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TIME EVOLUTION OF EXTERNAL SHOCKS ON MACROECONOMIC FLUCTUATIONS IN PACIFIC ALLIANCE COUNTRIES: EMPIRICAL APPLICATION USING TVP-VAR-SV MODELS

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Time Evolution of External Shocks on Macroeconomic Fluctuations in Pacific Alliance Countries: Empirical Application using TVP-VAR-SV Models*

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March 15, 2022

Abstract

This article provides empirical evidence on the evolution of the impact of external shocks on the macroeconomic dynamics of the Pacific Alliance (PA) countries. For this purpose, we estimate a family of VAR models that allows time variation (or constancy) of parameters, including the variance matrix (TVP-VAR-SV). The results suggest that: (i) fluctuations from China create the most significant and persistent responses: a 1% increase in China's growth raises growth by 0.3%-0.4% during the first year in Chile, Colombia, and Mexico; and by 0.8% in Peru; (ii) responses to export price shocks evolve considerably over time; e.g., the impact on growth in Chile and Peru tripled in 1994-2009 and then moderated until 2019; and (iii) unexpected Fed rate increases result in significant increases in AP countries' monetary policy rates, an effect that escalates during crisis periods and further deepens the negative impact on domestic output growth. Additionally, variance decomposition shows that external factors explained over 50% of deviations in the domestic variables considered in this work. In particular, the results show that external shock absorption over the sample is higher in Mexico and Peru. In contrast, the change in domestic dynamics in absence of external disturbances would have been milder in Chile and Colombia. Finally, we perform four robustness exercises, which imply the following modifications to the baseline model: (i) changing priors; (ii) modifying two external variables; (iii) using low-dimensional models (4, 5, and 6 variables); and (iv) expanding the model by adding a fiscal policy variable. The results do not change significantly relative to those found using the baseline model.

JEL Classification: C11, C32, F41, F44, F62.

Keywords: Macroeconomic Fluctuations, External Shocks, Autoregressive Vectors with Time-Varying Parameters, Stochastic Volatility, Bayesian Estimation and Comparison, Pacific Alliance Countries.

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Evolución Temporal de Choques Externos sobre Fluctuaciones Macroeconómicas en Países de la Alianza del Pacífico: Aplicación Empírica usando Modelos TVP-VAR-SV*

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15 de Marzo 2022

Resumen

Este artículo proporciona evidencia empírica sobre la evolución del impacto de los choques externos en la dinámica macroeconómica de los países de la Alianza del Pacífico (AP). Para ello estimamos una familia de modelos VAR que permite la variación (o constancia) temporal de los parámetros, incluyendo la matriz de varianzas (TVP-VAR-SV). Los resultados sugieren que: (i) las fluctuaciones de China crean las respuestas más significativas y persistentes: un aumento del 1% en el crecimiento de China aumenta el crecimiento en un 0.3%-0.4% durante el primer año en Chile, Colombia y México; y un 0.8% en Perú; (ii) las respuestas a los choques de precios de exportación evolucionan considerablemente con el tiempo; por ejemplo, el impacto sobre el crecimiento en Chile y Perú se triplicó en 1994-2009 y luego se moderó hasta 2019; y (iii) los aumentos inesperados de la tasa de la Fed dan como resultado aumentos significativos en las tasas de política monetaria de los países AP, un efecto que aumenta durante los períodos de crisis y profundiza aún más el impacto negativo en el crecimiento de la producción interna. Adicionalmente, la descomposición de la varianza muestra que los factores externos explican más del 50% de las desviaciones en las variables domésticas consideradas en este trabajo. En particular, los resultados muestran que la absorción de choques externos sobre la muestra es mayor en México y Perú. En contraste, el cambio en la dinámica interna en ausencia de perturbaciones externas hubiera sido más leve en Chile y Colombia. Finalmente, realizamos cuatro ejercicios de robustez, que implican las siguientes modificaciones al modelo de base: (i) cambio de priors; (ii) modificación de dos variables externas; (iii) uso de modelos de menor dimensión (4, 5 y 6 variables); y (iv) ampliar el modelo agregando una variable de política fiscal. Los resultados no cambian significativamente en relación con los encontrados utilizando el modelo de referencia.

Clasificación JEL: C11, C32, F41, F44, F62.

Palabras Claves: Fluctuaciones macroeconómicas, Choques Externos, Vectores Autorregresivos con parámetros Cambiantes en el tiempo, Volatilidad Estocástica, Estimación y Comparación Bayesiana, Países de la Alianza del Pacífico.

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1 Introduction

Historically, emerging market economies (EMEs) have been considerably affected by evolving international conditions. On the one hand, their good economic performance in 2002-2011 was driven to a considerable extent by a commodity price boom (in turn spurred by a surge in global activity) and a weakened U.S. dollar. On the other hand, economic deceleration caused by the structural implications of the Global Financial Crisis (GFC), and the subsequent withdrawal of monetary stimulus from advanced economies, created lingering policy challenges in EMEs.

This article seeks to explain the external environment's impact on macroeconomic fluctuations in EMEs as a basis for exploring potential responses to future changes in international conditions. Towards this end, we assess and quantify the impact of external shocks on output growth, inflation, and the interest rate in four important Latin American economies: Chile, Colombia, Mexico, and Peru, the members of the Pacific Alliance (PA) founded in 2012.

The PA bloc is intended as a mechanism for economic and trade integration aimed to promote macroeconomic policy coordination among member countries. This is aided by several common historic and economic features: all PA countries are commodity exporters; and have similar monetary frameworks (they adopted inflation targeting (IT) at the turn of the century) and fiscal rules (except Peru). Notably, they show high trade openness indices (55% on average, compared with 42% for the rest of Latin America).

This article seeks to contribute to the literature regarding three issues. First, we find evidence supporting the traditional view that external factors are the main source of macroeconomic fluctuations in EMEs (Calvo et al. (1993), Mendoza (1995), Kose (2002), Izquierdo et al. (2007), Rodríguez et al. (2018), Ojeda Cunya and Rodríguez (2022), Chávez and Rodríguez (2022), and Guevara et al. (2022), among others), in contrast with a body of research that maintains that the impact of external factors is overestimated (Lubik and Teo (2005), Aguirre (2011), and Schmitt-Grohé and Uribe (2018)). Along these lines, we estimate a family of VAR models that allow time variation (or constancy) of parameters, including the variance matrix (TVP-VAR-SV). Time variation is needed to control for eventual non-linearities associated with structural economic changes and heteroscedastic shocks. Additionally, we carry out the estimations using Bayesian methods to address the high dimensionality of the parameter space and non-linearities in the model. Second, we jointly analyze the three transmission channels whereby shocks propagate into small open economies: (i) the trade channel, via trading partners' demand; (ii) the financial channel, via international interest rate movements; and (iii) the price channel, via export price fluctuations. Finally, in view of the scarce evidence on PA countries' behavior during external shocks, we seek to understand the impact of evolving external conditions on the PA bloc's main macroeconomic variables, with an aim to identify macroeconomic reactions and policy implications for each member country.

Using quarterly data for 1994Q1-2019Q4, the results for the four economies suggest that models that allow time variation for certain (not all) groups of parameters and include stochastic volatility (SV) perform better than traditional VAR models and models where all parameters are time-varying, as in Primiceri (2005) and Cogley and Sargent (2005).

The results show that shocks originated by external demand, international prices, and financing conditions have significant and evolving repercussions on macroeconomic performance in PA countries. Real shocks originated in China stand out in impulse-response functions (IRFs): the two-year cumulative impact of a 1% increase in China's growth results in growth increases of 0.6% in Chile and Colombia, 0.8% in Mexico, and 1.2% in Peru. We also find that export price index (XPI) growth varies considerably over time in response to favorable shocks; e.g., the response to XPI growth tripled in Chile and Peru in 1994-2009. Additionally, Fed rate movements create significant and persistent shocks on monetary policy in the PA bloc, with a magnified impact during financial crises.

Historical decomposition reveals a predominantly external influence in 2002-2011, in a context of surging commodity prices and high global growth. In contrast, in 1994-2001 the influence of domestic shocks surpassed that of external ones, in a context of high domestic volatility and idiosyncratic shocks. In line with IMF (2014), we find that external factors explained, on average, more than half of growth, inflation, and interest rate deviations in PA countries over the sample period.

Moreover, we perform four complementary exercises to validate the robustness of the baseline model. To achieve this, we: (i) estimate the model changing the diffuse priors for more informative ones (using a training sample); (ii) modify two external variables (Fed interest rate and XPI growth); (iii) assess low-dimensional models (4, 5, and 6 variables); and (iv) extend the baseline model by adding a fiscal policy variable. The results do not change significantly relative to those calculated for the baseline model.

The article is divided as follows. Section 2 summarizes the literature on the relationship between external factors and economic performance in small open economies, with emphasis on the PA bloc. Section 3 describes the proposed methodology for estimating a family of TVP-VAR-SV models following Chan and Eisenstat (2018). Section 4 examines the results for the baseline model and discusses its economic interpretation. Section 5 suggests alternative exercises to validate the robustness of the proposed baseline model. Section 6 summarizes the conclusions. It should be noted that this article shows only the best-fitting models for each country. An appendix showing the figures and results for other models, as well as the robustness exercises, is available on request.

2 Review of the Literature

This section summarizes the main research on external shocks and their impact on EMEs' macroeconomic performance, especially in Latin America.

In the context of massive capital inflows into Latin America at the end of the 1980s, Calvo et al. (1993) emphasize the role of external factors in Latin American countries' economic cycles (around 50% of the forecast error variance for the real exchange rate in most of them). However, these results contrast with Ahmed and Murthy (1994), Hausmann and Gavin (1995), and Hoffmaister and Roldós (1997), who conclude that, in general, external factors have a relatively limited role; and that aggregate supply shocks are the main driver of economic fluctuations in developing economies.

Apart from methodological differences, Mendoza (1995) uses a real-business-cycle (RBC) model to support Calvo et al. (1993), arguing that external shocks (terms of trade in particular) explain around 50% of output and exchange rate variability. Kose (2002) applies a dynamic stochastic general equilibrium (DSGE) model for a small open economy, finding that global price shocks explain a significant share of economic cycle variability in developing economies.

Canova (2005) finds that the transmission of U.S.-originated shocks explains 19%-56% of the variance of eight main macroeconomic variables in eight Latin American countries. The author underscores the role of the financial channel in magnifying external disturbances. Using a different identification strategy, Mackowiak (2007) uses SVAR models to estimate that external shocks explain around 49% of the output variance in eight EMEs.

Izquierdo et al. (2007) and Osterholm and Zettelmeyer (2007) model the transmission of international shocks to growth in Latin America via VECM and BVAR specifications, respectively, finding that external factors explain 50%-60% of growth in PA countries.

Cesa-Bianchi et al. (2011) estimate a global VAR (GVAR) model for 26 economies, including five Latin American countries, to capture possible heterogeneities in the transmission of shocks to EMEs. They find that the long-term impact of an output shock in China on a typical Latin American economy has tripled since the mid-1990s. In contrast, the long-term impact of a U.S.

growth shock halved over the same period. In the same line, Winkelried and Saldarriaga (2013) confirm that China's increased weight in the global economy has resulted in greater impacts on third-party countries, especially small open economies like Latin American countries.

There is body of debate specifically about the relevance of external factors for PA countries. Using a VAR model with data for 1986-1997, Calvo and Mendoza (1998) identified a Granger causality from terms of trade to economic activity in Chile. Following a similar strategy, a work by the IMF (2012) assesses the sensitivity of economic activity to external shocks; and verifies that the latter (especially movements in copper price and changes in international financial conditions) have a significant impact on production in Chile. Moreover, Fornero et al. (2016) confirm that commodity price shocks are an important driver of business cycles in six commodity exporting countries (including Chile and Peru); and that such shocks affect output significantly through their impact on mining investment.

Regarding Colombia, Abrego and Osterholm (2008) find that external factors explain around 40% of output dynamics. The main external factors are global output (17%) and foreign direct investment (14%); and, to a lesser extent, the U.S. interest rate (10%) and the EMBI (10%). Additionally, Mahadeva and Gómez (2009) identify a high participation of real export prices and capital flows in Colombia's output fluctuations. Echevarría et al. (2012) underscore that the relevance of external factors has not been stable over time, arguing that, during the GFC, they explained close to 75% of Colombia's output dynamics, in contrast with 35% in 1998-1999. More recently, Melo-Becerra et al. (2020), using a more flexible empirical approach to the relationship between international conditions and output, estimated the impact of oil prices and output shocks; and identified different SV patterns in the variables, suggesting the relevance of methodologies with time-varying parameters and heteroscedastic variance (TVP-VAR-SV).

In the case of Mexico (an oil country like Colombia), Del Negro and Obiols-Homs (2001) conclude that changes in U.S. output, prices, and interest rates largely explain Mexico's output variance, even to a greater extent than oil prices. Sosa (2008) and Blecker (2009) support these findings, underscoring that oil and U.S. shocks are the main drivers of output fluctuations in Mexico, especially since the enactment of the North American Free Trade Agreement (NAFTA). Recently Carrillo et al. (2020) examined these U.S.-Mexico co-movements, finding that U.S. shocks explain around 75% of Mexico's expected output fluctuations over a three-year horizon.

In the case of Peru, an initial work by Dancourt et al. (1997) suggests that long-term macroeconomic performance is independent from development strategies and significantly linked to external shocks. Moreover, Nolazco et al. (2016), Mendoza and Collantes Goicochea (2017), and Rodríguez et al. (2018) use different methodologies to verify that external drivers explain 50%-96% of domestic output fluctuations. In the same line, a research by MEF (2019) calculates a 55% contribution.

Recent studies like Ojeda Cunya and Rodríguez (2022) and Rodríguez and Vassallo (2021) emphasize the advantages of using time-varying parameters and SV in discussing the role of external shocks in Peru's economic performance. These studies find that the share of external shocks in the variance of growth forecasts has increased over time, from about 10% in the mid-1990s to over 80% around the GFC, suggesting Peru's considerable dependence on, and vulnerability to, fluctuations in global variables.

As mentioned above, a significant body of global and regional literature points to external factors as the main driver of macroeconomic dynamics in EMEs like PA countries. However, recent studies, like Schmitt-Grohé and Uribe (2018), challenge this conclusion. Using specific SVAR models for 38 EMEs, they find that unanticipated terms-of-trade changes explain just around 10% of output variability on average. As their results contrast with the current standard approach, the authors suggest using commodity prices instead of aggregate indices for export/import unit values to improve the empirical model (a recommendation that we have considered in this study).

This work adheres to the methodology used initially by Cogley and Sargent (2005) and Primiceri (2005), who estimate TVP-VAR-SV models to assess monetary policy and its impact on the U.S. economy. Additionally, Primiceri (2005) uses recursion restrictions in the contemporaneous relationship matrix to provide a structural interpretation of the overall dynamics. Moreover, Clark (2011) and D'Agostino et al. (2013) show the fit and forecasting advantages of using models with time-varying parameters and SV.[1] At the same time, despite the improvements provided by flexible models, recent works like Chan et al. (2012), Nakajima and West (2013), and Belmonte et al. (2014) point out potential problems from overparameterization. In this context, we use a new estimation strategy suggested by Chan and Eisenstat (2018), who, in addition to the original TVP-VAR-SV model, implement six restricted versions based on different assumptions for time variability (or constancy) of intercepts, VAR coefficients, and the variance matrix. This strategy seeks to isolate the role of time variability for different groups of parameters.

In addition to addressing possible non-linearities in the relationship between external shocks and domestic macroeconomic dynamics, this study differs from previous work in considering the three main channels for the transmission of shocks to PA economies: prices, trade, and financial conditions. Towards this end, we performed a set of estimations starting from a baseline model with seven variables (four external and three domestic) and later carried out robustness exercises to support our main findings.

3 Empirical Strategy

3.1 The Econometric Model

We use a family of seven VAR models with different restrictions associated with the dynamics and nature of the parameters. First, we describe the TVP-VAR-SV model and then incorporate models identified as restricted versions into the analysis. Following Chan and Eisenstat (2018), we define an $n \times 1$ vector $y_t = (y_{1,t}, ..., y_{n,t})'$ of endogenous variables in period t. Therefore, the TVP-VAR-SV model can be expressed as:

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

where μ_t is an $n \times 1$ vector of time-varying intercepts, $\mathbf{B}_{1,t}...\mathbf{B}_{p,t}$ are the $n \times n$ matrices of coefficients associated with the vector of lagged endogenous variables, $\mathbf{B}_{0,t}$ is the $n \times n$ lower triangular matrix of contemporary effects with diagonal unit values, and $\boldsymbol{\Sigma}_t = diag(\exp(h_{1,t}), ..., \exp(h_{n,t}))$. The movement law for the logs of all variables $\mathbf{h}_t = (h_{1,t}, ..., h_{n,t})'$ is specified as an independent random walk:

$$\mathbf{h}_t = \mathbf{h}_{t-1} + \boldsymbol{\zeta}_t, \qquad \boldsymbol{\zeta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_h), \tag{2}$$

where the initial conditions $\mathbf{h}_0$ are also parameters to be estimated.

