejo (2008) and Jiménez et al. (2023) about the increasing potency of spending variables associated with better macroeconomic fundamentals.[6] However, studies by Chávez and Rodríguez (2023), Rodríguez et al. (2023), and Urbina and Rodríguez (2023) identify significant macroeconomic and fiscal vulnerability to p_t^* shocks, which may mitigate the increase in multiplier size and condition the effectiveness of fiscal policy.

Finally, the characteristics of the years corresponding to each regime affect the size of the multipliers. The first regime (1995-2002) was characterized by a period of weak public finances, with the primary goal of fiscal consolidation, thus conditioning the effectiveness of fiscal instruments to achieve this objective. In the second regime (2002-2019), the greater availability of resources and better macro-fiscal fundamentals, along with the structural changes documented by Santa María et al. (2009), provided an environment of greater credibility for fiscal policy; see Ilzetzki et al. (2013), Caputo and Saravia (2019) and Martinelli and Vega (2019).

5 Sensitivity of Tax Revenues to External Shocks

Figure 6 shows the IRF of tr_t to p_t^* shocks. The results from the RS-VAR-SV-R1 model indicate that the impact of external shocks is positive in both regimes and shows a positive trend towards the second regime. A 1% increase in p_t^* generates a 0.74% increase in tax revenue in the first regime, while in the second regime, the increase is 0.83%. The external shock remains persistent and positive for seven quarters, peaking one year after the initial shock.

The increased sensitivity of tax revenues to external shocks coincides with Peru's greater trade openness, as discussed in Chávez and Rodríguez (2023). The transmission channel operates through revenues from natural resources, particularly in a mining-centric economy like Peru; see Auty (1999), Ahmad and García-Escribano (2006), Orihuela and Echenique (2019). From 2002 onwards, Urbina and Rodríguez (2023) identify a greater exposure to p_t^* shocks due to the onset of a commodity price super cycle, consistent with our results. However, these effects may be partially mitigated by the decline in mineral prices from 2012 onwards; see Fiscal Council (2018).

Figure 7 presents the FEVD of tr_t. First, it shows that tr_t shocks dominate the short-term dynamics (first two quarters), explaining about 60% of the uncertainty in tax revenue growth before stabilizing around 10%. This relates to changes in tax legislation creating greater short-term uncertainty, especially measures affecting the mining sector. Second, y_t shocks lose relevance in the second regime, explaining 11% of tr_t uncertainty in the first regime but only 1% in the second regime. The greater stability in y_t following monetary and fiscal reforms (Martinelli and Vega, 2019) resulted in a stable proportion of fiscal revenues from the domestic economy, thus not introducing significant uncertainty.

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[6] Guevara (2018) studies the determinants of the size of multipliers and finds that macroeconomic fundamentals are important, especially the debt-to-GDP ratio, which decreased by 25 percentage points during the study period, providing greater space and credibility to fiscal policy.

In the second regime, the reduced influence of y_t shocks was offset by p_t^*, shocks, whose contribution increased from 10% in the first regime to 34% in the second regime, peaking at 46% in the short term. The greater uncertainty generated by external shocks is explained by the importance of commodity prices in natural resource revenues, particularly related to Peru's mining sector, leading to more volatile changes in the tax system and economic distortions; see Cordano and Balistreri (2010).[7] Ganiko and Montoro (2018) show that higher mineral price volatility translates into less predictable tax revenue fluctuations.[8] Expenditure variables also play a significant role in the uncertainty of tr_t, especially gk_t, and together, both components of expenditure explain around 50% of tr_t uncertainty in the long term. This is related to fiscal deficit changes driven by expenditure movements, necessitating increased permanent revenues to support greater fiscal space.

Figure 8 presents the HD of tr_t, showing a significant contribution of p_t^* shocks as a key determinant of tax revenue fluctuations through natural resource-related revenues, which are more volatile compared to other tax revenues linked to domestic demand. This result is consistent with Urbina and Rodríguez (2023) and Jiménez et al. (2023), who found that natural resource revenues have dominated tr_t fluctuations, showing a strong dependence on external conditions. Thus, the average growth of tax revenue increased from 1.8% in 1995-2002 to 12.6% in 2002-2011 (excluding the GFC episode), with 46.3% of this increase explained by p_t^* shocks. Without the external impulse, the average growth of tax revenue would have been 5 percentage points less than observed in the 2002-2011 period, characterized by greater trade openness and high commodity prices: see Chávez and Rodríguez (2023).

From 2012 onwards, the average growth of revenues for this period decreased to 1.1%, with p_t^* shocks contributing to a 10.1 percentage point reduction in the growth of tr_t on average (approximately 88.4% of the decline). Urbina and Rodríguez (2023) find that the drop in the value of mineral exports affected tax collection. This implies that gains in tax revenue through increases in p_t^* are transitory and can be reversed when commodity prices are unfavorable. The greater exposure to p_t^* shocks presents a significant risk that could compromise fiscal sustainability through unexpected declines in tax revenue. In 2001, revenues from commodities represented 3.3%, which changed to 20.3% in 2007, and then gradually decreased in the following years. According to the Fiscal Council (2016), this behavior directly results in large, unforeseen fluctuations in public revenues. A clear example is the GFC, where the growth of tax revenue fell by 18.4 percentage points, with over 90% of the decrease due to negative p_t^* shocks.

6 Results Including Data as of 2022Q4

Additionally, the models have been re-estimated to include the effects of the COVID-19 crisis, as regime-switching VAR models, which model abrupt changes in parameters and variance, can be an interesting alternative for modeling these data.

Table 5 presents the model selection exercise with the extended data, showing changes in the top three positions of the ranking. First, the CVAR model is no longer among the top three best-positioned models. Second, models with three regimes perform better than their two-regime counterparts. Thus, the top-ranked models are: RS-VAR-SV-R1 ($r = 3$), RS-VAR-R2 ($r = 3$), and RS-VAR-SV-R1 ($r = 2$). In this new ranking, the RS-VAR-R2 model improved 10 positions in response to the existence of an abrupt shock like COVID-19, which translates into parameter or variance changes depending on the model used. The results in Table 5 show that, including the

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[7] According to the Fiscal Council (2016), this directly translates into large unforeseen fluctuations in public revenues.

[8] For instance, in 2007, General Government revenues were 4.8% higher than projected in the previous year's Multiannual Macroeconomic Framework (MMM), whereas in 2015, these revenues were 3.3% lower than anticipated.

COVID-19 period, it is preferable to model the COVID-19 shock through a new variance regime change, which aligns with Lenza and Primiceri (2022), who explicitly model the change in shock volatility to account for the abrupt changes in y_t during the pandemic period. The rest of the results to be discussed are available in an Appendix upon request.

