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EXTERNAL SHOCKS AND ECONOMIC FLUCTUATIONS IN PERU: EMPIRICAL EVIDENCE USING MIXTURE INNOVATION TVP-VAR-SV MODELS

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Departamento Académico de Economía

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External Shocks and Economic Fluctuations in Peru: Empirical Evidence using Mixture Innovation TVP-VAR-SV Models*

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Abstract

We employ a family of mixture innovation, time-varying parameter VAR models with stochastic volatility (TVP-VAR-SV) to analyze the impact of external shocks on Peru's GDP growth, inflation, and interest rate from 1998Q1 to 2019Q4. Our key findings are as follows: (i) the model best fitting the data features time-varying parameters and variances with a certain likelihood; (ii) impulse-response functions reveal that a 1% increase in the growth rate of Peru's major trading partners (China and the U.S.) leads to a domestic GDP growth expansion of 0.65% and 0.21%, respectively; (iii) the forecast error variance decomposition shows that external shocks account for 65% of the long-term variability in output, 65% in inflation, and 67% in the interest rate; (iv) historical decomposition indicates that external shocks account for 50% of domestic GDP growth, particularly from 2002 onward. Lastly, we validate the results obtained in the primary specification through four robustness exercises.

Classification JEL: C32, C52, E31, F41.

Keywords: External Shocks, Macroeconomic Fluctuations, Time-Varying Parameter Vector Autoregressive Models, Stochastic Volatility, Mixture in Innovations, Peru.

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Choques Externos y Fluctuaciones Económicas en Perú: Evidencia Empírica utilizando Modelos TVP-VAR-SV con Mezcla en Innovaciones*

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Resumen

Empleamos una familia de modelos VAR de parámetros cambiantes en el tiempo y volatilidad estocástica (TVP-VAR-SV) con mezcla en las innovaciones para analizar el impacto de los choques externos en el crecimiento del PIB, la inflación y la tasa de interés de Perú desde el primer trimestre de 1998 hasta el cuarto trimestre de 2019. Nuestros hallazgos importantes son los siguientes: (i) el modelo que mejor se ajusta a los datos presenta parámetros que varían en el tiempo y varianzas con cierta probabilidad; (ii) las funciones de impulso respuesta revelan que un aumento del 1% en la tasa de crecimiento de los principales socios comerciales del Perú (China y Estados Unidos) conduce a una expansión del crecimiento del PIB interno del 0.65% y 0.21%, respectivamente; (iii) la descomposición de la varianza del error de predicción muestra que los choques externos representan el 65% de la variabilidad a largo plazo del producto, el 65% de la inflación y el 67% de la tasa de interés; (iv) la descomposición histórica indica que los choques externos representan el 50% del crecimiento del PIB interno, particularmente a partir de 2002. Por último, validamos los resultados obtenidos en la especificación primaria mediante cuatro ejercicios de robustez.

Clasificación JEL: C32, C52, E31, F41.
Palabras Clave: Choques Externos, Fluctuaciones Macroeconómicas, Modelos VAR con Parámetros Cambiantes, Volatilidad Estocástica, Mezcla en Innovaciones, Perú.

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1 Introduction

The impact of external shocks on the domestic economy is a persistent concern in the field of macroeconomics and policy-making. Models related to international trade, such as the one proposed by Bussière et al. (2013), emphasize that a high degree of trade integration in the global economy leads to significant impacts on domestic output due the increased sensitivity of domestic demand to external conditions. Additionally, small, open, developing countries that have a higher degree of financial and trade integration, following the primary export model, are more susceptible to international developments than countries with a strong domestic market. In this context, it is crucial to analyze the extent and evolution of the impact of external shocks on Peru, a small, open economy specialized in commodity trade.

The literature suggests that external shocks affect these economies through different channels. The first one is the financial channel, which impacts financing costs and capital flows through changes in foreign interest rates. Flores (2015) explains that an increase in the interest rate of the US Federal Reserve (Fed) generates capital outflows, resulting in reduced credit and investment, ultimately causing a significant and persistent decline in local economic activity. Furthermore, Contreras et al. (2017) explain that Peru is particularly exposed to this channel since private sector credit reached high levels of dollarization in the 1990s, making the country more sensitive to US monetary policy. Despite recent efforts to reduce financial dollarization, transactions in foreign currency persist at around 60%, meaning that a monetary shock in the federal funds rate can still have a significant impact on the Peruvian economy.