As the system in (1) is in structural form and the variance matrix $\boldsymbol{\Sigma}_t$ is diagonal, the estimation can be carried out recursively. For this purpose, we rewrite the model. We consider the $k_\beta \times 1$ vector of intercepts and coefficients associated with the lagged observations $\boldsymbol{\beta}_t = vec((\boldsymbol{\mu}_t, \mathbf{B}_{1,t}, ..., \mathbf{B}_{p,t})')$. The second $k_\gamma \times 1$ vector, containing the time-varying coefficients that characterize contemporaneous relationships between variables, is denoted by $\boldsymbol{\gamma}_t$. It should be noted that $k_\beta = n(np+1)$ and $k_\gamma = n(n-1)/2$. Therefore, equation (1) can be rewritten as:

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

[1] For more details about stochastic volatility, see Harvey et al. (1994), Kim et al. (1998), and Chib et al. (2006).

where $\widetilde{X}_t = \mathbf{I}_n \otimes (1, \mathbf{y}'_{t-1}, ..., \mathbf{y}'_{t-p})$ and $\mathbf{W}_t$ is an $n \times k_\gamma$ matrix that contains the appropriate elements of $-y_t$[2]. If $\mathbf{X}_t = (\widetilde{\mathbf{X}}_t, \mathbf{W}_t)$, we can simplify the above model to obtain a generic space-state representation:

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

where $\boldsymbol{\theta}_t = (\boldsymbol{\beta}'_t, \boldsymbol{\gamma}'_t)'$ has a $k_\theta = k_\beta + k_\gamma$ dimension and the coefficients have a random walk behavior:

$$\boldsymbol{\theta}_t = \boldsymbol{\theta}_{t-1} + \boldsymbol{\eta}_t, \quad \boldsymbol{\eta}_t \sim \mathcal{N}(\mathbf{0}, \boldsymbol{\Sigma}_\theta), \tag{4}$$

where the initial conditions $\boldsymbol{\theta}_0$ are also parameters to be estimated.

A standard TVP-VAR-SV specification takes all parameters in $\boldsymbol{\theta}_t = (\boldsymbol{\beta}'_t, \boldsymbol{\gamma}'_t)'$ and the variance matrix $\boldsymbol{\Sigma}_t$ to be time-varying. However, in order to assess the individual contribution of the two groups of parameters $\boldsymbol{\beta}_t$ and $\boldsymbol{\gamma}_t$, we consider three variants of the general model, all with SV. Along these lines, we consider: (i) a TVP-VAR-R1-SV model, where the parameters associated with lagged observations and intercepts in the VAR remain constant (i.e., $\boldsymbol{\beta}_t = \boldsymbol{\beta}_0$); (ii) a TVP-VAR-R2-SV model, where the coefficients that characterize contemporaneous relationships remain constant (i.e., $\boldsymbol{\gamma}_t = \boldsymbol{\gamma}_0$), as proposed by Cogley and Sargent (2005); (iii) a TVP-VAR-R3-SV model, where only the intercepts $\boldsymbol{\mu}_t$ are time-varying; (iv) a TVP-VAR model with time-varying coefficients but no SV, to isolate the effect of time variation, as suggested by Cogley and Sargent (2001); (v) a CVAR-SV model with constant VAR parameters and SV; and (vi) a traditional VAR (CVAR) model with neither time-varying parameters nor heteroscedastic variance.

3.2 Estimation and Criteria for Model Comparison

We estimate the above models using Gibbs Sampling, where draws are based on the precision sampling proposed by Chan and Jeliazkov (2009). The authors modify the algorithm introduced by Primiceri (2005), as discussed by Del Negro and Primiceri (2015). Complete estimation details can be found in Section 4 and Appendix A of Chan and Eisenstat (2018). It is convenient to assume that the initial values of the coefficients, covariances, log-volatilities, and hyperparameters are independent from each other. We assume that the priors for the initial states of the time-varying coefficients and the logs of the standard errors follow a Normal distribution: $\boldsymbol{\theta}_0 \sim \mathcal{N}(\mathbf{a}_\theta, \mathbf{V}_\theta)$, $\mathbf{h}_0 \sim \mathcal{N}(\mathbf{a}_h, \mathbf{V}_h)$. We also define a diagonal matrix of error covariances for the state equations of the form $\boldsymbol{\Sigma}_\theta = diag(\sigma^2_{\theta_1}, ..., \sigma^2_{\theta_{k_\theta}})$, $\boldsymbol{\Sigma}_h = diag(\sigma^2_{h_1}, ..., \sigma^2_{h_n})$. The diagonal elements in $\boldsymbol{\Sigma}_\theta$ and $\boldsymbol{\Sigma}_h$ are distributed independently as $\sigma^2_{\theta_i} \sim \mathcal{IG}(v_{\theta_i}, S_{\theta_i})$, $\sigma^2_{h_j} \sim \mathcal{IG}(v_{h_j}, S_{h_j})$, $i = 1, ..., k_\theta$, $j = 1, ..., k_h$ where $\mathcal{IG}$ denote the Inverse-Gamma distribution. Values for the hyperparameters are given in Section 4.2.

We use two indicators to compare the models: marginal likelihood (estimated using the Cross-Entropy method) and the Deviation Information Criterion (DIC). A frequently used metric for comparing Bayesian models is the Bayes Factor (BF), calculated as the ratio of marginal likelihoods $p(\mathbf{y}|M_i)/p(\mathbf{y}|M_j)$, where the numerator and denominator represent the marginal likelihoods of models i and j, respectively. The marginal likelihood is obtained by integrating the likelihood

[2] For example, when $n = 3$, $\mathbf{W}_t$ 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 $i = 1, 2$.

function with respect to the prior distributions of the parameters; i.e., $p(\mathbf{y}) = \int p\left(\mathbf{y}|\boldsymbol{\theta}\right) p\left(\boldsymbol{\theta}\right) d\boldsymbol{\theta}$. However, as this calculation method is time-consuming, we use the importance sampling approach proposed by Chan and Eisenstat (2015), which provides a more accurate and efficient way to calculate the marginal likelihood. Complete details concerning integrated likelihood estimation may be found in Section 4 and Appendix B of Chan and Eisenstat (2018).

Additionally, as a complementary indicator to the BF, we calculate the DIC, as originally proposed by Spiegelhalter et al. (2002). Using the notation suggested by Chan and Grant (2016), we define the goodness of fit as $D\left(\boldsymbol{\theta}\right) = -2\log f\left(\mathbf{y}|\boldsymbol{\theta}\right) + 2\log h(\mathbf{y})$, where $f(\mathbf{y}|\boldsymbol{\theta})$ is a function of the likelihood of the model and $h(\mathbf{y})$ is a function of the data. We also use a measure of the complexity of the model through the effective number of parameters, defined as $p_D = \overline{D\left(\boldsymbol{\theta}\right)} - D(\widetilde{\boldsymbol{\theta}})$, where $\overline{D\left(\boldsymbol{\theta}\right)} = -2E_{\boldsymbol{\theta}}\left[\log f\left(\mathbf{y}|\boldsymbol{\theta}\right) y\right] + 2\log h(\mathbf{y})$ is the posterior mean deviation and $\widetilde{\boldsymbol{\theta}}$ is an estimator of $\boldsymbol{\theta}$.

Using the above definitions, we present the DIC as the sum of the posterior mean deviation and the actual number of parameters: $DIC = \overline{D\left(\boldsymbol{\theta}\right)} + p_D$. After replacing some values and applying certain conditions, we obtain the following DIC version, which we use in this article:

$$DIC = -4E_{\boldsymbol{\theta}}\left[\log f\left(\mathbf{y}|\boldsymbol{\theta}\right)|\mathbf{y}\right] + 2\log f(\mathbf{y}|\hat{\boldsymbol{\theta}}). \tag{5}$$

We stress that we use the DIC based on the integrated likelihood, given the results obtained by Chan and Grant (2016), as other DIC forms are biased towards overparameterized models and show large standard errors.

4 Results

This section assesses several models with/without time-varying parameters or SV for each PA country to identify a consistent, plausible, and well-fitting model that can be instrumental in estimating and analyzing the time variation of the interaction between external shocks and the main domestic macroeconomic variables (growth, inflation, and interest rate). To achieve this, we use the standard instruments applied to VAR models: impulse-response functions (IRFs), historical decomposition (HD), and forecast error variance decomposition (FEVD).

4.1 Data

The seven models proposed are estimated individually for each economy using quarterly data for 1994Q1-2019Q4. We focus mainly on the period following the 1990s, when significant policy changes took place in PA countries (see Abiad et al. (2015)), notably the adoption of IT and rules-based fiscal frameworks. The models are estimated using one lag ($p = 1$) selected via the Bayes Information Criterion (BIC) for the version of the model with constant parameters.

The baseline model is made up of seven variables, which can be divided into two blocks consisting of four external and three domestic variables, respectively. The external block includes U.S. growth (y_t^{usa}), the Fed interest rate (i_t^*), China's growth (y_t^{chn}), and XPI growth for each PA economy (p_t^*). The series were obtained from Bloomberg and the Federal Reserve Bank of St. Louis, except for the XPIs, which were sourced from the IMF, as in Gruss and Kebhaj (2019). The domestic block includes growth (y_t), inflation (π_t), and short-term interest rate (i_t) series obtained from the central bank and ministry of finance websites of each country.

Figure 1 shows the three global variables in the external block, while Figure 2 shows the variables for each PA economy. They are all expressed in annual growth rates, except the (international and domestic) short-term interest rates.

The identification strategy is carried out using recursion restrictions à la Sims (1980), where the contemporaneous relationship matrix takes an inferior triangular form. This assumes that the variables are ordered from the most exogenous to the most endogenous; i.e., that the U.S. economy and monetary policy, China's economic dynamics, and export prices have a contemporaneous influence on the dynamics of economic variables in PA countries. However, the latter does not have a contemporaneous influence on external variables.

On the external front, the proposed order assumes implicitly that Fed policy responds to movements in U.S. economic activity. Additionally, U.S.-originated real and financial movements have an influence on investment and trade decisions in China, which in turn have direct implications for commodity prices.[3] On the domestic side, output fluctuations have direct implications for inflation; and, based on the growth-inflation dynamics (considering an implicit Taylor rule), the monetary authority responds by raising or cutting its policy rate.

4.2 Priors

We establish non-informative priors for all models to add uncertainty around the information used to calculate the parameters. In particular, for the TVP-VAR-SV general model we consider $\mathbf{a}_{\boldsymbol{\theta}} = 0$, $\mathbf{V}_\theta = 10 \times \mathbf{I}_{k_{\boldsymbol{\theta}}}$, $\mathbf{a}_h = 0$, $\mathbf{V}_h = 10 \times \mathbf{I}_n$. Additionally, we assume that the parameters associated with the degrees of freedom are small: $v_{\theta_i} = v_{h_j} = 5$; that $S_{\theta_i} = 0.01^2$ for the lagged variables and $S_{\theta_i} = 0.1^2$ for the intercepts; and that $S_{h_j} = 0.1^2$. The priors for the restricted models follow the same rationale according to the restrictions imposed. Finally, we obtain the posterior distributions of the parameters using an MCMC (Monte Carlo Markov Chain) algorithm. We follow the method proposed by Chan and Eisenstat (2018), who use Gibbs Sampling to estimate marginal densities (which cannot be obtained analytically) from random samples with known distributions (see Section 3.2).

4.3 Evidence of Time Variation in Parameters and Volatility

Prior to showing the results for the seven models, we provide support for using time-varying parameters and SV as econometric strategy. Following Bijsterbosch and Falagiarda (2015), we performed three coefficient variability tests: the Kolmogorov-Smirnov (K-S) test, the $t-$test, and the trace test. To implement them, we estimate the TVP-VAR-SV model and examine the distance between the prior and posterior distributions. Table 1 shows the three tests both for the whole sample and for two sub-samples with the same number of observations. The K-S and $t-$tests for the four economies suggests full variability of the coefficients associated with the innovation variance matrix (matrix $\mathbf{\Sigma}_t$); i.e., the results support our preference for a specification that considers SV. For the contemporaneous relationship coefficients (matrix $\mathbf{B}_{0,t}$), the $t-$test confirms full variability for all economies except Mexico (20/21 variable coefficients); and the K-S test indicates 15-18 variable coefficients out of 21. For the intercepts and coefficients of lagged variables (matrix $\mathbf{B}_{i,t}$), the K-S and $t-$tests yield the same result; i.e., more than 80% of the parameters should be considered time-varying, especially for Chile and Mexico. These results suggest that time variation may be related not only to innovation variance, but also to other parameters.

The trace test, developed by Cogley and Sargent (2005), establishes whether the trace of the prior variance matrix is significantly different from the trace of the posterior variance matrix. The results show that, in the cases of Chile and Peru, the trace of the prior variance matrix falls within the confidence interval for the median of the trace of the posterior variance matrix; i.e., in these

[3] It is worth noting that China and the U.S. together represent one-third of world demand for oil and more than 50% of the demand for industrial and precious metals.

cases there is no evidence of variance variability, which clashes with the previous tests. In contrast, for Colombia and Mexico, the trace of the prior variance matrix is significantly smaller than that of the posterior variance matrix, which provides evidence of time variation in these parameters.

4.4 Model Selection

Table 2 shows, for each PA economy, the two Bayesian selection criteria applied to all models: marginal likelihood (log-ML) and DIC, together with their standard deviations. For Chile and Peru, both criteria indicate that TVP-VAR-R3-SV is the best-fitting model. Besides including SV, the latter allows time variation for the intercepts in each equation (parameters associated with lags and contemporaneous effects are constrained to remain constant). In the case of Peru, these results, which are consistent with Ojeda Cunya and Rodríguez (2022) and Rodríguez and Vassallo (2021), may be due to the fact that the system chosen includes variables, like inflation and the policy interest rate, which were considerably volatile in the 1980s and 1990s; and abruptly became less fluctuating after the implementation of structural reforms.

We underscore that, using the BF, we calculate that the TVP-VAR-R3-SV model is 3.3×10^3 times preferred over the second-best model (TVP-VAR-SV) in the case of Chile, and 2.5×10^2 times preferred over the second-best model (CVAR-SV) in the case of Peru, reflecting the gains (in goodness of fit) from allowing time variation in the intercepts.

In the case of Colombia, the results are not straightforward. On the one hand, the DIC indicates that TVP-VAR-R3-SV is the best-fitting model, as in the cases of Chile and Peru. On the other hand, the BF suggests that TVP-VAR-R2-SV, which allows time variation in both the intercepts and the coefficients associated with the VAR's lagged data, is the most appropriate; i.e., greater flexibility is introduced for the parameters that describe the inertia associated with each variable in the system. In this case, the TVP-VAR-R2-SV model is 3.3×10^2 times preferred over the second-best model (TVP-VAR–R3-SV). Finally, the model chosen for Mexico is TVP-VAR-R1-SV, which only allows time variation in the contemporaneous relationship matrix. This model is 2.8×10^{32} times preferred over the second-best model (TVP-VAR-R3-SV), the largest distance between the selected and second-best models among PA countries.

As discussed within the marginal likelihood analysis, the selected and second-best models have in common that both incorporate SV into their structures; i.e., SV plays a fundamental role in their performance. For instance, in the case of Chile, the TVP-VAR-R3-SV model is 4.7×10^{57} times preferred over the CVAR model and 9.4×10^{61} times preferred over the TVP-VAR model. In the case of Mexico, the TVP-VAR-R1-SV model is 3.1×10^{140} times preferred over the CVAR model and 3.5×10^{132} times preferred over the TVP-VAR model. As the cases of Colombia and Peru are similar, the TVP-VAR and CVAR models are discarded for the four PA economies.

We then examine the SV component, given its fundamental role in modeling PA economies. Figures 3 and 4 show the performance over time of the standard deviation of the errors for each equation in the models that consider SV. In general, the volatility derived from the CVAR-SV model tends to exceed that from the other estimations, especially in the equations for the Fed interest rate and domestic inflation for each economy. Additionally, in most cases the deviations obtained from the TVP-VAR-SV and TVP-VAR-R2-SV models are in the lower range of the estimations (except for the XPI growth equation). This result may be due to the fact that, as time variation is allowed for a greater number of parameters (e.g., the TVP-VAR-SV model), the uncertainty captured via SV is lower compared to the models that restrict time variability (e.g., the CVAR-SV model); or, from a different perspective, not including time-varying intercepts seems to overestimate the time dynamics of the volatility of errors for each equation in the model.

In particular, Figure 3 shows the volatilities of the global equations for each PA economy. We underscore that the deviations associated with the equations for U.S. growth and the Fed interest rate reach relevant peaks in 2008 and 2009 (the Global Financial Crisis, GFC) and then moderate (except for the volatility of the error in the equation for the Fed rate, which increases over the last five years, probably due to the normalization of U.S. monetary policy after the GFC). For its part, volatility associated with the equation for China's growth shows an increasing trend in 1994-2008, when China reduced trade barriers, inserted itself into the world economy, and became a global leader. Following the GFC, volatility dropped drastically, reflecting a moderation probably associated with the structural changes introduced in the Chinese model in recent years.