The results of the transition probabilities for three regimes show that there is a new economic state from 2020Q1 to 2021Q4, during which mandatory lockdown measures caused sharp declines in economic growth and a subsequent statistical rebound the following year. In this new regime, y_t shocks represent more than 60% of the short-term uncertainty (first two quarters of y_t FEVD), while the remaining participation is dominated by gk_t, shocks, as fiscal policy is expected to respond to such an abrupt decline in economic growth. For their part, p_t^* shocks have a very reduced participation of approximately 1%, consistent with an external context paralyzed to prevent virus transmission between countries.

Regarding the HD of y_t, a drop of more than 30 percentage points was observed in the second quarter of 2020, with more than 90% of this decline due to a strong negative y_t shock, as the COVID-19 crisis began as a strong negative demand shock and continued as a negative supply shock. Supply shocks in this model are represented as exogenous changes in π_t, which does not necessarily reflect the effect of the forced shutdowns due to COVID-19 during this period. Consequently, the y_t shock (interpreted as an aggregate demand shock) dominates the fluctuations observed in the HD for these periods. The remaining percentage of the decline is related to the gk_t shock, as unconventional spending measures were prioritized over public investment, so one of the factors mitigating the growth decline is gc_t, which is related to the increased spending on transfers and payroll in the health sector.

7 Robustness Analysis

Robustness tests are grouped into four exercises: (i) increasing the number of lags ($p = 2$); (ii) alternative ordering; (iii-iv) different economic activity variables: the growth rate of non-primary GDP and the growth rate of private investment; (v-vi) different external variables: the growth rate of the S&P index and the growth rate of the terms of trade. The figures are available in an Appendix upon request.

Exercise (i) involves using two lags in the estimations. The main change occurs in the confidence bands of the IRFs of y_t to gc_t and tr_t shocks, which are wider than in the baseline results. Consequently, gc_t shocks are not statistically different from zero in the second regime, and tr_t shocks impact y_t only after one year. The rest of the results remain consistent.

Exercise (ii) aims to verify if the identification scheme affects the results obtained for tr_t shocks, which have not shown variation over time. In this new ordering, tax measures affect output contemporaneously: $\mathbf{y}_t = (p_t^*, gk_t, gc_t, tr_t, y_t, \pi_t, i_t)'$. First, we find that the maximum response of y_t to tr_t shocks occurs after one year and, contrary to expectations, tr_t shocks positively impact y_t during the first two quarters, similar to the results of Guevara (2018). Regarding the FEVD and HD results of y_t, during the first regime, tr_t shocks have a greater participation in the dynamics of y_t, reducing the importance of y_t shocks.

Exercise (iii) uses the growth rate of non-primary GDP (y_t^{GDPNP}) as an alternative economic activity variable. The IRFs results show that the response of y_t^{GDPNP} to gk_t shocks is greater than in the baseline results. In the first regime, the maximum response is 0.38%, while in the second regime, it is 0.60%. Regarding tr_t, shocks, the response of y_t^{GDPNP} is also greater. The maximum response is -0.15% for the first regime and -0.19% for the second regime. This result suggests that public investment and tax measures have a greater impact on non-primary sectors of the economy.

In contrast, gc_t shocks do not show variation over time and, compared to gk_t and tr_t shocks, have a smaller impact on y_t^{GDPNP} (approximately 0.15% in both regimes).

Exercise (iv) uses the growth rate of private investment (y_t^{INV}) as an alternative economic activity variable. The results show that gk_t and gc_t shocks positively impact y_t^{INV}, both with similar magnitudes, indicating no crowding-out effect. Additionally, the dynamics of y_t^{INV} are dominated by its own shocks and p_t^* shocks, which have similar importance. Regarding the FEVD of y_t^{INV}, the first regime is strongly dominated by y_t^{INV} shocks in a context of lower private investment, while the second regime is equally dominated by three shocks: gk_t, p_t^*, and y_t^{INV}.

Finally, exercises (v-vi) consider two alternative external variables: the S&P GSCI index ($p_t^{S\&PGSCI}$) and the growth rate of the terms of trade (p_t^{TOT}). In both cases, we find that the response of tr_t to $p_t^{S\&PGSCI}$ and p_t^{TOT} shocks is smaller than the results obtained in the baseline specification. However, when using $p_t^{S\&PGSCI*}$ as an external variable, we find a greater increase in the sensitivity of tr_t when comparing both regimes. For every 1% increase in $p_t^{S\&PGSCI}$, there is an additional increase in tr_t of 0.3 percentage points in the second regime (0.8%), compared to the first regime (0.5%). Additionally, whether using $p_t^{S\&PGSCI}$ or p_t^{TOT*}, the results show that their respective shocks are the main determinants of tr_t fluctuations. In particular, $p_t^{S\&PGSCI}$ better captures favorable external shocks for tr_t, while p_t^{TOT} better captures adverse external shocks.

8 Conclusions

This paper examines the impact and evolution of fiscal shocks on Peru's economic growth from 1995Q1 to 2019Q4. The evidence suggests that including time-varying parameters is relevant in a model that relates fiscal variables to economic activity. We find that the model best fitting the data features stochastic volatility as the sole source of variability, indicating significant gains in constraining the variability of certain components to avoid model over-parameterization.

Our main results show that fiscal policy based on public spending positively impacts economic activity. Despite this, inefficiencies in its use are evident, suggesting potential for improving its effectiveness as a countercyclical policy tool. Among public spending components, we find that gk_t has a greater impact than gc_t. Additionally, we find that tax measures have a limited effect on y_t compared to public spending.

Furthermore, over time, the spending variables have increased their capacity to affect y_t, while the impact of tr_t has not changed. These gains have occurred within a context of macro-fiscal stability supported by a favorable external environment. Greater government solvency can influence economic agents' expectations, reduce financing costs, and provide other benefits that enhance the effectiveness of spending variables. Therefore, it is essential to maintain macroeconomic stability and adhere to fiscal rules to optimize fiscal policy tools and enhance their efficiency. The aforementioned results have been corroborated through various robustness exercises. Additionally, the model has been extended to include data related to COVID-19, where the results suggest that, given the limitations of the methodology used, it is preferable to model the COVID-19 shock as a regime change in stochastic volatility.

This study has not explored the possibility of different identification schemes, which represents a future research agenda. Additionally, studying the determinants of fiscal multipliers and assessing the vulnerability of the fiscal space gained in recent years to a reversal of favorable external conditions is recommended for future work.