The second one is the trade channel, which affects export incomes and capital flows through the demand from key trading partners, namely China and the US for Peru. Therefore, the level of trade openness is a critical factor in determining a country's exposure to external shocks. As part of the reforms in the 1990s in Peru, foreign policy strategies, such as reducing and standardizing tariffs, increased the average level of trade openness[1] from 30% between 1994-2006 to 50% between 2007-2019; see Díaz-Cassou et al. (2020). These policies led to China and the US accounting for 29.4% and 12.3%, respectively, of Peru's total exports in 2019, becoming Peru's main trading partners.

Finally, there is the nominal or price channel, which is activated by fluctuations in the terms of trade when prices of export commodities, such as copper and gold, change; see Nolazco et al. (2016) and Rodríguez et al. (2023). One characteristic that makes the Peruvian economy particularly sensitive to external shocks is its heavy reliance on exports of primary commodities. Mendoza and Collantes Goicochea (2017) highlight that, among external factors, terms of trade constitute the most critical component, explaining 25.6% of the variance in real GDP growth during the period 2001-2016. This finding is supported by Rodríguez et al. (2018), Florián et al. (2018), Rodriguez et al. (2023a, 2023b), and Chávez and Rodríguez (2023), who find that external shocks from the nominal channel explain between 30% and 60% of the variability in GDP growth.

This document aims to provide further empirical evidence on the importance and evolution of external shocks on Peru's economic activity between 1998Q1-2019Q4 using a family of time-varying parameter, mixture innovation VAR models with stochastic volatility (TVP-VAR-SV), as proposed by Koop et al. (2009). This approach has the advantage of estimating where, when, and how parameters change. The results obtained in this study contribute to the literature on the effects of external shocks on Peru by providing new stylized facts or reinforcing previous evidence. Firstly, the results suggest that the model incorporating time-varying parameters and stochastic volatility with a 99% probability is the best fit for the data, outperforming the traditional VAR model and

[1] The degree of average trade openness is measured as the average percentage of the value of exports relative to domestic output.

other restricted or unrestricted models. Secondly, favorable external shocks from China's growth have the most substantial impact on domestic output, with an increase of up to 0.65%. Thirdly, external shocks explain between 60% and 65% of the forecast error variance decomposition (FEVD) for GDP growth, inflation, and interest rates.

The remainder of the document is structured as follows: Section 2 offers a literature review; Section 3 outlines the methodology used to estimate the TVP-VAR-SV models proposed by Koop et al. (2009); Section 4 describes the data used and examines the impacts of external shocks on GDP growth, inflation, and interest rate; Section 5 provides an analysis of various robustness exercises; and Section 6 presents our conclusions.

2 Literature Review

A considerable body of research suggests that external shocks have a significant impact on a country's domestic variables.[2] Mendoza (1995) examines the relationship between the terms of trade and economic fluctuations, finding that external shocks explain approximately 50% of output variability in G-7 countries. A similar result is found by Kose et al. (2003), who analyze economic fluctuations in North American countries, finding that external shocks explain 62.4% and 71.9% of growth variability in the US and Canada, respectively. Bergholt (2015) also finds that external shocks have a significant and persistent impact on the Canadian economy, increasing from 21.38% in the short term to 73.86% in the long term.

In Russia, Simola (2019) concludes that external shocks play a significant role in the economy, arguing that a 10% increase in oil prices and a 1% increase in US output result in a 2% long-term increase in real GDP growth. In the UK, for the period 1997-2019, Cesa-Bianchi et al. (2021) show that global shocks explain 52% of output variability, with international financial shocks being the primary drivers.