Figure 4 shows the median of the standard deviations of the innovations corresponding to each country's equations for specific variables. As expected, deviations associated with XPI growth are the highest, with peaks in 2008-2010 (above 20 for Chile, Mexico, and Peru; and up to 18 for Colombia). Following the GFC, this variable became considerably less volatile: in the case of Chile, deviations dropped below 10; and diminished to turn-of-the-century levels (12-14) in the other PA countries. Regarding the domestic variable blocks for each country, although measured with different scales, the volatility dynamics are similar: widely unstable episodes in 1994-2000 translating into high and fluctuating deviations, followed by moderation in the last periods. The latter is likely associated with responsible and consistent fiscal and monetary policy implementation since the turn of the new century. Castillo et al. (2016) examine the Great Moderation period for the case of Peru, emphasizing the key role of monetary policy in the significant decline of output volatility over the last 30 years. At the same time, Chile shows a standard deviation upturn in the equation for output growth towards the end of the sample.

4.5 Impulse-Response Functions (IRFs)

After estimating the parameters of the models, we calculate the IRFs for each point in time over the sample. Figure 5 shows the median of the responses of domestic variables to external shocks ($y_t^{usa}, i_t^*, y_t^{chn}, p_t^*$) for the seven models. We underscore that these shocks are normalized so that the IRFs can be read as elasticities (not standard deviations).

Against this backdrop, a positive real shock on U.S. growth results in a mixed output response in the four PA economies: the initial positive short-run response in economic activity reverts and becomes negative over time, notably in Chile and Peru, as reflected in the IRF dynamics of the model selected for both countries (TVP-VAR-R3-SV). In the cases of Colombia and Mexico, most models suggest a positive response to a favorable U.S.-originated shock. For Colombia, non-SV models show short-run responses above those for the selected TVP-VAR-R2-SV model and later return to the initial path. For Mexico, the IRF for the selected TVP-VAR-R1-SV model lies on the middle range of the IRFs for the other models, with very similar impacts and persistence patterns.

Results are also heterogenous for an unexpected raise in the Fed interest rate. In the cases of Chile and Colombia, the IRFs for the CVAR-SV and CVAR models suggest a positive output growth response, which is counterintuitive. In contrast, the IRFs for the TVP-VAR-SV and TVP-VAR-R3-SV models are more plausible. For Mexico and Peru, the results are clearer irrespective of the model (except for Mexico's TVP-VAR model): these countries experience a fall in the pace of economic activity in response to a tightening of international financial conditions. We point out that, for all models, this kind of shock also implies an upward reaction in domestic interest rates; i.e., central banks raise their policy rates.

We find that all PA economies benefit from an increase in China's growth in the short and medium run; i.e., this kind of shock has persistent effects, with different magnitudes depending of the model used. For instance, the IRFs for the TVP-VAR-SV and TVP-VAR models are below all other estimations and show less lasting effects (6-12 periods). In contrast, the CVAR-SV and

CVAR models show greater and more persistent effects (12-20 periods). The intermediate models, particularly TVP-VAR-R1-SV and TVP-VAR-R3-SV, tend to yield more reasonable IRFs, with moderate impacts relative to the other models.

Finally, in contrast with a shock on China's growth, the impact from a positive shock on XPI growth has a short-run duration, dissipating in 2-5 periods, with the exception of Chile (7-15 periods).

The following sections assess the results for the models selected using Bayesian criteria, as discussed in Section 4.4; i.e., TVP-VAR-R3-SV for Chile and Peru, TVP-VAR-R2-SV for Colombia, and TVP-VAR-R1-SV for Mexico.

4.5.1 Average Impact of External Shocks

This section describes the average impact of the four external shocks mentioned above on the domestic variables of each PA economy, with the purpose of assessing whether the results are significant across the sample. Figure 6 shows the median IRF and the associated credibility region (percentiles 16 and 84 of the distribution).

Row 1 of each panel in Figure 6 shows the impact of a 1% increase in U.S. output growth. The output responses in Chile and Peru are very similar: a short-run expansion, to a 0.2% peak between quarters 2-3, followed by a gradual decline, to a 0.2%-0.3% contraction around quarter 10. The shock dissipates towards the fourth year of the forecast horizon. These mixed dynamics are due to the nature of U.S. growth changes, which are transmitted to PA economies via the external demand and financial channels. An increase in U.S. growth (Chile and Peru's second major trading partner) stimulates exports to the U.S., in turn promoting domestic production. However, the results also show an upward Fed interest rate response to an increase in U.S. growth, which has a contractionary effect on Chile and Peru's growth. Moreover, both economies show an upward response of inflation and the domestic interest rate, although Peru's credibility region is wider than Chile's.

Colombia's positive output growth reaction peaks at 0.2% in quarter 3. Thereafter, the credibility bands include a zero value; i.e., the impact on output (and inflation) in the following periods is not significant. Mexico shows a much clearer response: a 1% increase in U.S. growth raises Mexico's growth by 0.7% towards quarter 3; and percentiles 16 and 84 are positive for close to eight quarters, reflecting a moderate persistence resulting from this kind of shock. This behavior is associated with the role of U.S. business cycles in Mexico's output fluctuations, given the considerable expansion of bilateral trade since the enactment of NAFTA (over 80% of Mexico's exports and close to half of its imports are traded with the U.S., its main trading partner). These results are in line with Sosa (2008), who concludes that the impact of a U.S. growth shock on Mexico's growth is very significant, close to one-to-one as a general rule.

Row 2 of each panel in Figure 6 shows the response of domestic variables to a 1% increase in the Fed interest rate. It is important to note that an upward Fed monetary shock results in a significant and persistent fall in U.S. economic activity, in line with theory. The results show that an unexpected raise in the Fed rate results in a lagged deterioration in PA countries' economic activity; i.e., the contractionary effect becomes more important after several months, especially in Chile, Mexico, and Peru; but is not significant in Colombia.

Again, the results for Chile and Peru are similar: a 1% increase in the Fed rate results in 0.4% fall in output growth in quarter 7 for Chile and in quarter 5 for Peru, with ample credibility regions including a zero value starting from quarter 12 for Chile and quarter 9 for Peru. Mexico experiences an important deterioration (around 0.7%) starting from the 10 first quarters after the shock, with persistent effects beyond the 20 quarters considered. These results are in line with, and similar to, those reported by Flores (2016). One way to understand these dynamics is considering that higher short-term rates translate into lower credit and, therefore, lower consumption and investment by U.S. households and firms. In turn, the latter reduce their imports, thereby creating less income in PA economies.

A main finding is that, following a contractionary Fed shock, interest rates increase in all PA countries, notably Mexico and Peru, thus creating an additional negative effects on economic activity. These empirical results provide evidence of the importance of U.S. monetary shocks; and might therefore contribute to enhancing the conduct of monetary policy in PA countries.

For its part, a 1% increase in China's growth (row 3 of each panel in Figure 6) results in positive and persistent effects on the pace of economic activity in all PA economies. Growth in Chile, Colombia, and Mexico show a positive effect of around 0.4% in quarters 5, 4, and 7 after the shock, respectively; and such gains persist until around the third year. In Chile, inflation and the domestic interest rate show a significant upward response, a result that is not as distinct in the cases of Colombia and Mexico.

Peru shows the highest growth impact, peaking at 0.8% in quarter 4 and persisting beyond quarter 12; i.e., the impact of an increase in China's growth is twice as large as for the other PA economies. In line with Bing et al. (2019), this considerable impact reflects not only the real effects from greater Chinese demand, but also an indirect effect via commodity prices. These authors estimate that a 1% fall in China's growth results in a 0.7%-1.4% contraction in Latin American growth. Moreover, using a GVAR model, the World Bank (2016) estimates that a 1% fall in China's growth results in a 0.2% deceleration in Chile, Colombia and Mexico; and a 0.7% deceleration in Peru. These results are very similar to those obtained by Cesa-Bianchi et al. (2011).

Row 4 of each panel in Figure 6 shows the IRFs for a shock on XPI growth for each economy. It is worth noting that commodity price volatility is important in explaining macroeconomic performance in PA countries, as the latter are mostly commodity exporters. World Bank information as of 2019 shows that copper exports are 50% of Chile's total exports; copper and gold exports together are 47% of Peru's total exports; and oil and coal exports together are 55% of Colombia's total exports. In contrast, Mexico's exports are more diversified (commodities were around 12% of total exports in 2019). At the same time, commodity exports are important in Mexico due to their contribution to fiscal revenues (20% from oil).

Considering this common feature of PA economies, the results show a short-run impact on growth (in contrast with real shocks from China), except in Chile, where it is more persistent. For Colombia and Peru, a 10% increase in XPI growth induces a 1% expansion in the same period, which lasts until quarters 5-6 after the shock. For Mexico, there is a 2% response in the same period, which dissipates rather quickly (towards quarter 3). In Chile, the expansion lasts longer: a 10% increase in XPI growth results in a 0.8% growth increase in the same period, which moderates progressively until quarter 9. Lastly, with the exception of Colombia, policy interest rates respond in a contractionary manner to a positive export price shock (i.e., the monetary authorities raise them).

4.5.2 Evolution of the Impact of External Shocks Over Time

An advantage of using TVP-VAR-SV models is the possibility to assess the impact of structural changes over time. Figure 7 shows the evolution over time of cumulative responses to the four shocks mentioned above for different horizons: the black, blue, and magenta lines show the cumulative responses toward the end of the first, second, and fifth year, respectively (we take the latter as the long-term response).

The cumulative one-year impact from a 1% increase in U.S. growth (row 1 of each panel in

Figure 7) has a limited time variation and creates a 0.1%-0.2% short-term growth increase in Chile, Colombia, and Peru. In contrast, the impact is considerable in Mexico: by 1994, domestic growth would have increased by 0.65% in the first year, although it would have been closer to 0.8% in recent periods. The cumulative response by the second year suggests similar dynamics, although with greater impacts: in 1994 Mexico's growth would have increased by 0.8% by the second year, but for 2019 the increase is estimated at 1%. These results reflect greater U.S.-Mexico integration and synchronicity, with a significant and immediate impact of U.S. shocks on Mexico's growth.

Row 2 of each panel in Figure 7 shows the cumulative responses to a 1% increase in the Fed rate. The two-year impacts on Chile, Mexico, and Peru have not fluctuated much over time, except under episodes like the U.S. crises of 2001 (the dot-com crash) and 2008. The fall in economic activity in these economies fluctuated, for the entire sample, between -0.5% and -0.2% by the second year after the shock. Additionally, in the four economies, the short-run monetary policy response was more important under international crisis episodes (2002 and 2009); and increased over time, reflecting greater relative synchronicity between Fed movements and central bank decisions in PA countries.

Regarding the impact from a 1% increase in China's growth (row 3 of each panel in Figure 7), the results are heterogenous among PA countries. The cumulative impact on Chile's growth does not vary considerably over time, with increases of around 0.3% in the first year. Towards the second year, the increase in growth, inflation, and the interest rate is around 0.6%, 0.7%, and 0.2%-0.4%, respectively. In Colombia, the variation in the cumulative impact by the second year is greater: on average, growth would have increased by 0.6% in 1994-2001 and 0.7% in 2002-2011; and returned to around 0.6% in the last periods. The results also show a slight fall in the impact on the policy interest rate in 2002-2011. In Mexico, the growth response fluctuates between 0.4% in the first year and 0.8% in the second year, with limited evidence of time variation in these impacts. Finally, Peru shows the widest and most persistent impacts: in response to an unexpected increase in U.S. growth, Peru's growth increases by around 0.8% in the first year, 1.2% in the second year, and 1.4% in the long run (five years).

The evolution of the one-year cumulative impact in response to a positive shock on XPI growth over the last 25 years suggests considerable time variation in all PA countries (row 4 of each panel in Figure 7), especially during the GFC. In Chile and Peru, this impact has experienced sustained increases since the beginning of the sample, with peaks in 2009 and 2010, and then decelerated considerably. In 1994 the effect from a 10% increase in XPI growth would have increased economic growth by around 0.5% in the first year in Chile and Peru; however, in 2009 this impact would have generated a response three times larger in these countries (1.5%), which is consistent with the high economic growth associated with the commodity boom. Over the last years, these impacts moderated towards pre-supercycle values (0.5%-1%).

In Chile, the impact is more significant beyond the first year: the increase in growth would have been close to 2% by the end of the second year in 2009; and would have moderated to 1% in 2019. In Colombia, the short-run effect would have started with 0.2% growth increases in 1994; and would have reached 2.0% by 2019. In Mexico, the impact would have evolved from 0.7% to 2.2%, with an interruption in 2011-2012, when oil prices experienced an abrupt correction. The evidence also suggests that the impacts on inflation and the interest rate increased over time.

4.6 Historical Decomposition (HD)

The results have so far confirmed that shocks originated in external demand, international prices, and financial conditions have significant and time-varying implications for macroeconomic performance in PA countries. At the same time, differing economic structures and idiosyncratic policies in each country have contributed to offsetting or magnifying such shocks. Along these lines, with the purpose of decomposing the real growth, inflation, and interest rate data into a trend (deterministic) component and the cumulative effects from structural shocks, we perform HDs on the models selected for each country.

Figure 8 shows a predominant external influence in 2002-2011, a period associated with a commodity boom and high global growth. In contrast, the contribution of domestic shocks exceeds that of external shocks in 1994-2001, a high-volatility period with idiosyncratic shocks. There is also a limited contribution of external shocks in the last part of the sample (2012-2019), a period of moderation in global growth and international price correction. In this context, and in line with IMF (2014), we find that external factors explained, on average, more than half of the deviations in growth, inflation, and interest rates in PA economies in 1994-2019.

The HDs for growth in Chile and Peru share certain common features. For both countries, growth shocks originated in China are the most important external factor, as China is their main trading partner and copper (a key XPI component) is their main export commodity. Therefore, shocks on XPI growth are important in the decomposition of domestic growth in Chile (to a lesser extent than in Peru). In line with Rodríguez and Vassallo (2021), we find that around 70% of Peru's average growth increase in 1994-2001 (4.2%) and 2002-2011 (6.2%) is explained by the four external factors identified in the baseline model.

Additionally, and mainly during financial crises, the contribution of U.S. growth shocks is negative and reverts after each crisis for around five more quarters. In particular, external disturbances predominate in 2009, in the wake of the Lehman Brothers collapse and the impact of the GFC. For example, out of a fall of 8.1 percentage points in Peru's growth in 2008-2009, 6.4 percentage points are explained by external factors. In Chile, out of a fall of 5.1 percentage points, 2.1 percentage points were explained by external factors. In the cases of Colombia and Mexico, growth variations are almost fully explained by external shocks, probably due to greater trade integration with the U.S.

Regarding inflation, external demand shocks (China) predominate in Chile, as well as magnified supply-side shocks during crisis periods. In Peru, inflation has been considerably influenced by export price dynamics and U.S. economic activity.

In Colombia, the contribution of growth shocks originated in China predominates in the periods close to the GFC, while in Mexico the relevant factor is the influence of U.S. growth disturbances. At the same time, the participation of Fed rate shocks is important in these economies for both the growth and inflation HDs. However, in line with Carrillo-Maldonado and Díaz Cassou (2019), we find that U.S. monetary policy shocks have lost relevance over time, which should come as no surprise, considering that the Fed rate basically remained flat in 2009-2015, and later raises were considerably lower than in the past.

We find that high interest rate volatility in the four economies in 1994-2001 was explained predominantly by domestic factors, mainly monetary and supply-side shocks. However, in later periods we identify an important moderation in this volatility, mainly associated with monetary structural reforms around the turn of the century; i.e., full IT adoption in 1999 in Chile, Colombia, and Mexico (Valdés (2007) and Urrutia et al. (2014)) and in 2002 in Peru (Rossini and Vega (2007)).

By disaggregating the effect of structural shocks we can build a counterfactual series to simulate a variable's behavior in absence of external shocks. Figure 9 shows the results, where the black lines represent the observed values and the orange lines show the corresponding counterfactual series. The differences become more pronounced in three sub-periods around the GFC: (i) in 2002-2008 (before the GFC), external disturbances enhanced average real growth in the four PA economies; (ii) in 2009, the external influence caused a deep fall in economic activity; and (iii) immediately after the GFC (2010-2011), external disturbances promoted recovery. That is, international conditions magnified growth dynamics in PA economies, mainly during the commodity price boom.

In absence of external shocks, macroeconomic fluctuations in PA countries would have followed a more moderate path without abrupt variations, mainly in crisis periods. For a more detailed examination of the sub-periods mentioned above, Table 3 compares observed vs. counterfactual growth figures. We find that, without external shocks, the average growth in 2002-2008 (before the GFC) would have been 0.3 percentage points lower for Chile and Colombia. For Mexico and Peru, it would have been 1.0 and 1.7 percentage points lower, respectively. Additionally, in 2009 the average growth for PA economies would have been 3.1 percentage points higher; i.e., the losses from the GFC would have been substantially lower. Specifically, the fall in economic activity would have been 4.0, 3.0, 2.9, and 2.7 percentage points lower in Mexico, Chile, Peru, and Colombia, respectively.