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Table 1. Tests for Time Variation in Coefficients and Volatility

Trace Test			
Trace	16% perc.	50% perc.	84% perc.
0.280	0.183	0.246	0.348
Kolmogorov-Smirnov test			
$\boldsymbol{\gamma}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
13/21	15/21	13/21	15/21
$\boldsymbol{\beta}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
43/56	46/56	46/56	45/56
$\mathbf{h}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
7/7	7/7	7/7	7/7
t-test			
$\boldsymbol{\gamma}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
21/21	21/21	21/21	21/21
$\boldsymbol{\beta}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
41/56	46/56	46/56	41/56
$\mathbf{h}_t$			
1995Q1-2004Q1	2004Q2-2019Q4	1995Q1-2006Q3	2006Q4-2019Q4
6/7	7/7	7/7	7/7

$\boldsymbol{\gamma}_t$ represents the coefficients of contemporaneous relationships, $\boldsymbol{\beta}_t$ are the coefficients associated to intercepts and lagged variables and $\mathbf{h}_t$ are the variances of innovations. $\boldsymbol{\gamma}_t$ has $(n \times (n-1))/2$ elements which are under the diagonal, $\boldsymbol{\beta}_t$ has n intercepts and $n \times n \times p$ parameters related to lags, and $\mathbf{h}_t$ has n elemets

Table 2. Models Selection

Model	log-ML$_{CE}$	SD	Rank
CVAR	-2198.843	0.011	4
RS-VAR-SV ($r = 2$)	-2316.350	0.457	15
RS-VAR-SV-R1 ($r = 2$)	$\mathbf{-2181.453}$	**0.061**	**1**
RS-VAR-R2 ($r = 2$)	-2215.728	0.077	5
RS-VAR-SV-R3 ($r = 2$)	-2221.866	1.390	7
RS-VAR-SV-R4 ($r = 2$)	-2310.201	0.675	14
RS-VAR-SV-R5 ($r = 2$)	-2237.477	0.817	8
RS-VAR-SV ($r = 3$)	-2351.379	0.478	17
RS-VAR-SV-R1 ($r = 3$)	-2190.528	0.101	2
RS-VAR-R2 ($r = 3$)	-2287.820	0.144	12
RS-VAR-SV-R3 ($r = 3$)	-2294.543	3.531	13
RS-VAR-SV-R4 ($r = 3$)	-2320.936	0.627	16
RS-VAR-SV-R5 ($r = 3$)	-2240.695	0.262	10
RS-VAR-SV ($r = 4$)	-2357.061	0.553	18
RS-VAR-SV-R1 ($r = 4$)	-2198.413	0.132	3
RS-VAR-R2 ($r = 4$)	-2219.234	0.105	6
RS-VAR-SV-R3 ($r = 4$)	-2238.439	1.499	9
RS-VAR-SV-R4 ($r = 4$)	-2369.747	0.769	19
RS-VAR-SV-R5 ($r = 4$)	-2245.856	0.394	11

Each Log ML_{CE} estimate is based on 10,000 evaluations of the integrated likelihood, using 10 parallel chains, where the importance sampling density is constructed using 10,000 posterior draws after a burn-in period of 1,000. Numerical Standard errors are in parenthesis.

Table 3. Relative Standard Deviation for Different Competing Models: Second Regime

Model	RS-VAR-SV	RS-VAR-R1-SV	RS-VAR-SV-R3	RS-VAR-SV-R4	RS-VAR-SV-R5
p_t^*	3.814	4.518	4.616	3.907	4.701
gk_t	1.488	0.876	0.868	1.125	0.930
gc_t	0.653	0.656	0.828	0.499	0.689
y_t	0.337	0.246	0.228	0.253	0.238
tr_t	2.502	1.736	2.400	1.465	1.276
π_t	0.464	0.317	0.433	0.399	0.417
i_t	0.083	0.017	0.025	0.047	0.013

Volatilities have been normalized respect to the first regime for every variable.

Table 4. One Year Fiscal Multipliers

Source	Cicle	Current Spending	Capital Spending	Tax Revenues
BBVA (2014)	Lineal	0.30	1.50	-0.18
MEF (2015)	Expansion	0.82	1.74	
	Recesion	0.95	1.69	
BCRP (2012-2015)	Lineal	0.46	0.75	
Vyturina y Leal (2016)	Expansion	0.05	0.40	
	Recesion	0.10	0.60	
STCF (2018)	Lineal	0.90	1.08	0.29
Meléndez and Rodríguez (2023)	TVP-VAR-SV-R1(a)	0.34	0.44	-0.10
Jiménez et. al (2023)	H-TVP-VAR-SV(b)	0.44	0.89	-0.11
RS-VAR-SV-R1 Model	First Regime	0.35	0.55	-0.33
	Second Regime	0.53	0.66	-0.30
CVAR Model	Lineal	0.38	0.52	-0.27

(a) Mean fiscal multiplier of selected model in Meléndez and Rodríguez (2023).
(b) Results presented are the mean of 4 models shown in Jiménez et al. (2023).

Table 5. Models Selection including COVID-19: 1995Q1-2022Q4

Model	log-ML$_{CE}$	SD	Rank
CVAR	-2586.762	0.02	4
RS-VAR-SV ($r = 2$)	-2705.422	0.14	9
RS-VAR-SV-R1 ($r = 2$)	-2575.697	0.23	3
RS-VAR-R2 ($r = 2$)	-2598.414	0.02	6
RS-VAR-SV-R3 ($r = 2$)	-2618.668	0.87	7
RS-VAR-SV-R4 ($r = 2$)	-2710.603	0.64	10
RS-VAR-SV-R5 ($r = 2$)	-3133.005	1.13	13
RS-VAR-SV ($r = 3$)	-2703.253	0.25	8
RS-VAR-SV-R1 ($r = 3$)	**-2552.300**	**0.21**	**1**
RS-VAR-R2 ($r = 3$)	-2562.473	0.04	2
RS-VAR-SV-R3 ($r = 3$)	-2593.936	1.16	5
RS-VAR-SV-R4 ($r = 3$)	-2804.668	0.89	11
RS-VAR-SV-R5 ($r = 3$)	-3127.246	2.04	12

Each Log ML_{CE} estimate is based on 10,000 evaluations of the integrated likelihood, using 10 parallel chains, where the importance sampling density is constructed using 10,000 posterior draws after a burn-in period of 1,000. Numerical Standard errors are in parenthesis.