In Asia, Chua et al. (1999) analyze the influence of shocks from the US and Japan on output growth in Korea and Malaysia. They find that external shocks have a greater contribution than domestic shocks in the long term (64% for Korea and 56% for Malaysia). Similarly, Zaidi and Fisher (2010) estimate an SVAR model using Malaysian data and find that external shocks account for 65% of output variability in the long term, with commodity prices and foreign GDP having the most significant impact. Likewise, Zaim and Karim (2014) calculate that shocks from Singapore, the US, and Japan explain 48% and 86% of Malaysia's inflation and interest rate variability, respectively, in the long term.

Ruffer et al. (2007) estimate a VAR model and find that external shocks are more relevant than domestic shocks (68.7% for China, 81% for Malaysia, 75% for Singapore, and 52.4% for Thailand). Similar evidence is found by Allegret et al. (2012), who estimate an SVAR model and find that the contribution of these shocks is significant in the long term (58.58% for China, 82.91% for Japan, 63.11% for Indonesia, 69.20% for the Philippines, and 75.19% for Singapore). Of the four external shocks used, the most important for the five countries is oil price.

In Latin America, studies indicate that external shocks play a significant role. Canova (2005) examines the impact of US shocks on output variability in eight countries (Mexico, Ecuador, Argentina, Peru, Uruguay, Brazil, Chile, and Panama) and concludes that external shocks make a substantial average contribution of 58%. Österholm and Zettelmeyer (2008) obtain a similar result

[2]However, Ahmed and Murthy (1994) for Canada, Hoffmaister and Roldós (1997) for Latin America and Asia, and Boschi and Girardi (2011) for other Latin American countries, among other authors, suggest that output is primarily influenced by domestic supply and demand shocks, and that external shocks do not play a significant role in GDP growth variations.

using a Bayesian VAR model for the period 1994-2006 with data from Argentina, Brazil, Chile, Colombia, Mexico, and Peru, finding that external shocks account for 50-60% of output variability.

In Bolivia, Jemio and Wiebelt (2003) find that a 10% drop in the terms of trade leads to a 2.5% reduction in GDP growth. In Colombia, Hernandez (2013) finds that shocks from commodities explain 30% of output variability. In Uruguay, Almada and Barreto (2017) estimate a Global Vector Autoregressive (GVAR) model and find that recessionary shocks of 1.34% and 3% on GDP growth in Argentina and Brazil, respectively, result in a 2% decline in domestic output growth.

In Peru, the consensus among most authors is that external shocks are the primary drivers of economic fluctuations. Dancourt et al. (1997) highlight that out of the six recessions occurring between 1950-1996, five coincided with adverse external shocks, leading to the conclusion that external factors play a central role in the country's economic oscillations. Castillo and Salas (2010) employed a VAR model with stochastic trends and determined that permanent terms-of-trade shocks account for 87% of output variability in the medium term. Similarly, Mendoza and Collantes Goicochea (2017) conclude that external factors (including US GDP growth, US inflation, 10-year US interest rates, China's GDP growth, and terms-of-trade growth) explain 67.11% of real GDP growth variations during 2001-2016, with terms of trade growth being the most influential. Additionally, Rodríguez et al. (2018) suggest that terms of trade represent the primary source of uncertainty in GDP growth, contributing to 50% of the forecast error variance within one year. Florián et al. (2018) arrive at similar findings, noting that anticipated terms-of-trade shocks account for 57% of output variation over two years.

Recent research in this field explores a range of TVP-VAR-SV models and Regime-Switching VAR models with stochastic volatility (RS-VAR-SV). Rodriguez et al. (2023a) present findings indicating that the growth of the S&P GCSI index explains 85% of the FEVD of output in the short term, while its influence on inflation hovers around 90%. Similarly, Rodríguez et al. (2023b) show that during the commodity boom period, external factors explained 80% of GDP growth fluctuations, thus confirming their pivotal role as the primary source of uncertainty. Additionally, Chávez and Rodríguez (2023) employ RS-VAR-SV models to demonstrate that, following the adoption of an inflation targeting (IT) regime in 2002, external shocks account for 70% of output variability.

This research seeks to make a valuable contribution by offering additional empirical evidence for Peru, employing a distinct methodology. Following the approach of Koop et al. (2009), a family of TVP-VAR-SV models with mixture innovations is used, allowing for the estimation of when, where, and how variances and parameters change. Notably, this model shares a common feature with the works of Chávez and Rodríguez (2023) and Rodríguez et al. (2023) in specifying three channels for the transmission of external shocks to the Peruvian economy: cfinancial, ommercial, and nominal.