Finally, immediately after the GFC (2010-2011), the average recovery would have been 2.6, 2.2, 1.5, and 0.6 percentage points lower in Mexico, Peru, Chile, and Colombia, respectively. These results suggest that external influence on domestic output dynamics was greater in Mexico and Peru during the commodity boom. This influence has been more moderate, both in boom and crisis periods, in Chile and Colombia.

At the same time, there are no significant differences between the observed and counterfactual data for inflation and the interest rate in 1994-2001. As with output growth, the main divergences occur in 2002-2011. We confirm that both the 2008-2009 general inflation surge and the subsequent downward correction were influenced by an important external component. Additionally, the reduction in interests rates after the GFC in the four PA economies would have been much more gradual and moderate in absence of external disturbances, especially in Colombia and Mexico.

4.7 Forecast Error Variance Decomposition (FEVD)

Finally, we carry out an FEVD to identify the contributions of external shocks to long-term macroeconomic fluctuations in PA economies. Figure 10 shows the evolution over time of the FEVDs for domestic growth, inflation, and the interest rate in the models selected for each country. We underscore that the FEVD is instrumental in dividing the forecast error variance for each variable into the components attributable to each shock. In particular, for each point in time we calculate the medians of the parameters; and use each set of parameters to forecast variables h periods ahead.[4]

The panels for the four PA economies in Figure 10 have a common feature: a limited participation of all external factors in the mid-1990s and the turn of the century (around 10%-40%), which grew steadily to peak values around 2009 (above 90% in Mexico) and moderated (and even fell slightly) in recent years. Additionally, the participation of monetary and supply-side shocks predominate within the domestic block, especially in the initial sample years; however, following IT adoption and central banks' greater use of a short-run interest rate as monetary instrument, this participation drops abruptly and even disappears in some cases.

On the external front, XPI growth had a limited participation in the 1990s, but grew to a significant FEVD share in all PA countries. Another key factor is China's growth, which had an important participation, especially from 1994 to the GFC. U.S. growth shows a lower participation, but remains present in all FEVDs. Finally, Fed rate participation increased sporadically in crisis periods (2002 and 2008).

Table 4 shows the average participation of external and domestic factors in growth within the baseline model. In 1994-2001, external factors explained 33% and 38% of growth fluctuations in

[4] The forecast horizon considered in this article is $h = 20$ quarters.

Colombia and Peru, respectively. In 2002-2011 this contribution doubled (73% and 79%, respectively). In the cases of Chile and Mexico, the participation of external factors was 48% and 50% in 1994-2001, respectively; and increased to 80% and 92% in 2002-2011. In all cases, the participation of international factors in output fluctuations increases significantly during commodity booms.

This participation moderates slightly towards the last part of the sample (2012-2019), except for Mexico, where external factors almost fully explain domestic growth variability (94% on average). Sorting PA countries according to their long-term vulnerability to external shocks, we obtain the following result: Mexico 93%, Colombia 88%, Peru 65%, and Chile 47%. At the same time, we emphasize that: (i) FEVD participations reflect the uncertainty sources that determine forecasts for the relevant variables (in contrast with HD, which reflects historic contributions); and (ii) FEVD results are sensitive to the specification of the external variables used in the model, as discussed later in the section on robustness exercises.

5 Robustness Analysis

With the purpose of validating the results in Section 4, we propose four complementary exercises, which imply the following changes in the baseline model: (i) using informative priors via a training sample; (ii) modifying two external variables (Fed Funds Rate and XPI growth); (iii) using low-dimensional models (4, 5, and 6 variables); and (iv) expanding the model by including public investment in the domestic block. For space reasons, the figures for this sections have been grouped in an Appendix, which is available on request.

5.1 Changes in Priors

We choose a training sample, as in Primiceri (2005), to obtain an informative prior that can provide more objective information compared with the diffuse prior used by Chan and Eisenstat (2018). We use the first 10 years of the sample (40 observations covering 1994Q1-2003Q4) to calibrate the prior distribution of the initial conditions. For example, in order to characterize the mean and variance of $\boldsymbol{\theta}_0$ we choose the OLS estimations ($\hat{\boldsymbol{\theta}}_{OLS}$) and four times their variance in a constant VAR, estimated in the initial sub-sample. This prior captures the characteristics of the initial dynamics of the complete system and establishes a prior that is closer to, and more objective for, each parameter.

Table 5 shows the values for the marginal likelihood and the DIC. The results confirm the gains (in terms of goodness of fit) from considering SV. Additionally, TVP-VAR and CVAR continue to be the least-fitting models, thereby confirming the preference for models that include SV. The models selected for Chile, Colombia, and Peru in the main section hold up; but, in the case of Mexico, the BF and the DIC indicate that the best-fitting model using informative priors is TVP-VAR-R3-SV (which includes time-varying intercepts).

In general, the sign and magnitude of the impacts remain the same for all countries, thus confirming the robustness of the baseline model using more restricted priors. The most important differences are the following: (i) Chile shows a slightly higher output growth response to a Fed rate shock, but a lower response to a shock on China's growth; (ii) Colombia's output growth response to a U.S. growth shock becomes non-significant; and (iii) Peru's output growth response to a favorable XPI growth shock is more significant (0.1% at the moment of the shock using the baseline model vs. 0.15% using informative priors).

In general, we confirm that Fed rate and XPI growth shocks create greater variability in cumulative domestic responses, in contrast with the more stable responses to shocks on U.S. and China's growth. In particular, the short-term output growth response to a shock on XPI growth shows an upward trend from 1994 to 2009 in Chile and Peru, with 0.2% and 0.25% peaks, respectively, and moderates towards the final periods. Colombia's responses show peaks around 2009 (0.15%), but also a surge in the last part of the sample, with values close to 0.2% in 2019. In Mexico, cumulative responses are slightly lower than in the baseline model.

Both HDs and FEVDs show that the higher domestic contribution to disturbances, identified at the beginning of the sample (1994-2001), gives way to a greater relevance of international conditions in 2002-2011. In general, the results are consistent with those for the baseline model.

5.2 Changes in Variables

This second exercise uses an alternative measure of the Fed interest rate, known as the Shadow Fed Fund Rate, introduced by Wu and Xia (2016); and replaces XPI growth for the terms-of-trade (TOT) index growth for each country to capture export/import movements. We note that we will continue to denote these variables as i_t^* and p_t^* in the HDs and FEVDs, respectively. The Bayesian criteria in Table 6 confirm that the least-fitting models are those that do not consider SV modelling. Additionally, we use the models selected via marginal likelihood: TVP-VAR-R2-SV for Chile and Colombia, and TVP-VAR-R3-SV for Mexico and Peru.

The IRFs differ very little from the results of the baseline model. The sign and significance of the IRFs remain unchanged in response to an unexpected increase in the Shadow Rate for Chile, Colombia, and Peru (non-significant for Colombia); but the magnitudes differ. For instance, output growth in Chile falls to a -0.25% low by quarter 7, while the baseline model estimates it at -0.4% by quarter 8. In Mexico, an increase in the Shadow Rate results in a maximum 0.5% fall in output growth in quarter 5, while the baseline model estimates it at -0.7% in quarter 8. In the case of Peru, inclusion of the Shadow Rate in the model moderates the impact on output growth relative to the baseline model.

Substituting TOT growth for XPI growth also results in certain differences: in Chile, a positive shock on TOT growth is more beneficial to economic activity than a favorable shock on XPI growth. The results remain unchanged for Colombia; but in Mexico the response to a TOT growth shock decreases by half relative to the impact of an XPI growth shock estimated using the baseline model. In the case of Peru, the output growth response to a TOT growth shock is non-significant.

The FEVDs show greater differences. The contribution of international conditions to output growth variability remains the same for Chile and Colombia (around 45% and 80% in 2019, respectively). In contrast, TOT growth inclusion slightly moderates this contribution in the cases of Mexico and Peru. In Mexico, the contribution of external shocks is around 75% in 2002-2011 and falls gradually to close to 60% in 2019. Similarly, in Peru this contribution rises to a peak of 75% in 2009 and moderates to 35% by 2019.

5.3 Smaller-Dimension Models

5.3.1 Four-Variable Model

In this version, the external block is made up of one variable, XPI growth, for each PA economy. The domestic block shows the classic macroeconomic order (output growth, inflation, and interest rate). The Bayesian criteria in Table 7 are instrumental in selecting the best-fitting model for each country: TVP-VAR-R3-SV for Chile and Peru; and TVP-VAR-R2-SV for Colombia and Mexico.

The results indicate that a positive shock on XPI growth translates into a favorable and immediate output growth response in PA economies. In the period of the shock, Mexico shows the greater impact (a 0.4% increase, significant until quarter 3), followed by Chile and Colombia (with increases close to 0.2%, significant until quarters 8 and 4, respectively). Finally, Peru shows a 0.1% increase in output growth, significant until quarter 2.

The cumulative one-, two-, and five-year responses of domestic variables are qualitatively similar to those described by the baseline model. The impact on output growth in Chile, Colombia, and Peru increases in the periods around the GFC (with an important surge towards the end of the sample in Colombia). In Mexico, the one-year cumulative response increases abruptly in 1994-2001 and later moderates. We point out that the impacts of XPI growth changes on output growth in the four-variable model tend to be larger that those estimated using the baseline model (except for Peru). These differing results seem to be closely associated with the omission of relevant variables in the model specification.

The conclusions about the HDs and FEVDs for PA countries' domestic variables, even with one external variable, are basically the same as for the baseline model: a distinct predominance of external shocks in the configuration of PA countries' macroeconomic fluctuations. In all cases, this predominance peaks during the GFC. At the same time, this vulnerability, as reflected by the FEVD, receded in the last years of the sample: after peaking around 95% (Chile) and 80% (Peru) in 2009, there is evidence of an important moderation by 2019, with a 40% participation in both economies (a result that contrasts with the findings from the baseline model).

5.3.2 Five-Variable Model

The external block includes the international interest rate channel (i_t^*), leaving the Fed rate as the most exogenous variable in the system; i.e., Fed decisions affect global financial and liquidity conditions, which have a contemporaneous impact on commodity prices. Both external variables have a direct effect on PA economies, as characterized by the domestic blocks described above.

Like in the four-variable model, the models selected for this robustness exercise are TVP-VAR-R3-SV for Chile and Peru; and TVP-VAR-R2-SV for Colombia and Mexico (Table 7). We note that, in the case of Peru, the DIC selects the TVP-VAR-R1-SV model, where the parameters for lagged observations and the intercepts remain constant; however, since the selection criteria provide different results, we choose the best model according to marginal likelihood.

The IRFs for a Fed rate shock change substantially relative to the baseline model. Output growth responses in Mexico and Peru are statistically null (percentiles 16 and 84 include a zero value). Colombia shows a slightly positive reaction in quarter 1, which clashes with economic theory. In Chile, growth contracts persistently for almost 16 quarters (12 quarters in the baseline model).

For their part, domestic macroeconomic responses to a shock on XPI growth maintain their sign and persistence relative to the baseline model. However, the magnitude of output growth responses is slightly higher in this robustness exercise; i.e., they are overestimated relative to the baseline model.

Finally, time variability continues to be the differentiating feature, especially regarding export price shocks. In addition, the involvement of external factors in variance decomposition continues to predominate, with a considerable contribution of international interest rate disturbances during the GFC and the dot-com crash.

5.3.3 Six-Variable Model

The previous model included information on the financial and price channels. However, as for our purposes it is also necessary to consider the external demand channel, we include economic activity growth in China (y_t^{chn}). We continue to take U.S. monetary policy as the most exogenous variable, as it directly affects financing costs in economies of global importance like China. In turn, we consider that the pace of economic activity in China has important implications for commodity indices.

We use Bayesian criteria (Table 7) to select the best-fitting models: TVP-VAR-R3-SV for Chile, Colombia, and Mexico; and CVAR-SV for Peru. The latter is similar to the TVP-VAR-R3-SV model, although it does not include time-varying intercepts.

The IRFs suggest that inclusion of China's growth within the system contributes to correctly identifying the marginal impact of Fed rate shocks on Chile, Mexico, and Peru. Additionally, positive shocks on China's growth have a favorable effect on commodity indices and, in turn, on PA countries' growth, with peak impacts of 0.3% in Chile, 0.4% in Colombia and Mexico, and 0.8% in Peru by quarter 4. These responses last 8-12 quarters; i.e., the IRFs indicate a moderate persistence.

The decompositions show that most of the variability attributable to commodity indices shifts to China's growth, especially in 2002-2011, when Chinese expansion reached historic highs and propelled a global commodity boom. In sum, FEVD and HD results for the four-, five-, and six-variable models are qualitatively similar and consistent with the findings in Sections 4.6 and 4.7.

5.4 Inclusion of Fiscal Policy in the Baseline Model

This exercise incorporates fiscal policy into the baseline model in the form of real public investment growth (g_t^{pub}). In this case, g_t^{pub} becomes the most exogenous domestic variable, as increasing the share of public investment in GDP is a fiscal policy decision. We perform this exercise only for Chile and Peru, in view of limitations in accessing real public investment growth data for the other PA countries. The series were obtained from Chile's Budget Directorate (DIPRES) and the Central Reserve Bank of Peru.

We estimate the eight-variable model using the non-informative priors described in Section 4.2 for the seven models. Table 8 shows the Bayesian criteria, which point to TVP-VAR-R3-SV as the best-fitting model for both Chile and Peru, thus confirming the robustness and relevance of this model for their economic structures.

In general, g_t^{pub} inclusion into the model does not substantially modify the IRFs for the baseline model, and therefore the influence of external shocks on the domestic variables preserves its impact and significance. On the domestic front, g_t^{pub} has a distinct positive effect on domestic growth, evidencing the potential of fiscal policy to propel economic activity. At the same time, the impacts on inflation and the interest rate are not clear.

In Chile, output growth increases by 0.1% in the initial period and returns gradually to the initial path (percentiles 16 and 84 are positive until quarter 8). In Peru, the impact on output growth at the moment of the shock is greater but of shorter duration (0.25% at the moment of the shock; and percentiles 16 and 84 are positive until quarter 6). These results reflect a moderate persistence in response to a shock, probably associated with the fact that expanding the provision of public goods (e.g., infrastructure) stimulates employment in the short run and enhances medium- and long-run gains by increasing the capital endowment.

Additionally, we find that the two-year cumulative impact (blue line) in Chile has not been constant over time: it was around 0.4% in 1994, increased gradually to 0.6% in 2015, and peaked at over 1.0% in the last four years. This impact has also grown significantly in Peru since the beginning of the 2000s, implying that currently an increase in g_t^{pub} would yield higher returns on GDP that in the previous decade. Specifically, the response to a 1% increase in g_t^{pub} is an estimated 0.2% cumulative two-year output growth increase. However, in more recent periods, like 2019, such a shock would increase output growth by 0.3%. Therefore, the results suggest that the impact of fiscal policy on domestic economic activity has increased in Chile and Peru. These results are in line with Jiménez and Rodríguez (2019), who find that output growth responses to public capital expenditure shocks (associated with g_t^{pub}) in Peru have increased over time.

HD results confirm that, historically, external shocks have been the main drivers of domestic fluctuations, particularly during commodity booms. Additionally, g_t^{pub} shocks on both economies have a greater participation in output growth decompositions. Chile shows a distinct positive impulse in periods prior to the GFC (2005-2008); however, following the 2009 fall, public investment contributes negatively to recovery (2010-2011). Peru shows a positive impulse from g_t^{pub} in key periods like 1998-1999, when the economy experienced both external and domestic shocks (international crises and the El Niño Phenomenon, respectively), and to a lesser extent during the GFC (2009-2010).

In sum, the inclusion of a fiscal policy variable does not alter the IRFs for external shocks; and the HDs show that such shocks remain predominant. However, the inclusion of real public investment growth within the system changes the FEVD results significantly. The FEVD analysis shows that g_t^{pub} contribution in both countries was 50% of output variation on average over the sample, surpassing external factors as main uncertainty source for long-run domestic growth.

In particular, in the case of Chile, external conditions explained around 30% of output fluctuations in 1994-2001, peaked at 60% in 2009, and finally fell to 10% in 2019. Inflation shows a similar pattern; but domestic factors remain predominant in interest rate behavior in 1994-2001 (around 80% of domestic interest rate variability). Regarding output growth variability in Peru, external factors explain around 20% in 1994-2001, peak at 50% in 2009, and decline to close to 30% in 2019. External factor participation in inflation variability peaks at close to 70% in 2009 and declines to 40% in 2019; but, like in Chile, it remains limited in explaining interest rate variability in 1994-2001.

While external factors continued to grow in influence during the commodity boom (especially China's growth and XPI changes), their contribution decreased in favor of the fiscal variable. In this regard, the literature indicates that the fiscal multiplier of g_t^{pub} on output is greater than the unit, exceeding the multipliers for other fiscal expenditure and revenue multipliers; see Végh et al. (2018). In addition to its impact, this variable shows considerable volatility relative to output: the standard deviation of g_t^{pub} is 5.7 times that of output over the sample (in line with the findings by Castillo et al. (2007) for Peru), which introduces further uncertainty in output growth behavior.