Table 6. Robustness Check: Model Selection

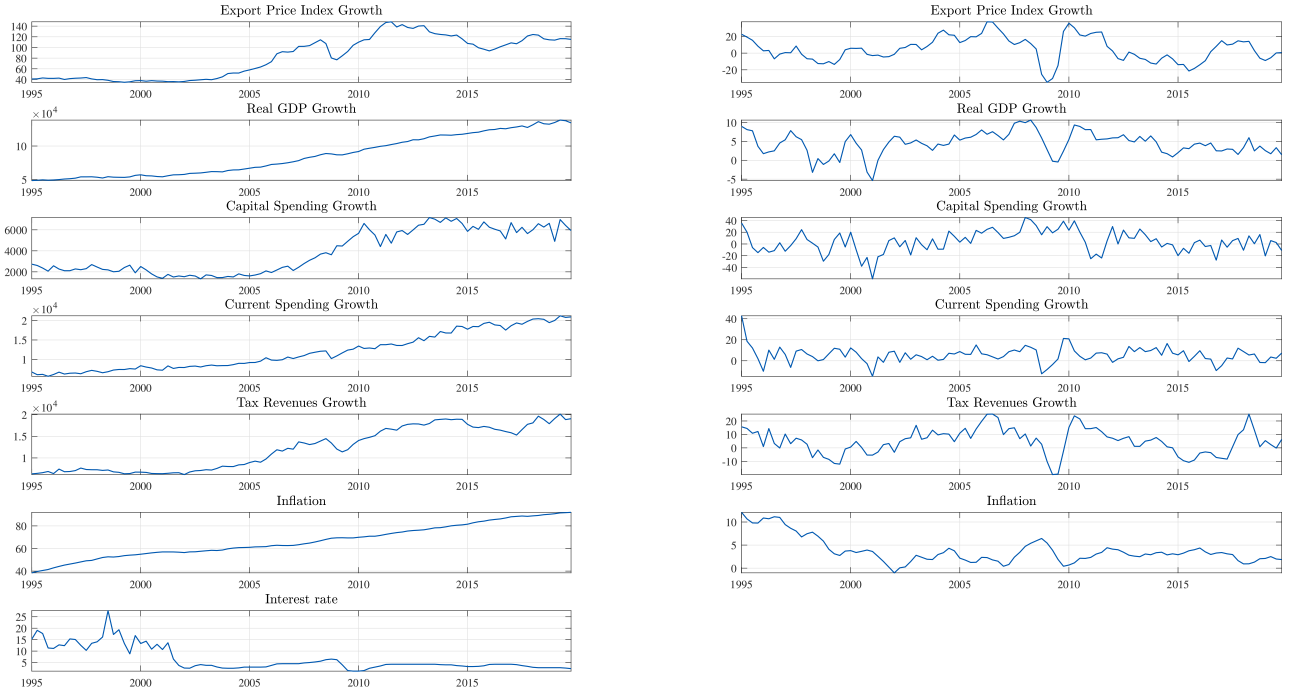
Model	log-ML$_{CE}$	SD	Rank	log-ML$_{CE}$	SD	Rank
	(a) $p = 2$			(b) Alternative Ordering		
CVAR	-2196.446	0.014	2	-2200.937	0.019	2
RS-VAR-SV ($r = 2$)	-2283.286	0.433	6	-2314.706	0.149	7
RS-VAR-SV-R1(r = 2)	**−2187.637**	**0.213**	**1**	**−2186.586**	**0.059**	**1**
RS-VAR-R2 ($r = 2$)	-2224.858	0.071	3	-2281.284	0.134	4
RS-VAR-SV-R3 ($r = 2$)	-2240.754	1.545	4	-2223.941	0.888	3
RS-VAR-SV-R4 ($r = 2$)	-2333.926	0.603	7	-2312.907	0.652	6
RS-VAR-SV-R5 ($r = 2$)	-2248.931	0.263	5	-2281.726	0.644	5
	(c) Non Primary GDP			(d) Investment		
CVAR	-2188.827	0.020	2	-2435.615	0.012	2
RS-VAR-SV ($r = 2$)	-2297.970	0.320	6	-2511.481	0.172	6
RS-VAR-SV-R1(r = 2)	**−2170.761**	**0.075**	**1**	**−2431.231**	**0.069**	**1**
RS-VAR-R2 ($r = 2$)	-2205.196	0.154	3	-2445.923	0.031	3
RS-VAR-SV-R3 ($r = 2$)	-2215.354	1.517	4	-2466.842	1.326	4
RS-VAR-SV-R4 ($r = 2$)	-2308.735	0.678	7	-2586.697	2.569	7
RS-VAR-SV-R5 ($r = 2$)	-2282.440	0.569	5	-2490.806	0.803	5
	(e) S&P GSCI			(f) Term of Trade		
CVAR	-2295.807	0.013	2	-2166.957	0.015	2
RS-VAR-SV ($r = 2$)	-2389.727	0.848	6	-2265.055	0.254	6
RS-VAR-SV-R1(r = 2)	**−2292.760**	**0.190**	**1**	**−2152.586**	**0.081**	**1**
RS-VAR-R2 ($r = 2$)	-2318.350	0.029	3	-2181.578	0.056	3
RS-VAR-SV-R3 ($r = 2$)	-2343.858	1.273	4	-2194.481	1.366	4
RS-VAR-SV-R4 ($r = 2$)	-2415.222	0.546	7	-2267.108	1.633	7
RS-VAR-SV-R5 ($r = 2$)	-2344.692	0.785	5	-2200.561	0.435	5

Each Log ML_{CE} estimate is based on 10,000 evaluations of the integrated likelihood, using 10 parallel chains, where the importance sampling density is constructed using 10,000 posterior draws after a burn-in period of 1,000. Numerical Standard errors are in parenthesis.

Table 7. Robustness Check: Relative Standard Deviations for the Second Regime

Model	RS-VAR-SV	RS-VAR-R1-SV	RS-VAR-SV-R3	RS-VAR-SV-R4	RS-VAR-SV-R5	RS-VAR-SV	RS-VAR-R1-SV	RS-VAR-SV-R3	RS-VAR-SV-R4	RS-VAR-SV-R5
			(a) $lag = 2$					(b) Alternative Ordering		
p^*_t	3.852	4.475	4.553	4.072	4.635	3.805	4.678	4.665	4.250	4.504
gk_t	2.539	0.866	0.845	1.011	1.025	8.093	1.206	1.116	1.411	1.182
gc_t	2.921	0.718	0.796	0.521	0.834	1.244	0.488	0.508	0.487	0.523
y_t	0.431	0.252	0.223	0.249	0.243	0.775	0.275	0.246	0.271	0.255
tr_t	3.481	1.893	2.425	1.765	1.536	1.821	1.089	1.062	1.777	1.358
π_t	0.678	0.351	0.486	0.474	0.446	0.690	0.399	0.423	0.433	0.409
i_t	0.208	0.022	0.026	0.049	0.015	0.216	0.017	0.024	0.048	0.013
			(c) Non Primary GDP					(d) Investment		
p^*_t	7.124	4.043	4.384	3.033	0.459	4.037	4.988	4.754	3.191	4.169
gk_t	5.752	0.808	0.820	1.388	0.786	3.893	0.757	0.689	1.407	0.768
gc_t	8.340	0.656	1.440	0.4898	0.344	2.584	4.079	3.449	0.515	0.634
y_t	1.193	0.279	0.271	0.291	0.215	0.814	0.267	0.255	0.371	0.241
tr_t	2.497	1.597	2.641	1.891	1.485	1.601	2.213	1.987	1.642	1.359
π_t	0.695	0.312	0.552	0.501	0.485	0.765	0.492	0.619	0.521	0.437
i_t	0.923	0.019	0.062	0.046	0.015	0.113	0.019	0.025	0.042	0.015
			(e) S&P GSCI					(f) Term of Trade		
p^*_t	3.614	3.243	3.429	2.721	3.077	4.967	3.264	2.195	2.779	1.666
gk_t	4.544	0.897	0.913	2.713	0.913	4.359	0.881	1.378	1.329	0.952
gc_t	0.690	0.465	0.606	0.478	0.587	2.391	0.472	1.918	0.548	0.590
y_t	0.331	0.239	0.216	0.315	0.251	0.459	0.242	0.227	0.287	0.229
tr_t	2.878	1.066	1.738	1.222	1.147	8.828	1.420	4.817	1.305	0.896
π_t	0.692	0.333	0.506	0.514	0.489	0.677	0.500	0.507	0.514	0.460
i_t	0.052	0.018	0.024	0.047	0.016	0.175	0.017	0.025	0.053	0.012

Volatilities have been normalized respect to the first regime for every variable.