3 Methodology

The econometric model is a mixture innovation TVP-VAR-SV model, as proposed by Koop et al. (2009), hereafter referred to as the Benchmark model, where both the transmission mechanism and the variance matrix can change over time. The model incorporates three blocks of parameters that can evolve differently over time: one is associated with the parameters of the VAR model coefficients, another with the error variance matrix, and the third with the contemporaneous effect coefficients. The advantage of the model is that it allows for estimating where, when, and how changes in parameters occur, rather than assuming a particular model in which all parameters change over time with a probability equal to 1, as in Primiceri (2005).

The reduced form of the TVP-VAR-SV model under a state-space form is:

$$y_t = X_t B_t + u_t \quad t = 1, 2, \ldots, T \tag{1}$$

$$B_{t+1} = B_t + v_t \quad t = 1, 2, \ldots, T \tag{2}$$

where y_t is an $n \times 1$ vector of observations for the dependent variables; B_t is an $m \times 1$ vector of states (VAR model coefficients); X_t is an $n \times m$ matrix containing explanatory variable data (each row of X_t contains lags of dependent variables and an intercept); $u_t \sim \mathcal{N}(0,\ H_t)$ and $v_t \sim \mathcal{N}(0,\ Q_t)$ for $t = 1, 2, ..., T$. The errors in equations (1) and (2), u_t and v_s, are mutually independent for all t y s. The Gibbs sampler algorithm proposed by Carter and Kohn (1994) is used for drawing the state variables $B_t = (B_1, ..., B_T)'$.[3]

To allow the variance matrix of innovations and contemporaneous effect coefficients in the measurement equation to vary over time, a triangular decomposition is used, such that $H_t = A_t^{-1}\Sigma_t\Sigma_t'(A_t^{-1})'$, where Σ_t is a diagonal matrix with elements on the diagonal being $\sigma_{j,t}$ for $j = 1, ..., n$ and A_t is a lower triangular matrix:

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & & 0 \\ 0 & \sigma_{2,t} & 0 & \ldots & \vdots \\ \vdots & \ddots & \ddots & \ddots & \\ & & & \sigma_{n-1,t} & 0 \\ 0 & \cdots & & 0 & \sigma_{n,t} \end{bmatrix}, \quad A_t = \begin{bmatrix} 1 & 0 & \cdots & & 0 \\ \alpha_{21,t} & 1 & 0 & \cdots & \vdots \\ \vdots & \ddots & \ddots & \ddots & \\ & & & 1 & 0 \\ \alpha_{n1,t} & \cdots & & \alpha_{n(n-1),t} & 1 \end{bmatrix}$$

where Σ_t contains the variances and A_t contains the contemporaneous relationships. Additionally, the stochastic volatility framework is used for Σ_t, i.e., $\sigma_t = (\sigma_{1,t}, ..., \sigma_{n,t})'$ where $h_{i,t} = \ln(\sigma_{i,t})$ and $h_t = (h_{1,t}, ..., h_{p,t})'$. The elements of the h_t vector evolve according to $h_{t+1} = h_t + \eta_t$, where $\eta_t \sim \mathcal{N}(0, W)$ and exhibits no autocorrelation or correlation with the disturbance terms u_t and v_t. Koop et al. (2009) adapt the algorithm from Kim et al. (1998) and transform equation (1):

$$y_t^* = A_t(y_t - Z_t\alpha_t) = A_t(A_t^{-1}\Sigma_t\epsilon_t) = \Sigma_t\epsilon_t, \tag{3}$$

where ϵ_t are independent and distributed as $\mathcal{N}(0,\ I_t)$. This system of measurement equations becomes a linear system through the following transformation of (3): $y_{i,t}^{**} = \ln\left[(y_{i,t}^*)^2 + \overline{c}\right]$, where $\overline{c}$ is a compensation constant that guarantees non-null values as proposed by Fuller (1996). This leads to the following state-space form:

$$\begin{aligned} y_t^{**} &= 2h_t + e_t, \\ h_t &= h_{t-1} + \eta_t, \end{aligned} \tag{4}$$

where $e_t = \ln(\epsilon_t^2)$, e_t, and η_t are uncorrelated, and e_t is distributed through a mixture of seven normal distributions according to Kim et al. (1998).