The results confirm that g_t^{pub} has considerable impact on output and is the greater source of uncertainty for output growth in Chile and Peru. Along these lines, Mendoza and Collantes Goicochea (2017) suggest that this variable is the best macroeconomic policy instrument for impacting economic activity. Therefore, while external factors have historically had a direct impact on domestic economic activity, we emphasize that domestic instruments like g_t^{pub} (which have experienced a growing impact over time) can be effective stabilizing tools, precisely against unfavorable external shocks.

6 Conclusions

This article seeks to examine and quantify the evolution of the impact of external shocks on the macroeconomic dynamics of PA countries. For this purpose, we asses jointly the main transmission channels through which these shocks propagate to small and open economies: the trade, financial, and price channels. Instead of using traditional estimation tools, we adopt a Bayesian approach to estimate a family of VAR models that allow time variance (or constancy) for certain groups of parameters and the variance matrix (TVP-VAR-SV).

The results for the four PA economies suggest that models that allow time variation for certain (not all) parameters, and include SV, perform better than traditional VAR models and models where all parameters are time-varying, as in Primiceri (2005) or Cogley and Sargent (2005).

The impulse-response analysis throws three main findings. First, China's output fluctuations create the most significant and persistent impacts, reinforced by a positive chain reaction in export prices. Second, we identify considerable time variation in PA countries' macroeconomic responses to favorable XPI shocks. Third, unexpected Fed rate increases result in significant increases in PA countries' monetary policy rates, an effect that escalates during crisis periods and further deepens the negative impact on domestic output growth.

Additionally, variance decompositions show that external factors explained over 50% of growth, inflation, and interest rate deviations in PA economies, notably in a context of booming commodity prices, high global growth, and financial crisis (2002-2011). Specifically, we find that in 2009, in absence of external shocks, average growth in the PA bloc would have been 3.2 percentage points higher.

In particular, the results show that external shock absorption over the sample is higher in Mexico and Peru. A counterfactual exercise suggests that, in absence of external disturbances, output dynamics would have changed the least in Chile and Colombia. On the contrary, external factors have led to important gains (and losses) in Mexico and Peru; i.e., they are highly vulnerable to changes in international conditions.

These conclusions confirm that small open commodity-exporting economies face considerable challenges from their exposure to changes in the international environment. Notably, strengthening the capacity to implement countercyclical policies should be a priority, as they are the main tool for attenuating macroeconomic volatility in the face of unfavorable external shocks. Specifically, building fiscal savings and foreign exchange reserves in boom times creates greater room for maneuver and enhances resources for withstanding such disturbances.

Finally, we point out the following limitations: (i) the computational complexities in calculating Bayesian criteria and limitations in data availability hinder the estimation of larger models; and it would be useful to (ii) test the sensitivity of the results under a different identification scheme (e.g., sign restrictions); and (iii) restrict the existence of domestic (in addition to contemporaneous) effects of the external block by implementing an exogenous block.

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Table 1. Tests for Time Variation in Coefficients and Volatility

	(1) Chile				(2) Colombia			
Test	Matrix Coefficients	Subsample 1	Subsample 2	Full Sample	Matrix Coefficients	Subsample 1	Subsample 2	Full Sample
Kolomogorov-Smirnov	$B_{0,t}$	18/21	15/21	18/21	$B_{0,t}$	14/21	14/21	15/21
	$B_{i,t}$	52/56	47/56	53/56	$B_{i,t}$	47/56	44/56	49/56
	Σ_t	7/7	7/7	7/7	Σ_t	7/7	7/7	7/7
$t-$test	$B_{0,t}$	21/21	20/21	21/21	$B_{0,t}$	19/21	21/21	21/21
	$B_{i,t}$	50/56	44/56	53/56	$B_{i,t}$	46/56	41/56	46/56
	Σ_t	7/7	7/7	7/7	Σ_t	7/7	7/7	7/7
Trace Test	Trace	16% perc.	50% perc.	84% perc.	Trace	16% perc.	50% perc.	84% perc.
	0.28	0.17	0.22	0.30	0.08	0.13	0.17	0.22
	(3) Mexico				(4) Peru			
Test	Matrix Coefficients	Subsample 1	Subsample 2	Full Sample	Matrix Coefficients	Subsample 1	Subsample 2	Full Sample
Kolomogorov-Smirnov	$B_{0,t}$	17/21	18/21	17/21	$B_{0,t}$	16/21	15/21	15/21
	$B_{i,t}$	52/56	51/56	53/56	$B_{i,t}$	48/56	49/56	51/56
	Σ_t	7/7	7/7	7/7	Σ_t	7/7	7/7	7/7
$t-$test	$B_{0,t}$	21/21	19/21	20/21	$B_{0,t}$	21/21	21/21	21/21
	$B_{i,t}$	49/56	46/56	52/56	$B_{i,t}$	47/56	43/56	49/56
	Σ_t	7/7	7/7	7/7	Σ_t	7/7	7/7	7/7
Trace Test	Trace	16% perc.	50% perc.	84% perc.	Trace	16% perc.	50% perc.	84% perc.
	0.25	0.29	0.38	0.51	0.28	0.23	0.31	0.42

Number of time varying parameters according to Kolmogorov-Smirnov test and $t-$test are reported. Matrix $B_{0,t}$ represents the coefficients of contemporaneous relationships, $B_{i,t}$ are the coefficients associate to intercepts and lagged variables, and Σ_t are the variances of innovations. For each country, these two tests are performed for the full sample and for two additional subsamples: 1994Q2-2006Q4 and 2007Q1-2019Q4. In the Trace test, the trace of the prior variance matrix is reported, as well as the lower, upper and median level of the trace of the posterior variance matrix.

Table 2. Log Marginal Likelihood and DIC estimates for Baseline Model (numerical standard errors in parentheses)

	(1) Chile				(2) Colombia			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1331.2	0.26	2251.0	1.29	-1323.5	0.28	2236.8	1.42
TVP-VAR	-1465.8	0.70	2448.3	6.84	-1457.0	0.80	2412.5	1.33
TVP-VAR-R1-SV	-1345.1	1.22	2149.0	1.55	-1330.5	0.79	2108.4	1.36
TVP-VAR-R2-SV	-1333.0	0.74	2213.3	2.24	**-1316.1**	**0.71**	2187.0	1.66
TVP-VAR-R3-SV	**-1323.1**	**0.70**	**2131.4**	**0.82**	-1321.9	1.37	**2101.9**	**1.85**
CVAR-SV	-1338.3	0.11	2142.1	1.43	-1332.4	0.14	2160.7	3.62
CVAR	-1455.9	0.02	2387.7	0.25	-1462.8	0.01	2382.1	0.21
	(3) Mexico				(4) Peru			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1426.5	0.34	2426.5	1.31	-1418.4	0.20	2394.2	1.65
TVP-VAR	-1650.3	2.52	2700.5	5.45	-1574.7	1.08	2579.6	2.84
TVP-VAR-R1-SV	**-1345.1**	**1.22**	**2149.0**	**1.55**	-1405.2	1.25	2261.5	2.11
TVP-VAR-R2-SV	-1425.0	0.72	2389.2	1.43	-1407.1	0.92	2350.6	1.01
TVP-VAR-R3-SV	-1419.8	0.70	2292.9	1.24	**-1392.8**	**1.01**	**2247.8**	**2.55**
CVAR-SV	-1442.6	1.32	2345.8	2.54	-1398.3	0.74	2273.6	2.43
CVAR	-1668.6	0.02	2801.2	0.19	-1579.9	0.02	2620.3	0.33

For each model we obtain a total of 10,000 final posterior draws. $Log - ML$ estimates are based on 10,000 evaluations of the integrated likelihood, where the importance sampling density is constructed using the 10,000 posterior draws. DIC estimates are computed using 10 parallel chains; in each chain the integrated likelihood is evaluated for the 1,000 posterior draws kept from each estimation chain - a total of 10,000 evaluations. SD indicates standard errors. Bolded values indicate best model.

Table 3. HD of Domestic GDP Growth for Specific Periods (in %)

(A) Baseline Model

Average Period	Chile (TVP-VAR-R3-SV) Actual	Chile Count.	Colombia (TVP-VAR-R2-SV) Actual	Colombia Count.	Mexico (TVP-VAR-R1-SV) Actual	Mexico Count.	Peru (TVP-VAR-R3-SV) Actual	Peru Count.
1994-2001	5.1	5.1	1.9	2.0	3.1	2.9	3.9	4.1
2002-2008	5.0	4.7	4.7	4.4	2.2	1.2	6.6	4.9
2009	−1.5	1.5	1.1	3.8	−5.1	−1.1	1.1	4.0
2010-2011	6.0	4.5	5.7	5.1	4.4	1.8	7.5	5.3
2012-2019	2.7	2.8	3.2	3.2	2.3	1.9	3.8	3.8

(B) Robustness 1

Average Period	Chile (TVP-VAR-R3-SV) Actual	Chile Count.	Colombia (TVP-VAR-R2-SV) Actual	Colombia Count.	Mexico (TVP-VAR-R3-SV) Actual	Mexico Count.	Peru (TVP-VAR-R3-SV) Actual	Peru Count.
1994-2001	5.1	4.7	1.9	1.4	3.1	3.7	3.9	4.5
2002-2008	5.0	3.1	4.7	3.5	2.2	−0.1	6.6	3.8
2009	−1.5	1.3	1.1	4.1	−5.1	−1.9	1.1	4.6
2010-2011	6.0	3.3	5.7	5.4	4.4	0.6	7.5	4.1
2012-2019	2.7	2.9	3.2	3.6	2.3	1.5	3.8	3.7

(C) Robustness 2

Average Period	Chile (TVP-VAR-R2-SV) Actual	Chile Count.	Colombia (TVP-VAR-R2-SV) Actual	Colombia Count.	Mexico (TVP-VAR-R3-SV) Actual	Mexico Count.	Peru (TVP-VAR-R3-SV) Actual	Peru Count.
1994-2001	5.1	5.0	1.9	2.1	3.1	3.1	3.9	4.3
2002-2008	5.0	4.5	4.7	3.9	2.2	1.7	6.6	5.2
2009	−1.5	2.6	1.1	3.5	−5.1	0.3	1.1	4.4
2010-2011	6.0	4.7	5.7	5.1	4.4	3.4	7.5	6.0
2012-2019	2.7	2.6	3.2	3.3	2.3	2.3	3.8	3.8

Average real GDP Growth (YoY % change) with and without external shocks for country-specific selected model. "Actual" represents observed GDP Growth values and "Count." the counterfactual GDP Growth. Selected Models for each country are reported in parentheses.

Table 4. FEVD of Domestic GDP Growth for Specific Periods (in %)

(A) Baseline Model

Average Period	Chile (TVP-VAR-R3-SV)		Colombia (TVP-VAR-R2-SV)		Mexico (TVP-VAR-R1-SV)		Peru (TVP-VAR-R3-SV)	
	Domestic	External	Domestic	External	Domestic	External	Domestic	External
1994-2001	52	48	67	33	50	50	62	38
2002-2011	20	80	27	73	8	92	21	79
2012-2019	36	64	18	82	6	94	28	72
2009	11	89	14	86	7	93	11	89
2019	53	47	12	88	7	93	35	65

(B) Robustness 1

Average Period	Chile (TVP-VAR-R3-SV)		Colombia (TVP-VAR-R2-SV)		Mexico (TVP-VAR-R3-SV)		Peru (TVP-VAR-R3-SV)	
	Domestic	External	Domestic	External	Domestic	External	Domestic	External
1994-2001	44	56	55	45	47	53	62	38
2002-2011	14	86	21	79	7	93	19	81
2012-2019	28	72	19	81	7	93	36	64
2009	8	92	12	88	6	94	13	87
2019	43	57	12	88	7	93	39	61

(C) Robustness 2

Average Period	Chile (TVP-VAR-R2-SV)		Colombia (TVP-VAR-R2-SV)		Mexico (TVP-VAR-R3-SV)		Peru (TVP-VAR-R3-SV)	
	Domestic	External	Domestic	External	Domestic	External	Domestic	External
1994-2001	42	58	66	34	59	41	71	29
2002-2011	16	84	29	71	23	77	36	64
2012-2019	41	59	25	75	45	55	59	41
2009	12	88	19	81	25	75	26	74
2019	52	48	19	81	55	45	67	33

Mean Variance Decomposition of GDP Growth for the Selected Models in each Country. Selected Models for each country are reported in parentheses.

Table 5. Robustness Analysis 1. Changing Priors: Log Marginal Likelihood and DIC estimates

	(1) Chile				(2) Colombia			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1452.7	0.15	2796.2	0.77	-1374.2	0.17	2368.0	0.88
TVP-VAR	-1504.9	0.52	2977.3	3.52	-1425.6	0.39	2441.3	1.12
TVP-VAR-R1-SV	-1408.6	0.49	2402.6	1.42	-1372.4	0.49	2208.7	1.61
TVP-VAR-R2-SV	-1472.6	0.17	2494.6	2.16	**-1328.8**	**0.72**	2238.0	1.78
TVP-VAR-R3-SV	**-1316.3**	**1.02**	2273.2	2.11	-1378.1	1.43	**2136.9**	**1.09**
CVAR-SV	-1362.0	0.12	**2266.9**	**1.12**	-1344.4	0.12	2144.9	1.13
CVAR	-1533.9	0.02	2869.2	0.19	-1474.8	0.01	2369.6	0.29
	(3) Mexico				(4) Peru			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1442.9	0.15	2521.5	0.78	-1572.5	0.45	2329.3	0.67
TVP-VAR	-1796.2	0.32	2789.7	0.87	-1623.3	0.12	2500.2	1.20
TVP-VAR-R1-SV	-1452.5	0.56	2319.4	1.02	-1562.7	0.44	2269.0	1.35
TVP-VAR-R2-SV	-1373.6	0.43	2356.3	1.78	-1420.4	0.41	2380.1	0.94
TVP-VAR-R3-SV	**-1321.2**	**0.52**	**2318.9**	**1.75**	**-1416.4**	**0.79**	2245.2	2.11
CVAR-SV	-1325.1	0.31	2394.7	2.48	-1492.4	0.72	**2223.2**	**0.97**
CVAR	-1578.9	0.01	2600.9	0.21	-1628.6	0.01	2730.4	0.22

Robustness 1 uses more diffuse priors on the error variance of VAR coefficients. For each model we obtain a total of 10,000 final posterior draws. $Log-ML$ estimates are based on 10,000 evaluations of the integrated likelihood, where the importance sampling density is constructed using the 10,000 posterior draws. DIC estimates are computed using 10 parallel chains; in each chain the integrated likelihood is evaluated for the 1,000 posterior draws kept from each estimation chain - a total of 10,000 evaluations. SD indicates standard errors. Bolded values indicate best model.

Table 6. Robustness Analysis 2. Changing Foreign Variables: Log Marginal Likelihood and DIC estimates

	(1) Chile				(2) Colombia			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1269.3	0.21	2105.5	1.55	-1264.4	0.27	2109.8	0.94
TVP-VAR	-1390.6	0.59	2300.4	4.75	-1384.9	0.20	2289.7	2.29
TVP-VAR-R1-SV	-1288.9	0.97	2039.0	1.42	-1280.0	1.03	**2009.4**	**1.64**
TVP-VAR-R2-SV	**-1265.9**	**0.69**	2080.7	1.08	**-1260.6**	**0.78**	2078.5	1.77
TVP-VAR-R3-SV	-1266.2	0.77	**2033.3**	**1.03**	-1273.9	1.17	2010.1	1.81
CVAR-SV	-1285.0	0.19	2156.8	0.87	-1286.1	0.09	2063.7	2.26
CVAR	-1395.1	0.02	2279.0	0.32	-1411.6	0.02	2289.8	0.27
	(3) Mexico				(4) Peru			
Model	log-ML	SD	DIC	SD	log-ML	SD	DIC	SD
TVP-VAR-SV	-1290.4	0.18	2120.2	1.25	-1281.8	0.17	2124.7	1.67
TVP-VAR	-1458.8	0.96	2378.2	6.72	-1462.0	2.21	2358.3	5.87
TVP-VAR-R1-SV	-1279.0	0.55	2114.4	1.31	-1289.1	1.28	**2023.2**	**1.75**
TVP-VAR-R2-SV	-1282.6	0.68	**2108.1**	**1.13**	-1278.0	1.06	2093.9	1.97
TVP-VAR-R3-SV	**-1274.3**	**0.63**	2112.3	1.20	**-1275.5**	**0.78**	2033.9	1.66
CVAR-SV	-1313.7	0.20	2224.8	1.87	-1322.1	0.18	2130.5	0.92
CVAR	-1538.1	0.01	2569.5	0.39	-1458.8	0.01	2404.8	0.17

Robustness 2 changes the Fed Funds Rate to the Shadow Rate, and the country-specific Export Price Index Growth to the S&P Goldman Sachs Commodity Index Growth. Bolded values indicate best model.