(a) Levels

(b) Growth Rates

Figure 1. Time Series: Sample 1994Q4 - 2019Q4

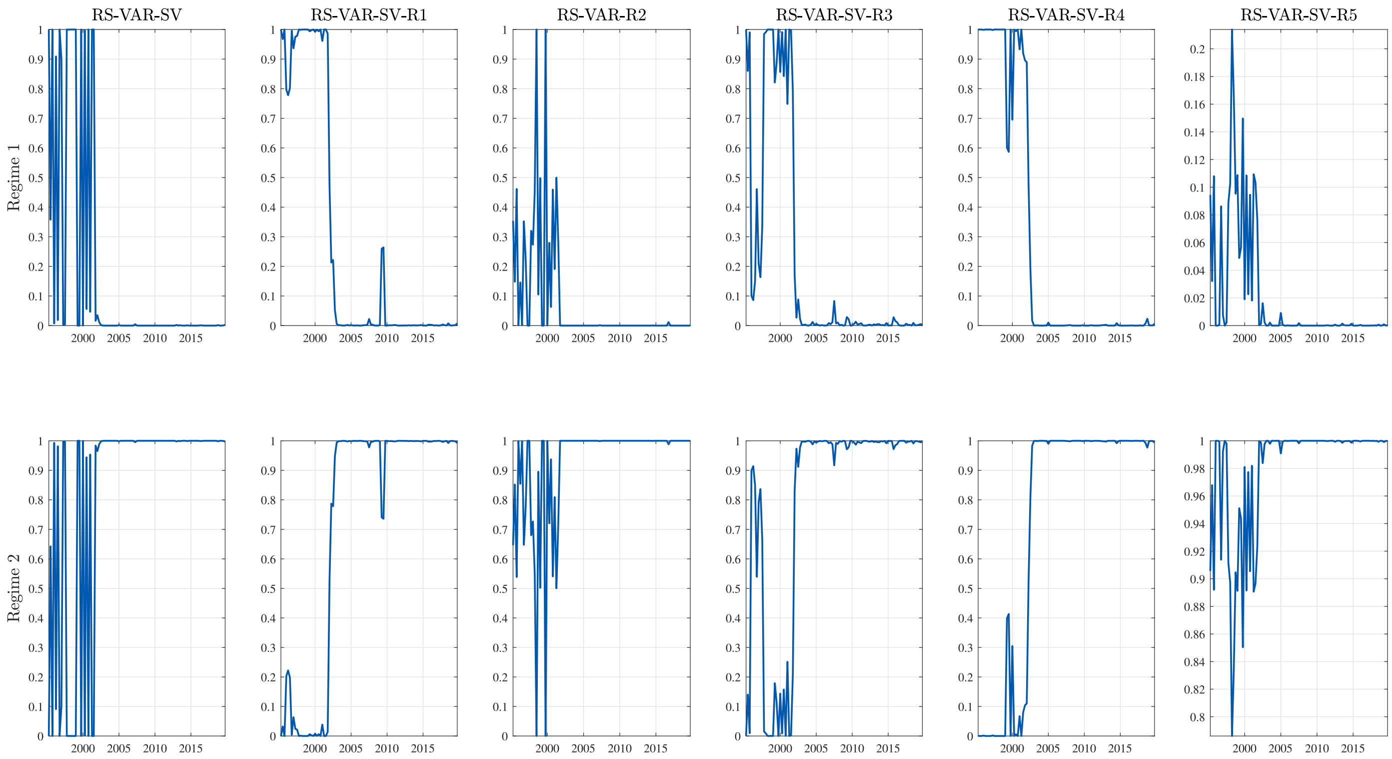


Figure 2. State Probabilities in RS-VAR Models

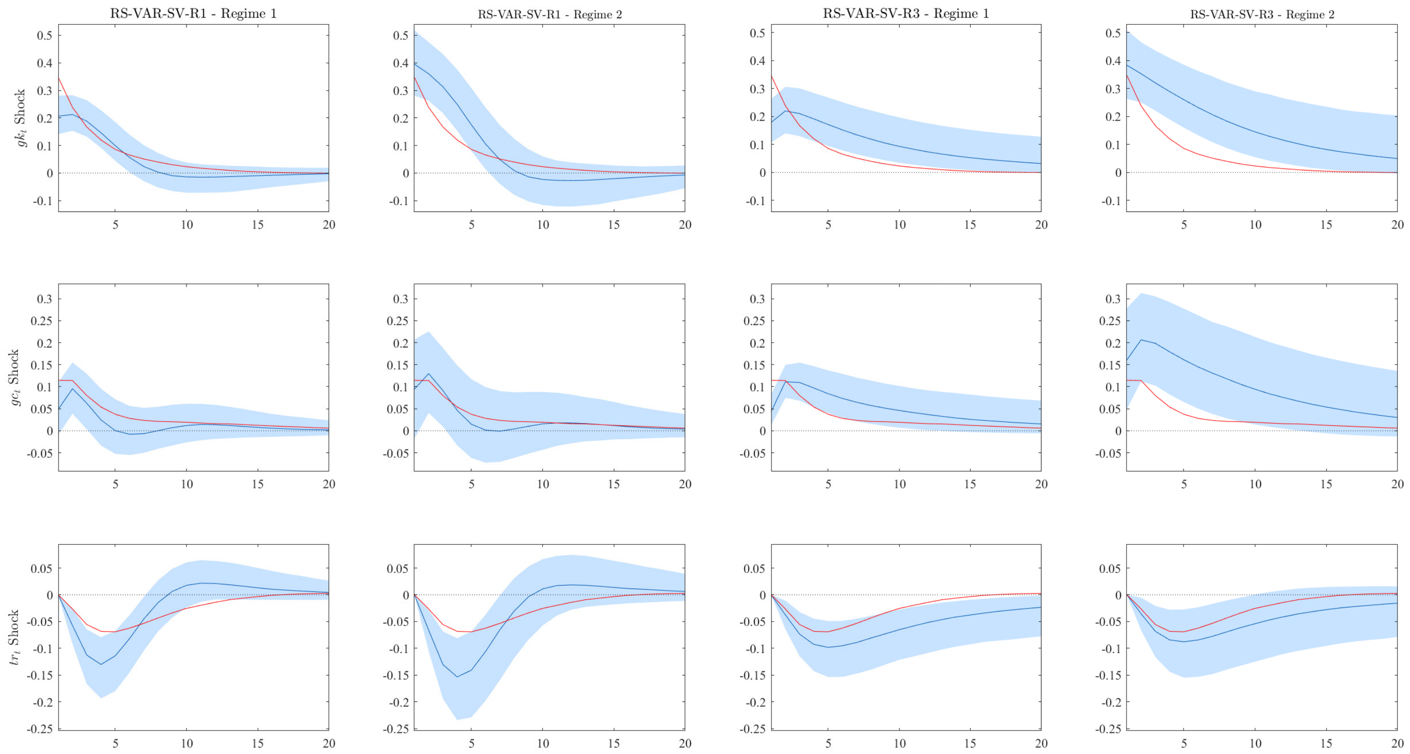


Figure 3. Median Values of IRFs of GDP Growth to Fiscal Shocks. The