For A_t, which contains the contemporaneous effect coefficients, Koop et al. (2009) stack the unrestricted elements by rows into a vector $\frac{n(n-1)}{2}$ as $\alpha_t = (\alpha_{21,t},\ \alpha_{31,t},\ \alpha_{32,t}, ...,\ \alpha_{n(n-1),t})'$ that evolves according to $\alpha_{t+1} = \alpha_t + \zeta_t$, where $\zeta_t \sim \mathcal{N}(0, S)$ and exhibits no autocorrelation or correlation with the disturbance terms u_t, v_t, and η_t. Koop et al. (2009) transform the measurement equation (1) so that the Carter and Kohn (1994) algorithm can be used for drawing the states:

$$A_t(y_t - X_t'\widehat{B}_t) = A_t(\widehat{y}_t) = \Sigma_t\epsilon_t = \xi_t \tag{5}$$

[3]For more details, see the Appendix of Koop et al. (2009).

where $\xi_t \sim \mathcal{N}(0, \Sigma_t \Sigma_t')$ and is independent of ζ_t. The structure of A_t is used to solve for $\widehat{y}_t$ on the left-hand side and obtain the following approximate state-space form:

$$\begin{aligned} \widehat{y}_t &= S_t \alpha_t + \xi_t, \\ \alpha_{t+1} &= \alpha_t + \zeta_t, \end{aligned} \tag{6}$$

where S_t is detailed in Koop et al. (2009), and $\widehat{y}_{i,t}$ is the i-th element of $\widehat{y}_t$.

As for the mixture of innovations, the model allows for breakpoints in the VAR model coefficients (B_t), and in the matrix of variances and contemporaneous effect coefficients H_t (Σ_t y A_t), where these breakpoints can occur at any time. Therefore, $K_t = (K_{1t},\ K_{2t},\ K_{3t})'$ for $t = 1, ..., T$, where $K_{1t} \in \{0,\ 1\}$ controls the breakpoint in the VAR model coefficients, $K_{2t} \in \{0,\ 1\}$ controls the breakpoints in the variances, Σ_t; and $K_{3t} \in \{0, 1\}$ controls the breakpoints in the contemporaneous effect coefficients, A_t. Therefore, the state equations for B_t, h_t and α_t are reformulated as follows:

$$B_{t+1} = B_t + K_{1t} v_t, \tag{7}$$

$$h_{t+1} = h_t + K_{2t} \eta_t, \tag{8}$$

$$\alpha_{t+1} = \alpha_t + K_{3t} \zeta_t, \tag{9}$$

where a Bernoulli distribution is used for the hierarchical order of the prior of K_{jt}; $p(K_{jt} = 1) = p_j$ for $j = 1, 2, 3$, i.e., p_j is the probability of a breakpoint occurring at time t. Additionally, breakpoints occur independently in B_t, Σ_t y A_t.

3.1 Posterior Computation

To estimate the posterior distributions of the parameters in the Benchmark model, a Markovian MCMC (Monte Carlo Markov Chain) algorithm is employed. Regarding the VAR model coefficients (B_t), a Wishart prior is used for $Q^{-1} : Q^{-1} \sim \mathcal{W}(\underline{v}_Q,\ \underline{Q}^{-1})$, where the posterior for Q^{-1} is a Wishart distribution: $Q^{-1}|Data \sim \mathcal{W}(\overline{v}_Q,\ \overline{Q}^{-1})$. For $\mathbf{\Sigma}_t$, a Wishart prior is used for $W^{-1} : W^{-1} \sim \mathcal{W}(\underline{v}_w,\ \underline{W}^{-1})$, where the posterior for W^{-1} is a Wishart distribution: $W^{-1}|Data \sim \mathcal{W}(\overline{v}_w,\ \overline{W}^{-1})$. For A_t, a Wishart prior is employed for S_j^{-1} :$S_j^{-1} \sim \mathcal{W}(\underline{v}_{Sj},\ \underline{S}_j^{-1})$, where S_j^{-1} is a Wishart distribution: $S_j^{-1}|Data \sim \mathcal{W}(\underline{v}_{Sj},\ \underline{S}_j^{-1})$. Finally, concerning the hierarchical prior of K_{jt}, a conjugate Beta prior is used for $p_j : p_j \sim \mathcal{B}(\underline{\beta}_{1j},\ \underline{\beta}_{2j})$. Thus, the conditional posterior for p_j es $p_j \sim \mathcal{B}(\overline{\beta}_{1j}, \overline{\beta}_{2j})$, where $\overline{\beta}_{1j} = \underline{\beta}_{1j} + \sum_{t=1}^{T} K_{jt}$ y $\overline{\beta}_{2j} = \underline{\beta}_{2j} + T - \sum_{t=1}^{T} K_{jt}$.