Table 7. Robustness Analysis 3. Lower-Dimensional Models: Log Marginal Likelihood and DIC estimates

	(1) Chile						(2) Colombia					
	4 variables		5 variables		6 variables		4 variables		5 variables		6 variables	
Model	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC
TVP-VAR-SV	-925.7 (0.05)	1691.7 (0.70)	-997.8 (0.14)	1763.4 (0.97)	-1160.7 (0.18)	2006.8 (1.47)	-916.2 (0.14)	1674.4 (0.55)	-976.0 (0.14)	1724.5 (1.39)	-1147.0 (0.30)	1978.9 (1.03)
TVP-VAR	-1013.5 (0.12)	-1825.8 (5.89)	-1117.9 (0.34)	1921.4 (6.10)	-1298.3 (0.65)	2211.3 (7.25)	-982.1 (0.04)	1747.5 (0.40)	-1088.2 (0.05)	1863.0 (1.22)	-1284.3 (1.15)	2160.1 (1.87)
TVP-VAR-R1-SV	-923.9 (0.10)	-1662.2 (0.70)	-998.5 (0.35)	1685.0 (0.87)	-1162.9 (0.82)	1897.4 (0.53)	-910.9 (0.07)	1636.8 (0.29)	-979.1 (0.34)	1648.7 (0.30)	-1147.9 (0.76)	1857.4 (0.89)
TVP-VAR-R2-SV	-921.5 (0.06)	-1667.8 (1.05)	-994.6 (0.28)	1736.4 (1.14)	-1161.0 (0.92)	1977.1 (2.02)	**−904.3** (0.13)	1637.9 (0.64)	**−963.9** (0.28)	1685.5 (0.62)	-1139.1 (0.64)	1935.9 (0.78)
TVP-VAR-R3-SV	**−920.2** (0.15)	**1643.9** (0.43)	**−986.1** (0.33)	**1680.4** (0.80)	**−1148.1** (0.61)	**1891.9** (0.97)	-913.2 (0.11)	**1634.7** (0.49)	-966.8 (0.37)	**1633.7** (0.59)	**−1138.2** (0.77)	**1856.7** (2.58)
CVAR-SV	-924.1 (0.07)	1706.0 (2.23)	-995.0 (0.04)	1779.6 (2.66)	-1157.6 (0.09)	2048.0 (0.16)	-927.2 (0.02)	1661.3 (1.14)	-993.3 (0.04)	1724.0 (2.30)	-1151.1 (0.09)	1864.3 (1.87)
CVAR	-1016.4 (0.01)	1818.5 (0.15)	-1121.4 (0.01)	1933.3 (0.18)	-1297.0 (0.01)	2189.7 (0.28)	-1010.9 (0.01)	1796.2 (0.21)	-1117.4 (0.02)	1913.4 (0.21)	-1296.7 (0.01)	2172.0 (0.20)
	(3) Mexico						(4) Peru					
Model	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC	log-ML	DIC
TVP-VAR-SV	-1024.0 (0.28)	1877.4 (0.59)	-1082.8 (0.24)	1926.6 (0.94)	-1255.0 (0.20)	2180.5 (1.18)	-945.0 (0.11)	1720.9 (0.76)	-1009.2 (0.21)	1780.0 (1.03)	-1172.5 (0.15)	2017.9 (1.28)
TVP-VAR	-1157.5 (1.39)	2038.0 (8.14)	-1258.1 (1.04)	2149.8 (7.39)	-1479.3 (2.38)	2429.5 (5.52)	-1080.1 (0.39)	1922.4 (2.32)	-1165.1 (0.49)	1996.9 (5.14)	-1373.1 (2.59)	2265.4 (4.96)
TVP-VAR-R1-SV	-1030.5 (0.08)	1860.9 (0.54)	-1095.2 (0.52)	1868.0 (0.86)	-1261.0 (1.08)	2082.9 (1.36)	-942.8 (0.07)	1686.9 (0.30)	-1003.4 (0.35)	**1683.6** (0.58)	-1162.6 (0.80)	**1881.9** (1.22)
TVP-VAR-R2-SV	**−1019.1** (0.14)	1853.2 (0.67)	**−1079.0** (0.32)	1901.7 (1.32)	-1252.5 (0.54)	2147.4 (1.14)	-939.0 (0.15)	1693.4 (0.79)	-1006.4 (0.23)	1750.9 (1.74)	-1176.7 (0.68)	1997.3 (3.02)
TVP-VAR-R3-SV	-1027.2 (0.08)	**1844.5** (0.20)	-1080.0 (0.18)	**1838.5** (0.24)	**−1247.5** (0.43)	**2064.8** (0.36)	**−937.7** (0.17)	**1670.7** (0.67)	**−997.7** (0.16)	1687.4 (1.09)	-1162.3 (0.85)	1908.7 (1.94)
CVAR-SV	-1029.4 (0.06)	1858.0 (0.14)	-1082.6 (0.07)	1842.1 (0.20)	-1256.3 (0.07)	2071.0 (0.27)	-954.2 (0.08)	1723.4 (12.6)	-1001.5 (0.08)	2154.5 (21.4)	**−1156.0** (0.09)	2411.4 (23.0)
CVAR	-1247.4 (0.01)	2260.7 (0.09)	-1338.1 (0.01)	2350.3 (0.21)	-1518.1 (0.01)	2613.8 (0.26)	-1098.6 (0.01)	1977.6 (0.11)	-1195.4 (0.01)	2078.0 (0.23)	-1368.2 (0.01)	2328.7 (0.17)

Robustness 3 evaluates models with 4, 5 and 6 variables. Standard errors are reported in parentheses. Bolded values indicate best model.

Table 8. Robustness Analysis 4. Adding Public Investment Growth to the Baseline Model: Log Marginal Likelihood and DIC estimates

	(1) Chile		(2) Peru	
Model	log-ML	DIC	log-ML	DIC
TVP-VAR-SV	−1861.1 (0.45)	3196.9 (2.32)	−1872.7 (0.47)	3210.8 (2.36)
TVP-VAR	−2010.5 (0.86)	3386.0 (5.01)	−2067.2 (2.53)	3426.4 (8.86)
TVP-VAR-R1-SV	−1861.2 (1.66)	3045.8 (1.24)	−1867.5 (1.33)	3026.5 (1.38)
TVP-VAR-R2-SV	−1861.9 (1.70)	3139.0 (2.04)	−1876.1 (1.20)	3152.0 (2.89)
TVP-VAR-R3-SV	**−1829.1** (1.33)	**3000.3** (1.46)	**−1838.3** (0.99)	**2999.7** (1.67)
CVAR-SV	−1841.5 (0.16)	3147.2 (8.33)	−1852.9 (1.23)	3439.4 (22.4)
CVAR	−1974.1 (0.01)	3253.6 (0.26)	−2038.5 (0.02)	3379.2 (0.27)

Baseline Model including Real Growth of Public Investment. Standard errors are reported in parentheses. Bolded values indicate best model.

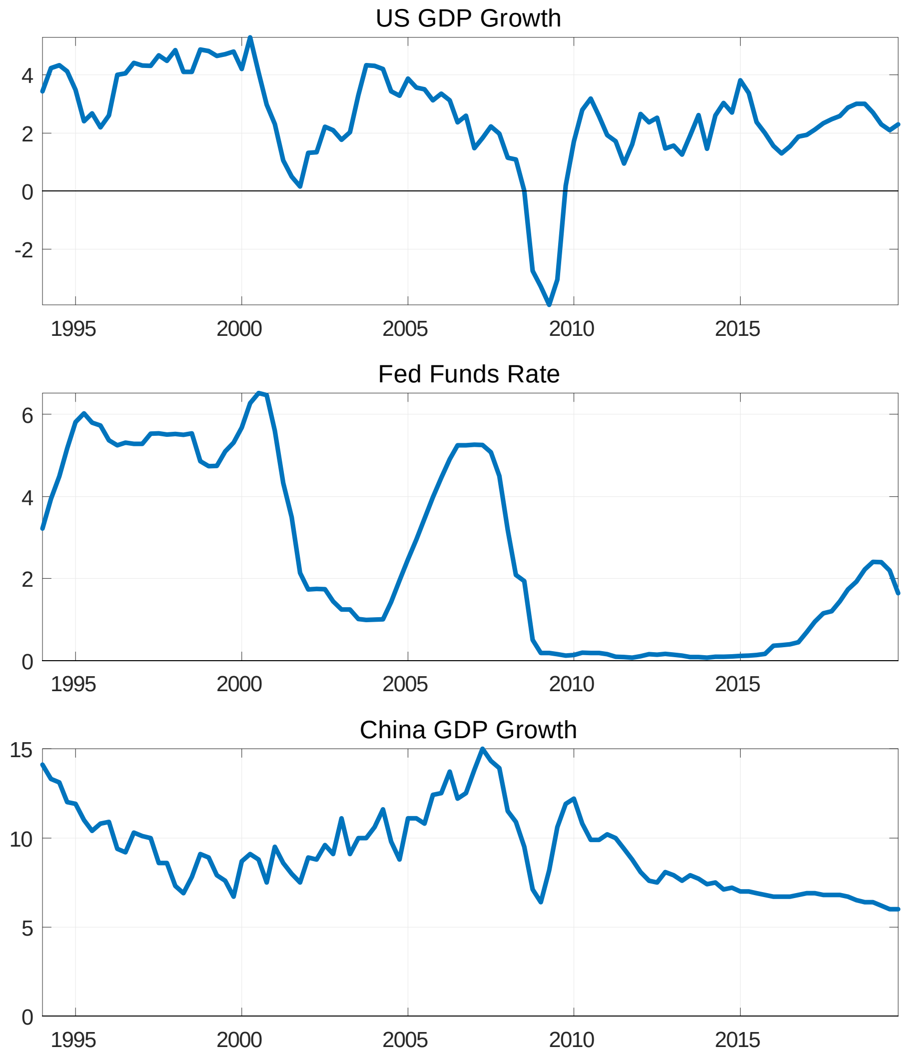
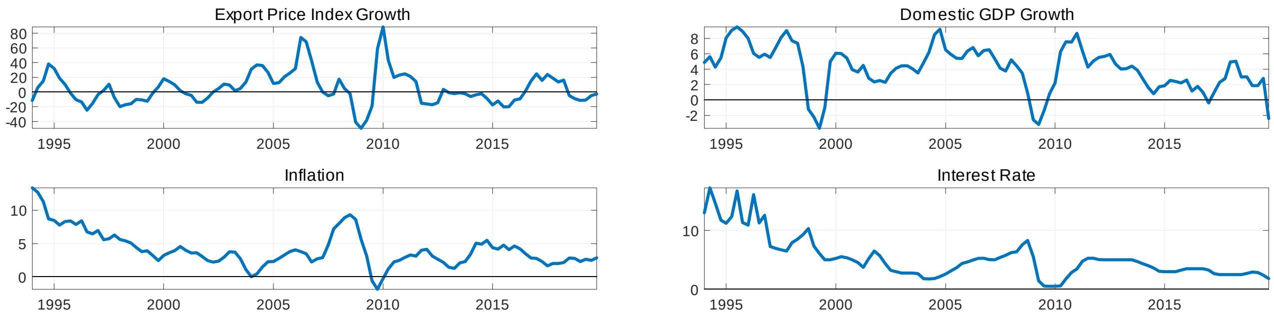
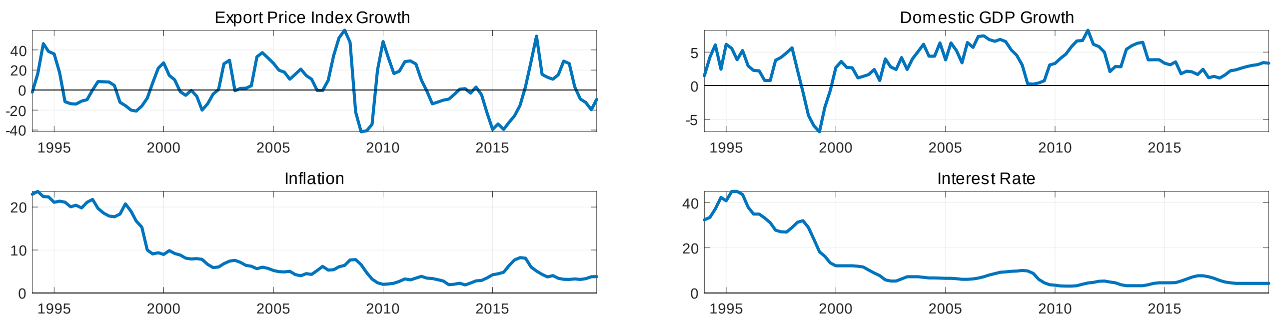


Figure 1. Global Series used for all Country-Specific Models in Annual Growth Rates. Interest Rate in levels

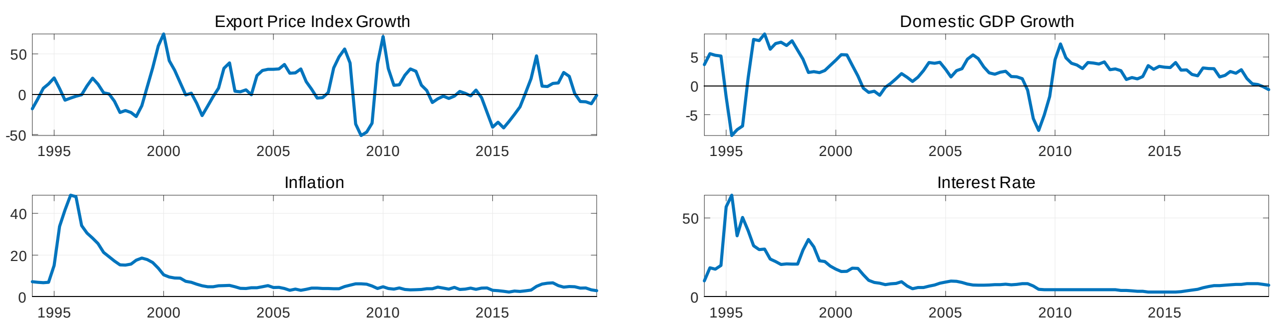
(1) Chile



(2) Colombia



(3) Mexico



(4) Peru

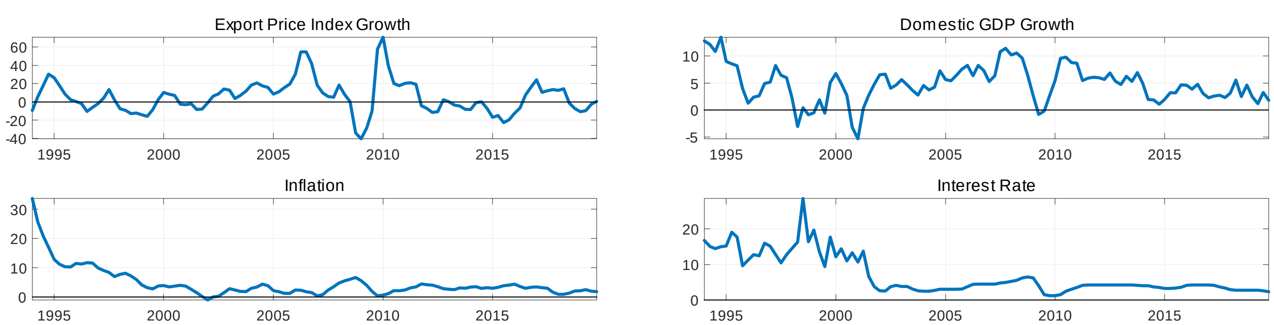
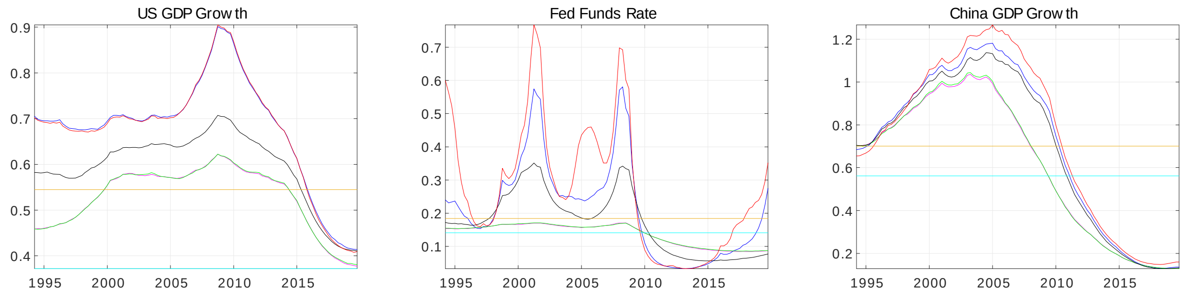
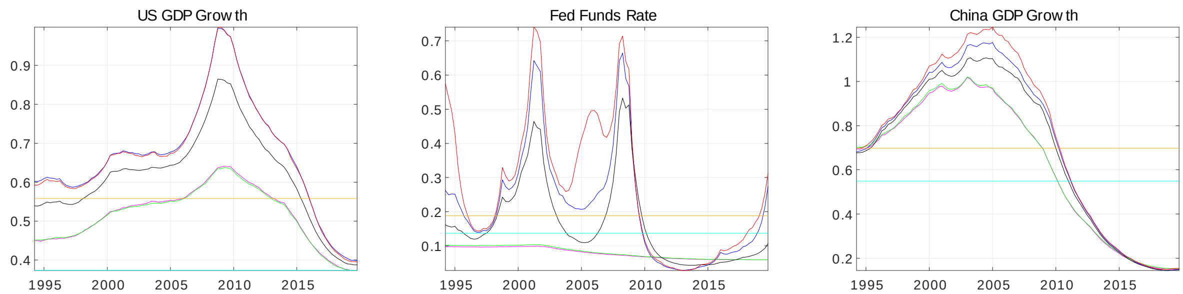


Figure 2. Country-specific Series for PA Economies in Annual Growth Rates. Interest Rates in levels.