blue solid line represents the RS-VAR-SV-R1 and RS-VAR-SV-R3 Models and the shaded area, its 68% error band. The red solid line represents the CVAR Model

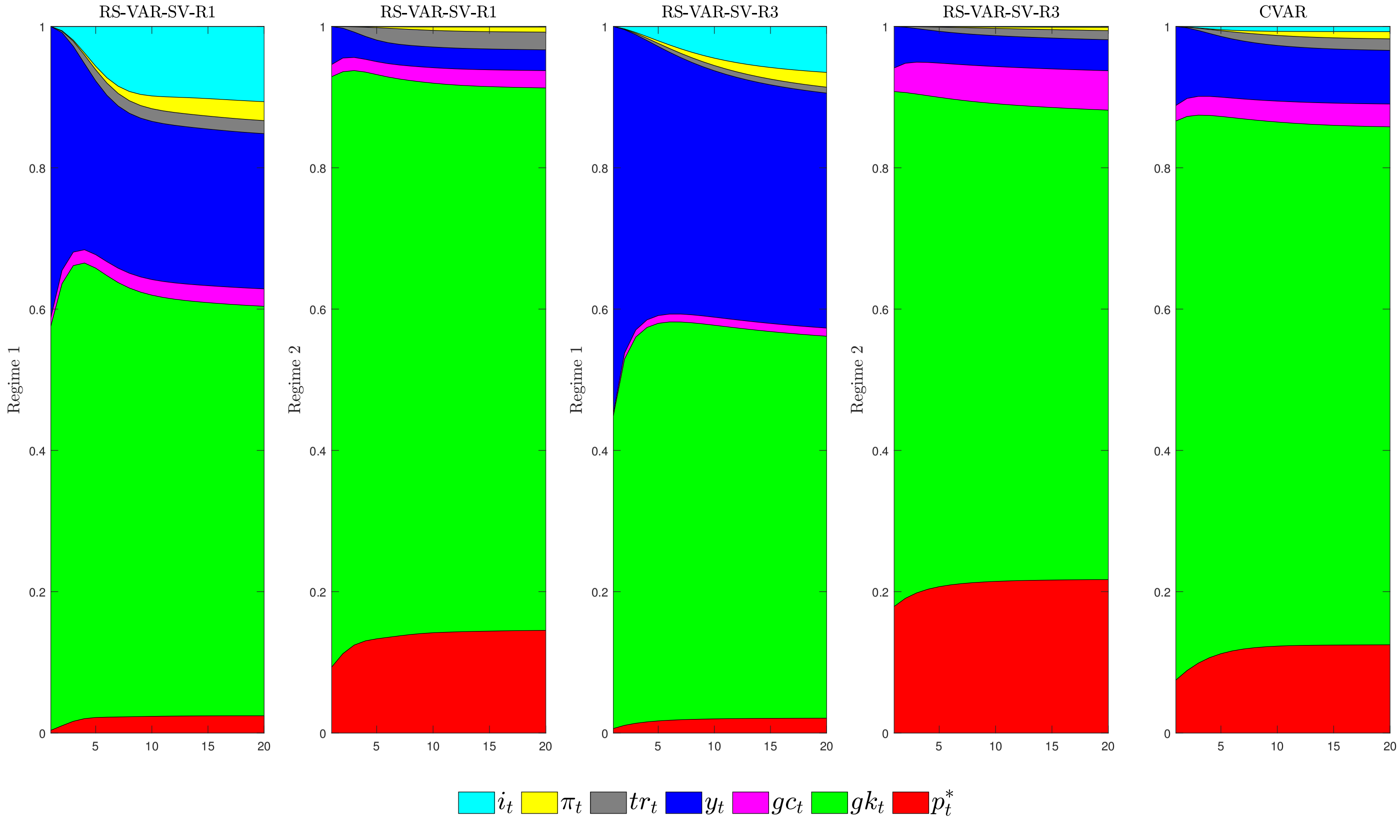


Figure 4. FEVD of GDP Growth in the RSVAR-SV-R1, RS-VAR-SV-R3 and CVAR Models.