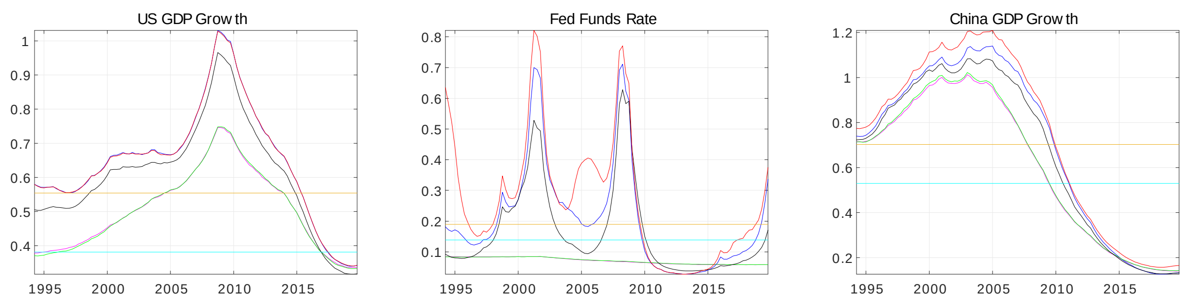
(1) Chile



(2) Colombia



(3) Mexico



(4) Peru

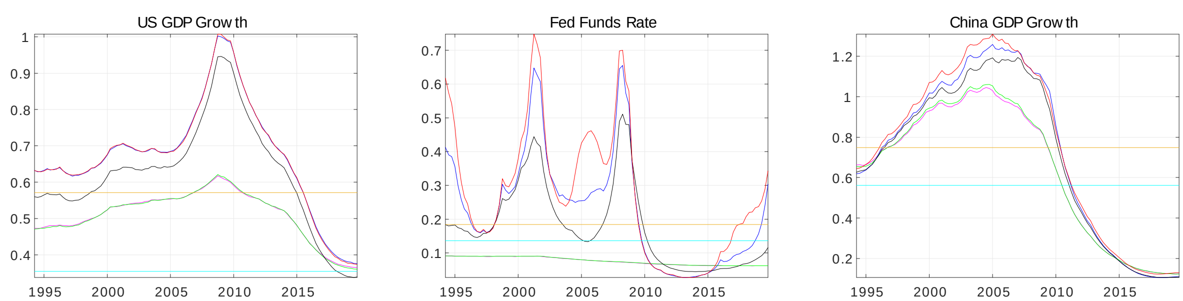
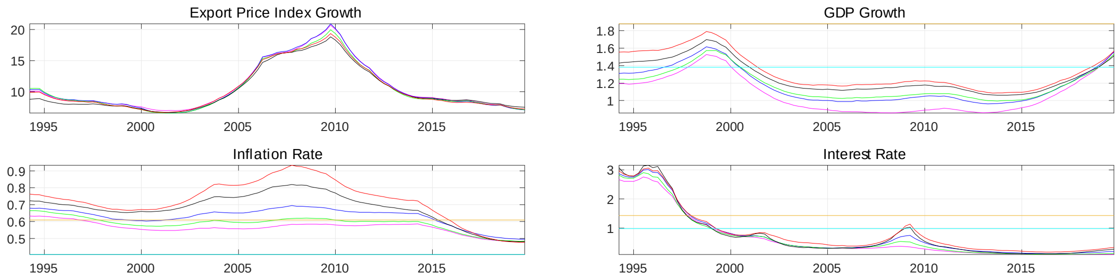
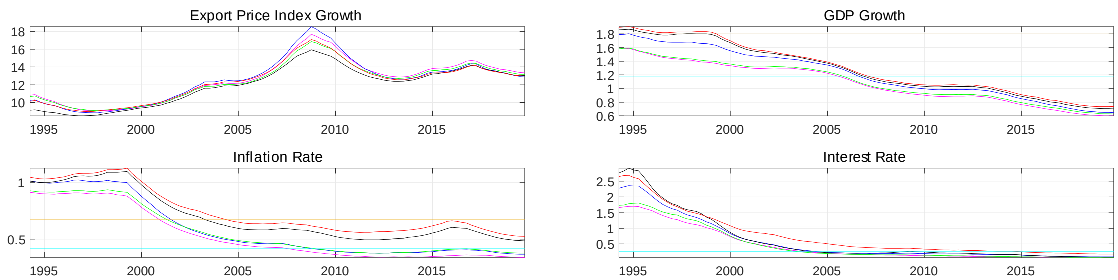


Figure 3. Stochastic Volatility. Standard Deviation of the Innovations in Global Equations for PA Countries. Median values. The magenta line represents the TVP-VAR-SV model; the blue line: TVP-VAR-R1-SV; the green line: TVP-VAR-R2-SV; the black line: TVP-VAR-R3-SV; the red line: CVAR-SV; the cyan line: TVP-VAR; and the yellow line: CVAR.

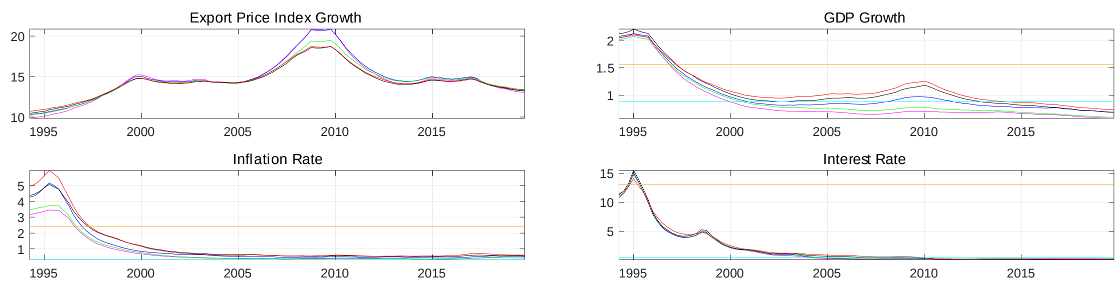
(1) Chile



(2) Colombia



(3) Mexico



(4) Peru

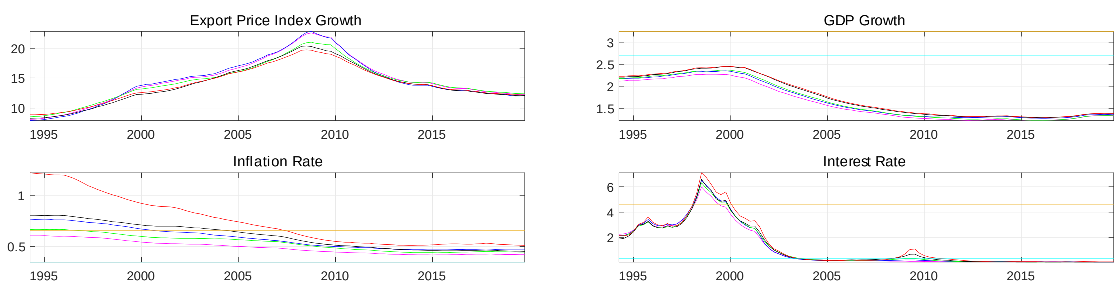


Figure 4. Stochastic Volatility. Standard Deviation of the Innovations in Country-Specific Equations for PA Countries. Median values. The magenta line represents the TVP-VAR-SV model; the blue line: TVP-VAR-R1-SV; the green line: TVP-VAR-R2-SV; the black line: TVP-VAR-R3-SV; the red line: CVAR-SV; the cyan line: TVP-VAR; and the yellow line: CVAR.

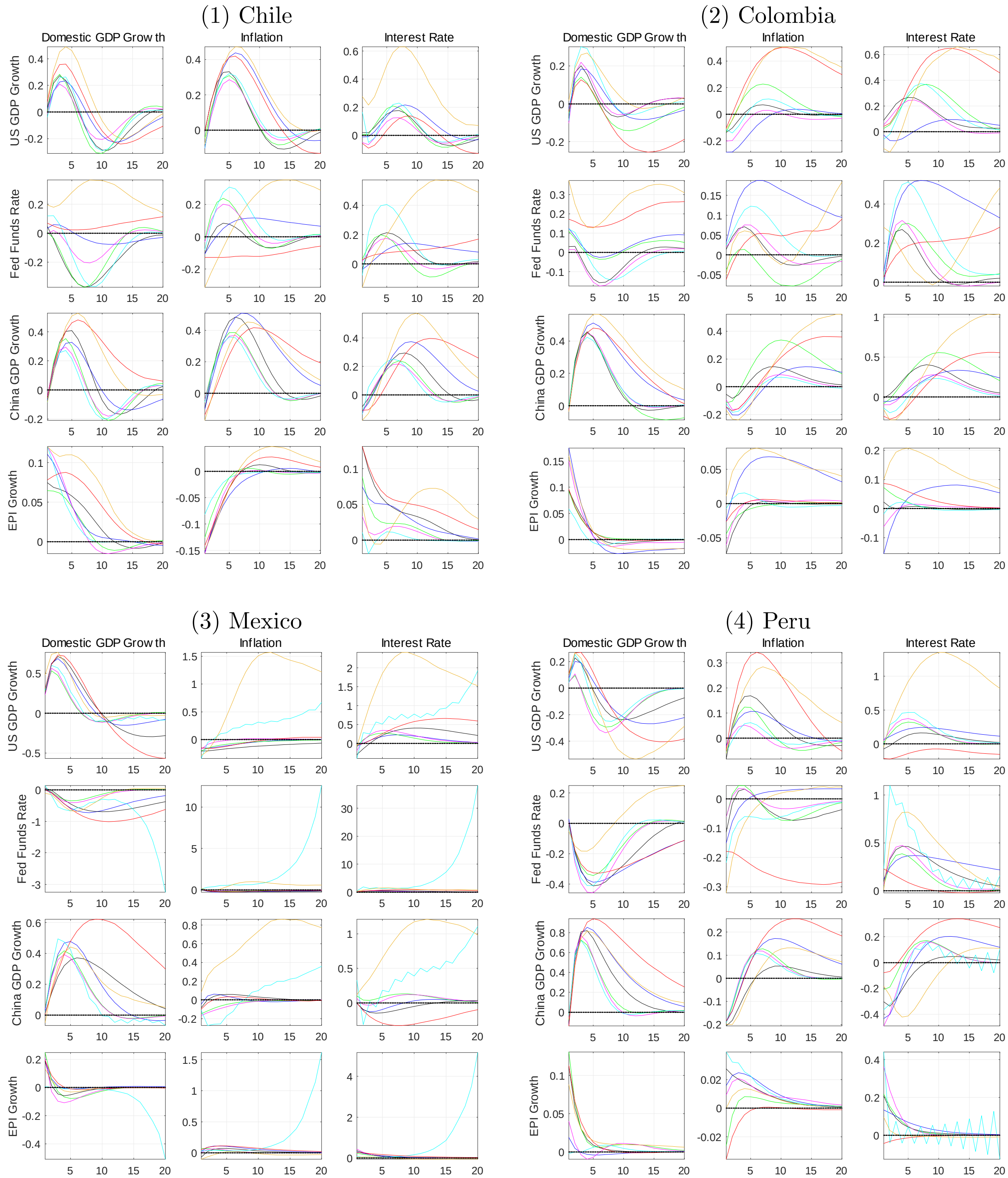


Figure 5. Median IRFs of Domestic Variables to different Shocks for all the Models. Columns represents the response of Domestic GDP Growth, Inflation and Interest Rate to a set of External Shocks, ordered in each row. The magenta line represents the TVP-VAR-SV model; the blue line: TVP-VAR-R1-SV; the green line: TVP-VAR-R2-SV; the black line: TVP-VAR-R3-SV; the red line: CVAR-SV; the cyan line: TVP-VAR; and the yellow line: CVAR.

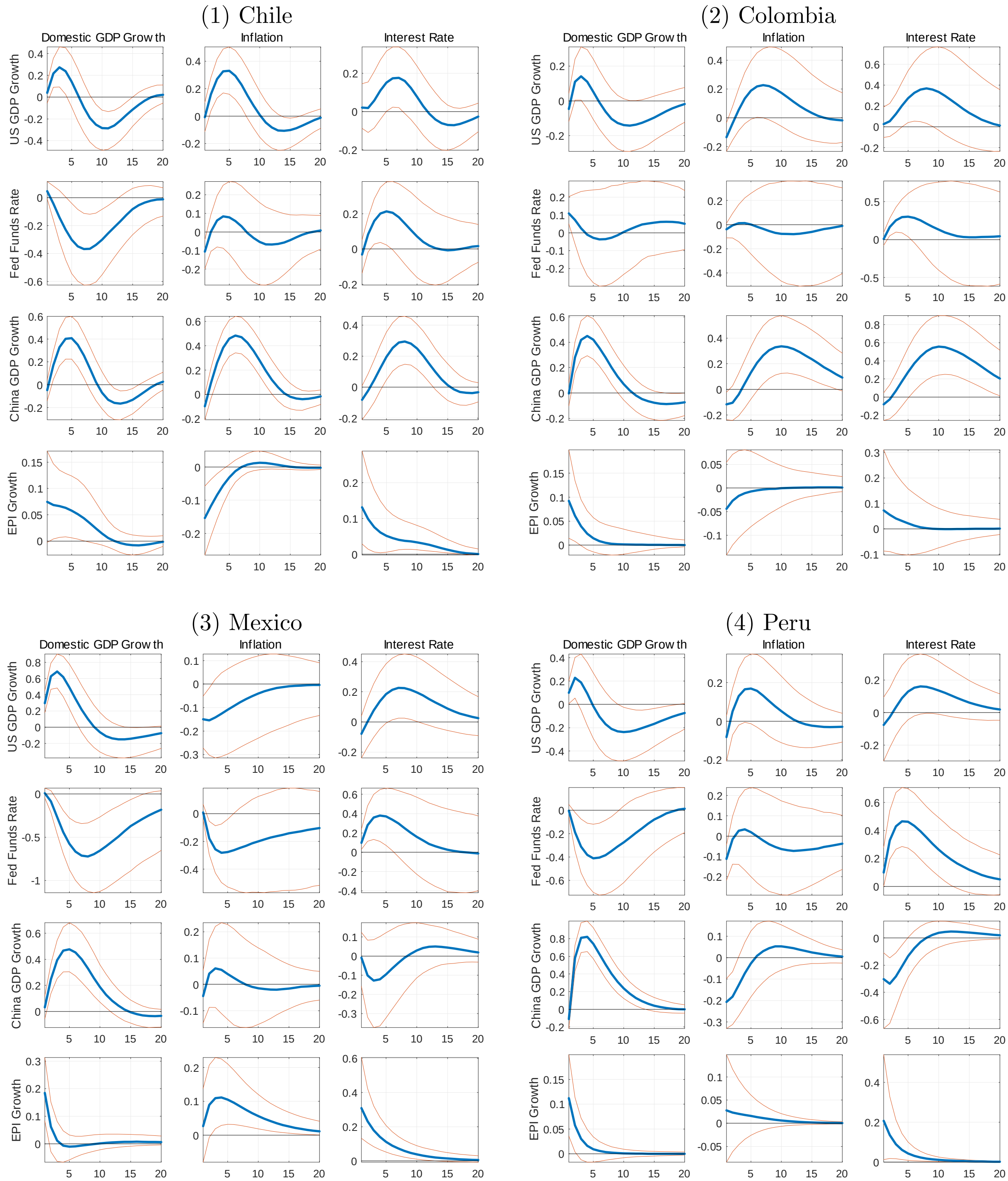


Figure 6. Median IRFs of Domestic Variables to different Shocks. The solid blue lines: TVP-VAR-R3-SV model for Chile and TVP-VAR-R2-SV model for Colombia. The dotted red lines its 68% error band. Columns represents the response of Domestic GDP Growth, Inflation and Interest Rate to a set of External Shocks, ordered in each row.