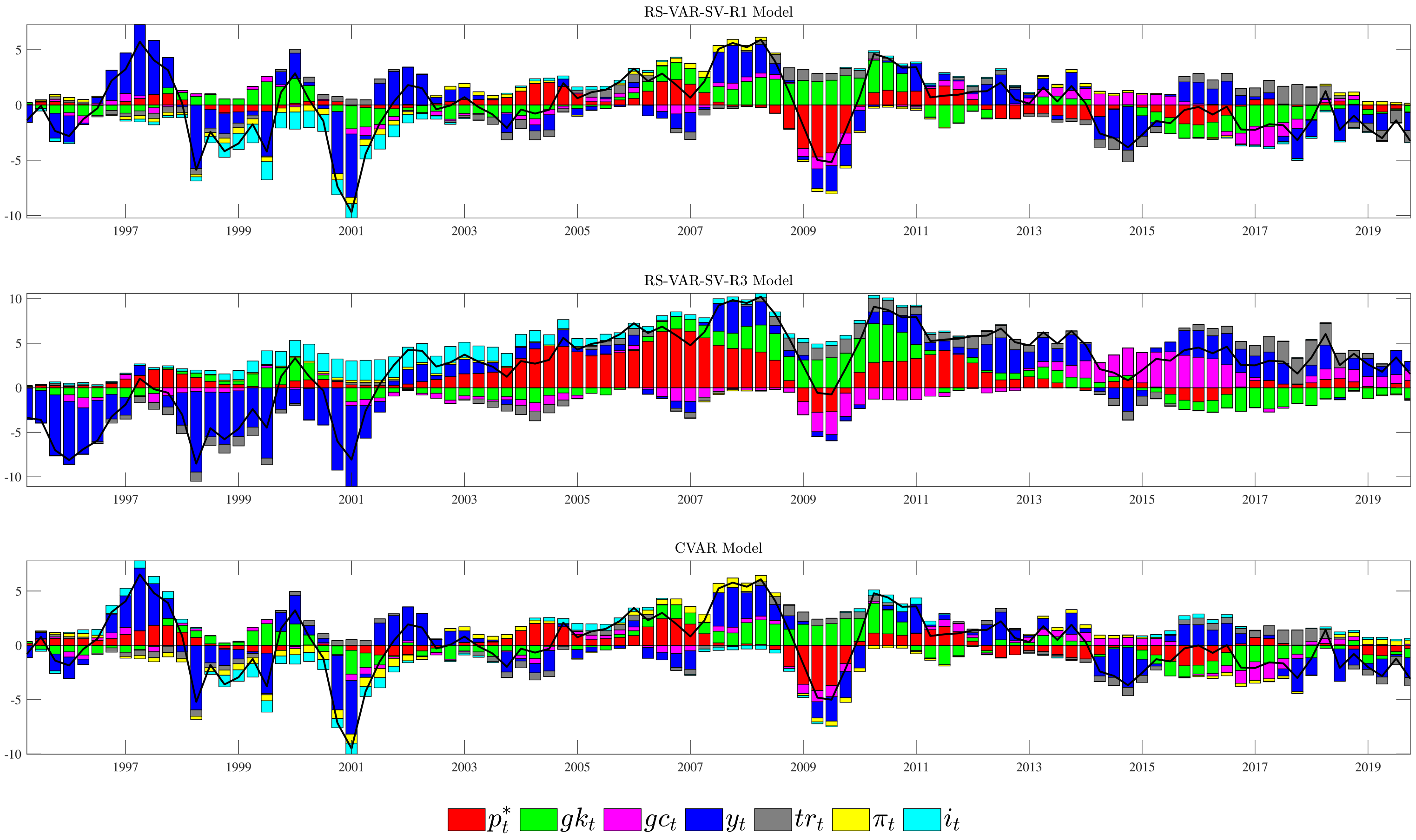


Figure 5. HD of GDP Growth in the RS-VAR-SV-R1, RS-VAR-SV-R3 and CVAR Models.

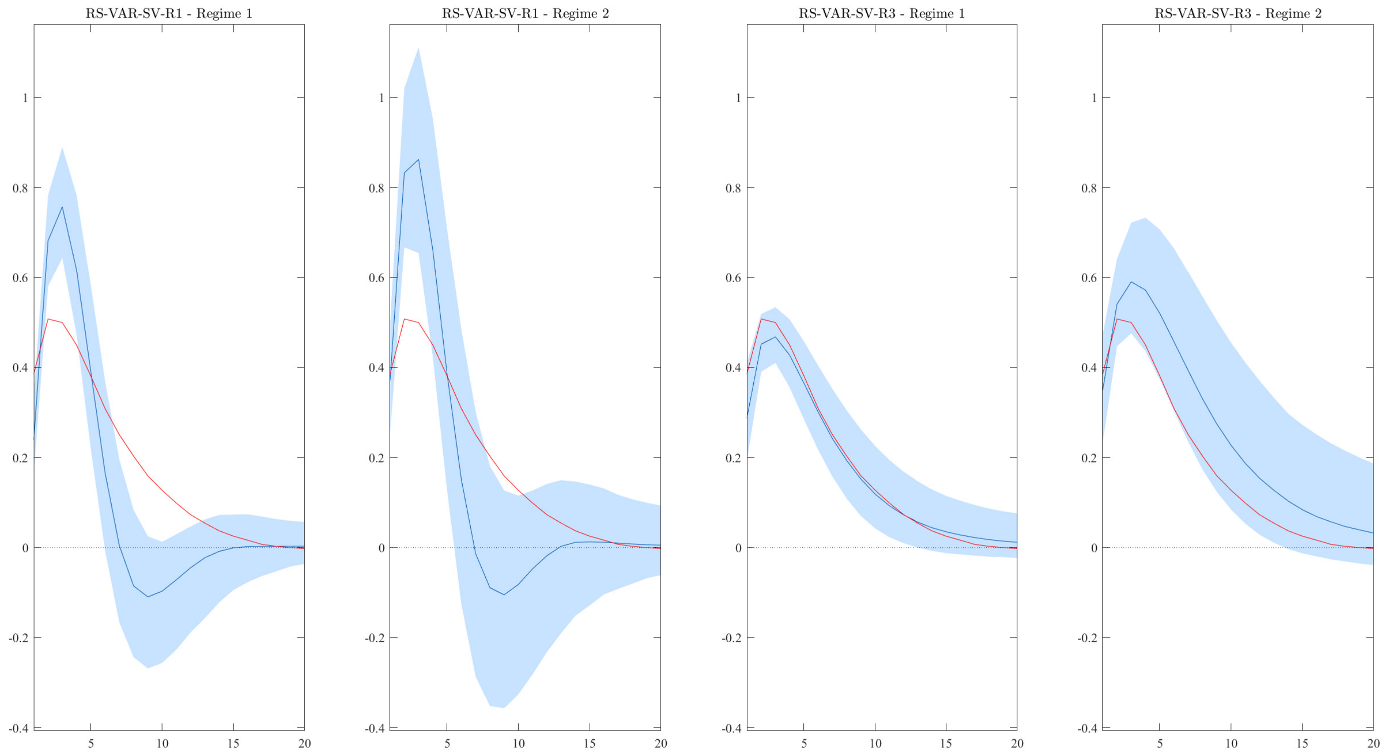


Figure 6. Median Values of IRFs of TR Growth to External Shocks. The blue solid line represents the RS-VAR-SV-R1 and RS-VAR-SV-R3 models and the shaded area, its 68% error band. The red dotted line represents the CVAR model.

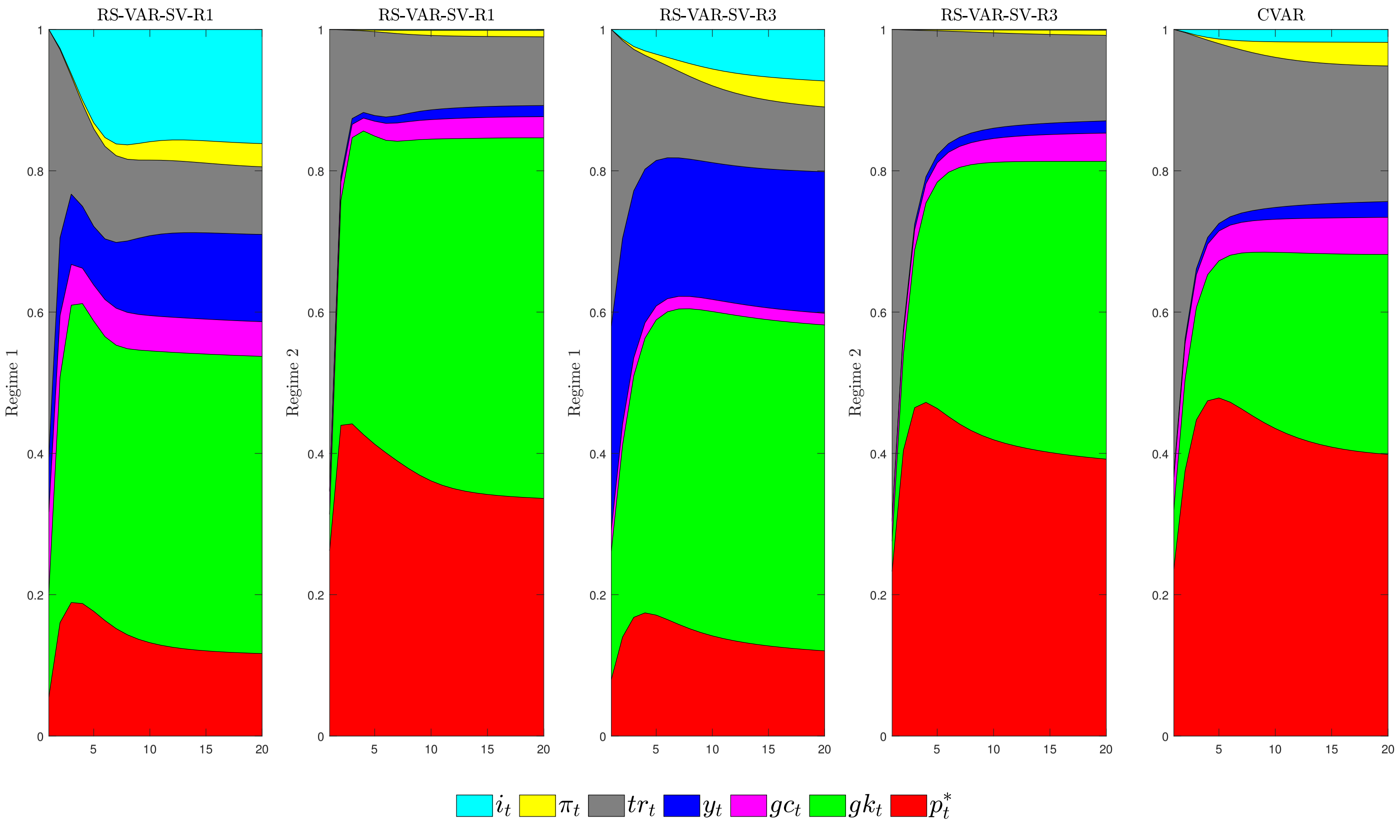


Figure 7. HD of TR Growth in the RS-VAR-SV-R1, RS-VAR-SV-R3 and CVAR Models.

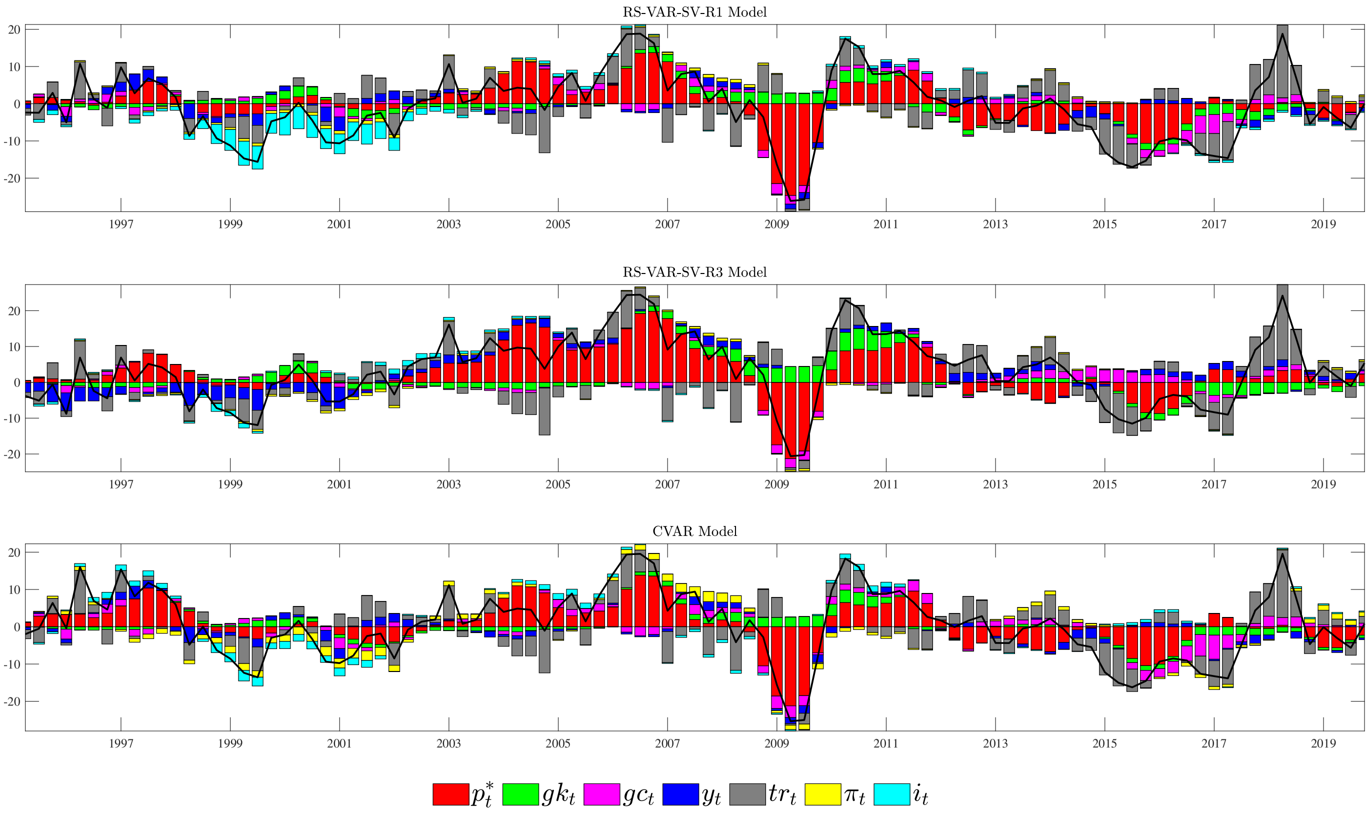


Figure 8. HD of TR Growth in the RS-VAR-SV-R1, RS-VAR-SV-R3 and CVAR Models.

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