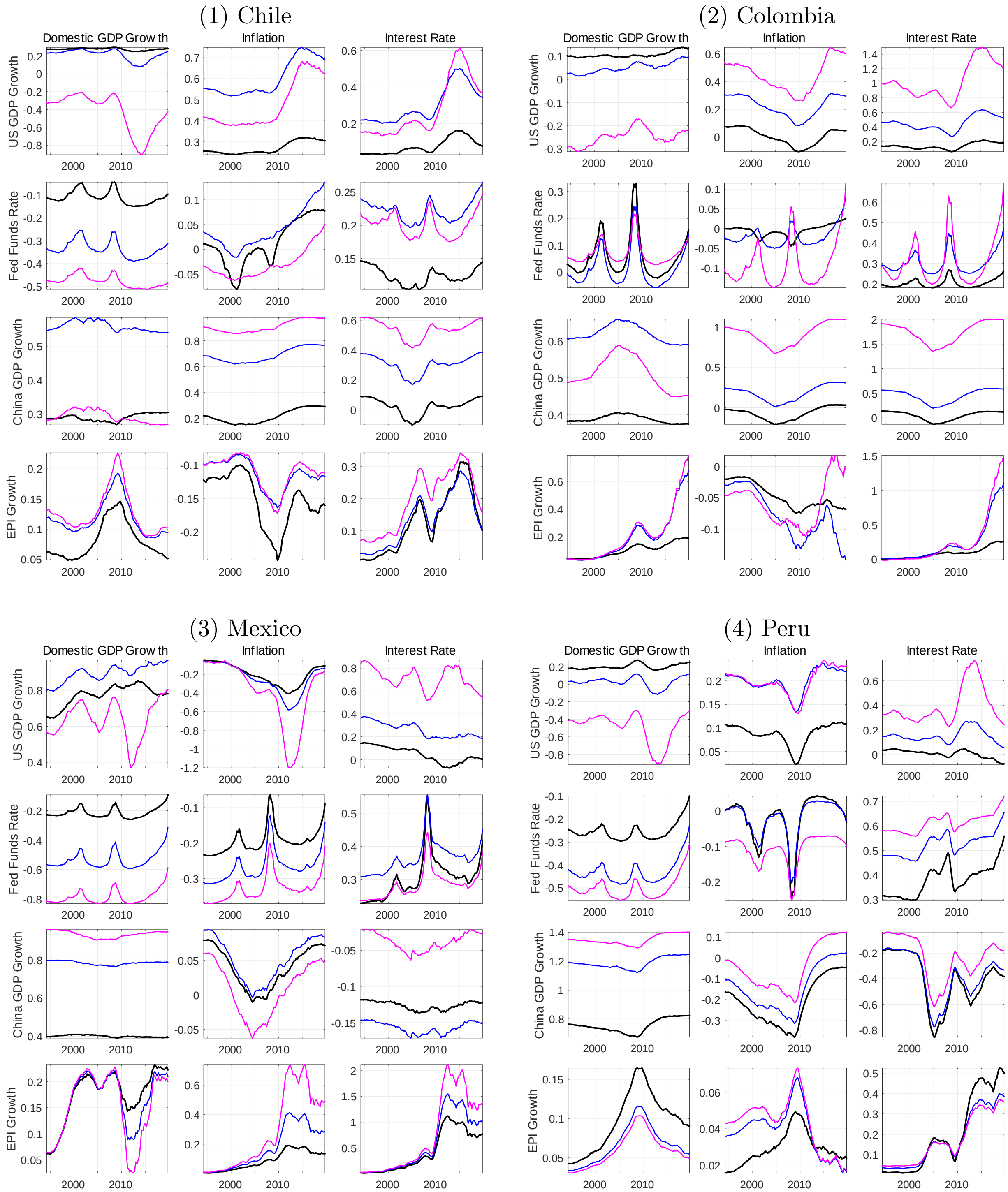


Figure 7. Evolution of Impulse Responses of Domestic Variables to different External Shocks at Specific Horizons over time, Median values. Cumulated response at the end of the First Year (black line), Second Year (blue line) and Fifth Year (magenta line).

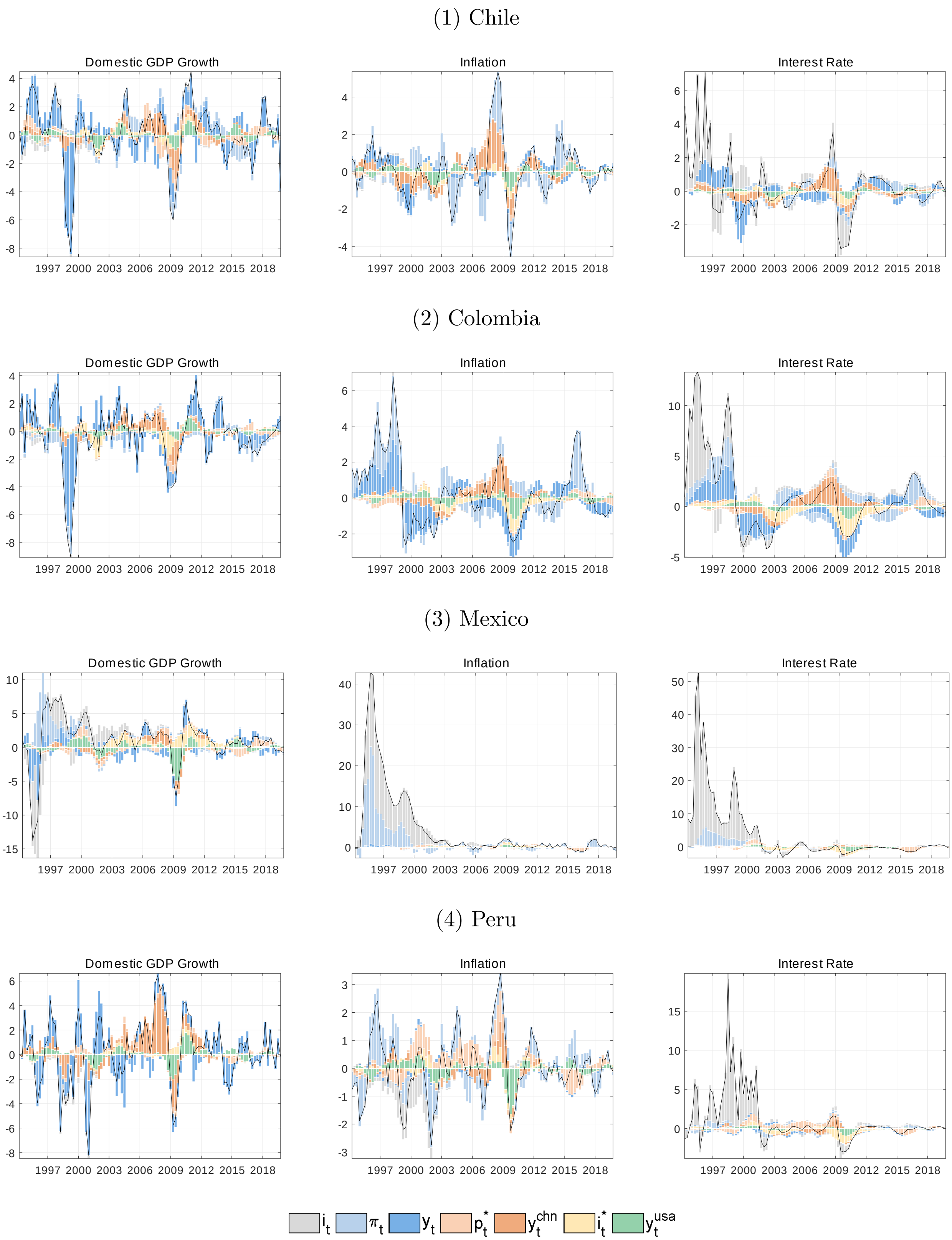
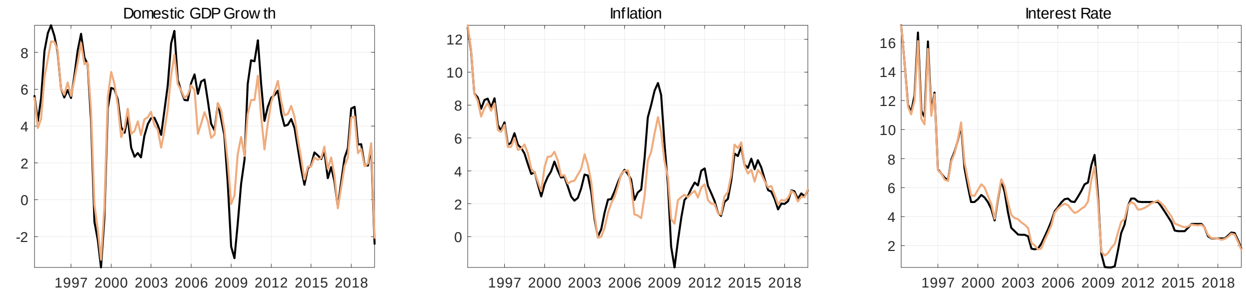
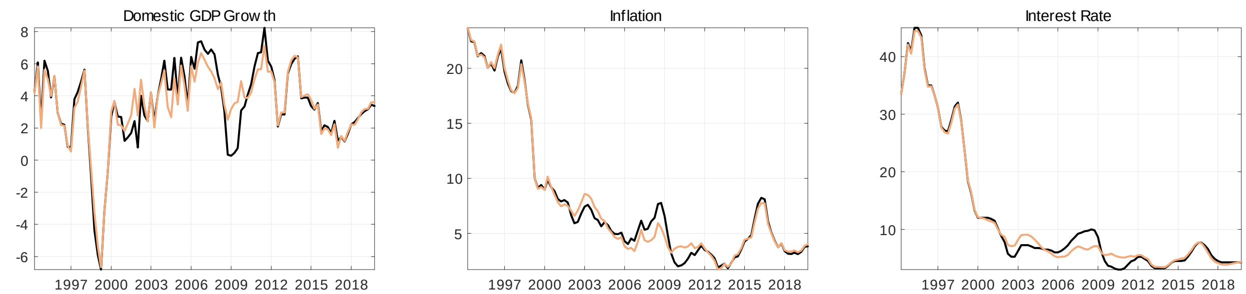


Figure 8. HD of Domestic GDP Growth, Inflation and Interest Rate for the selected models:TVP-VAR-R3-SV Model for Chile and Peru; TVP-VAR-R2-SV Model for Colombia; and TVP-VAR-R1-SV Model for Mexico.

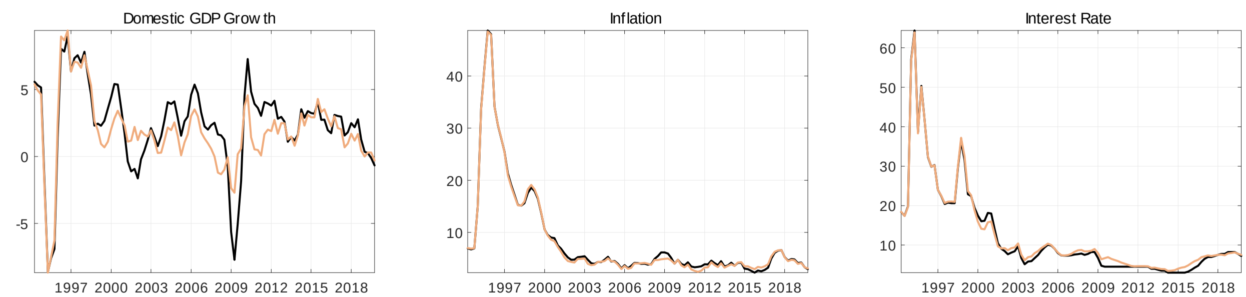
(1) Chile



(2) Colombia



(3) Mexico



(4) Peru

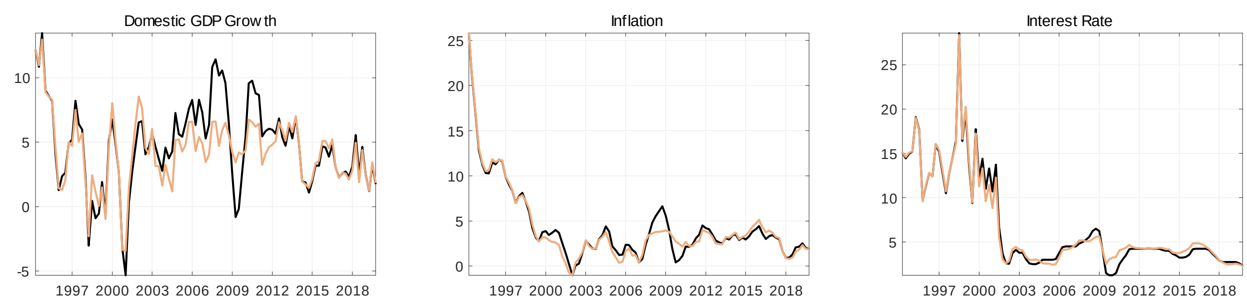


Figure 9. Evolution of the Domestic GDP Growth, Inflation and Interest Rate in the absence of External Shocks for the selected models: TVP-VAR-R3-SV Model for Chile and Peru; TVP-VAR-R2-SV Model for Colombia; and TVP-VAR-R1-SV Model for Mexico. Black lines denotes Actual Values and Orange lines denotes Counterfactual Values.

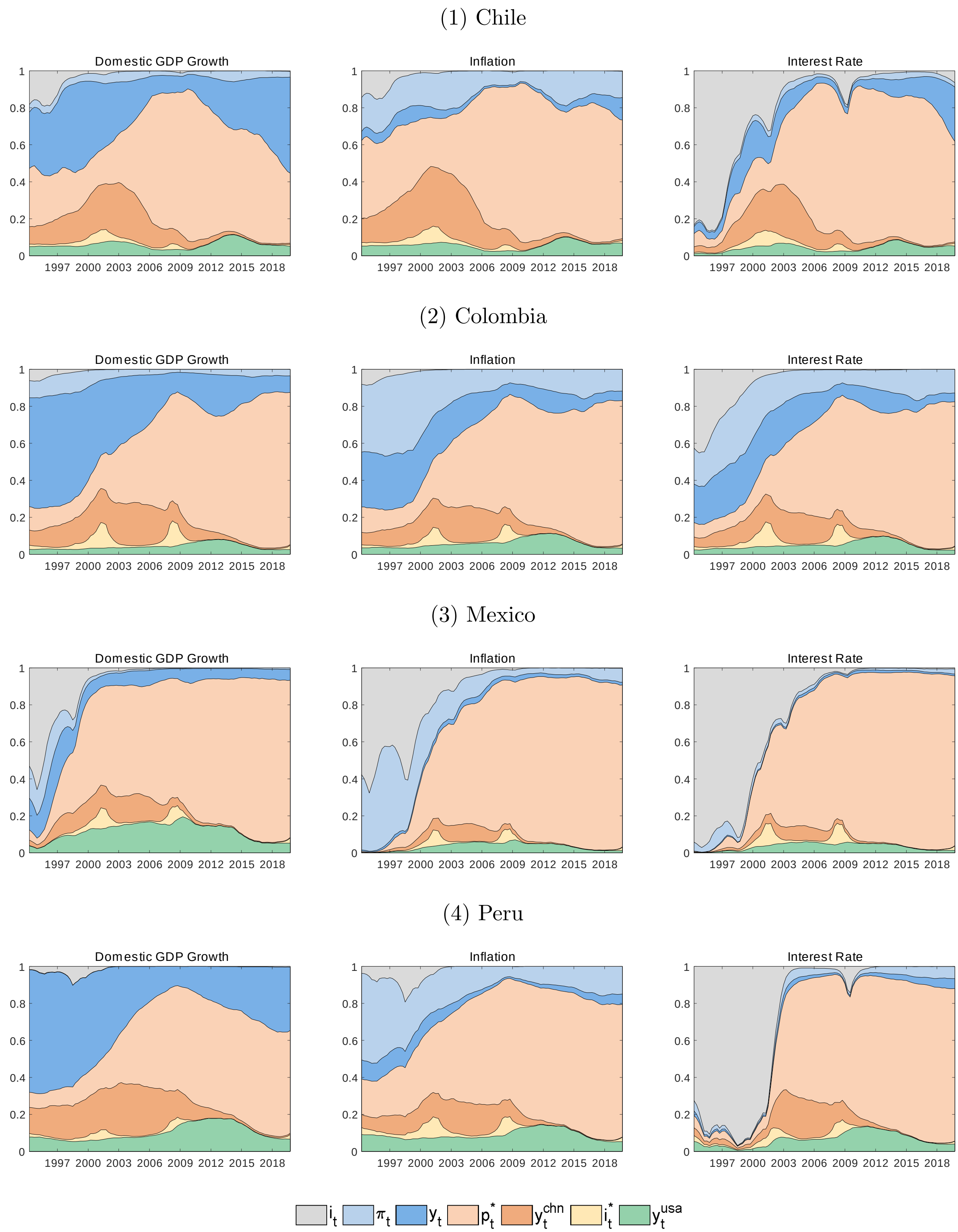


Figure 10. Time Evolution of the FEVD of Domestic GDP Growth, Inflation and Interest Rate for the selected models: TVP-VAR-R3-SV Model for Chile and Peru; TVP-VAR-R2-SV Model for Colombia; and TVP-VAR-R1-SV Model for Mexico.

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