Koop et al. (2009) combine the algorithm from Gerlach et al. (2000) with Carter and Kohn (1994) to obtain draws of K_{1t} and B_t (conditioned on all other parameters of the model, including K_{2t} and K_{3t}). Subsequently, they combine the algorithm from Gerlach et al. (2000) with the extension by Kim et al. (1998) to obtain draws of K_{2t} and Σ_t (conditioned on all other parameters of the model, including K_{1t} and K_{3t}). Finally, they combine the algorithm from Gerlach et al. (2000) with Carter and Kohn (1994) to obtain draws of K_{3t} and A (conditioned on all other parameters of the model, including K_{1t} and K_{2t}).

3.2 Other Models

Building upon the Benchmark model proposed by Koop et al. (2009), the following additional versions are considered: (i) the Primiceri model (2005) that imposes $K_{1t} = K_{2t} = K_{3t} = 1$, i.e., all three blocks of parameters vary over time; (ii) a model that assumes that the coefficients of contemporaneous effects are constant over time (Benchmark A_t constant model) assuming $K_{3t} = 0$, similar to Cogley and Sargent (2005); (iii) a model that restricts both variances and coefficients of contemporaneous effects to be constant over time (Benchmark A_t and Σ_t constant model), imposing $K_{2t} = K_{3t} = 0$, akin to Cogley and Sargent (2001); (iv) the Benchmark A_t and B_t constant model, assuming only variances vary, i.e., $K_{2t} = 1$; (v) the Benchmark B_t constant model, imposing that the coefficients of the VAR model are constant over time, i.e., $K_{1t} = 0$; and (vi) the classic Constant VAR model (CVAR), assuming $K_{1t} = K_{2t} = K_{3t} = 0$.

3.3 Model Performance Evaluation

Following Carlin and Louis (2000), we use the expected value of the log-likelihood function as a conventional information criterion to compare the models described in 3.2. To obtain this value, let $\mathbf{Y}$ stack all the data in the dependent variables, and let λ denote all the model parameters except K_1, K_2 and K_3 and the states themselves. Gerlach et al. (2000) describe how to calculate $p(\mathbf{Y}|K_t, \lambda)$. Therefore, we calculate $p(\mathbf{Y}|K_1, \lambda)$, $p(\mathbf{Y}|K_2, \lambda)$, and $p(\mathbf{Y}|K_3, \lambda)$ and average these values.

4 Empirical Evidence

In this Section, we begin by introducing the data used in the analysis. Subsequently, we delve into the empirical findings, which encompass insights into parameter evolution, error volatility in the employed variables, impulse-response functions (IRFs) of domestic variables to external shocks, forecast error variance decomposition (FEVD), and historical decomposition (HD) of domestic variables.

4.1 Data

The data used in this study consists of quarterly time series expressed in annual growth rates, except for local and international interest rates. The sample period covers 1994Q1 to 2019Q4, and the data series have been sourced from the databases of the Central Reserve Bank of Peru (BCRP), Bloomberg, and the Federal Reserve Bank of St. Louis (FRED). The system comprises a total of seven variables categorized into two blocks: an external block, encompassing the first four variables, and a domestic block, encompassing the remaining variables. The external block comprises the US economic growth (y_t^{usa}), the Fed policy interest rate, (i_t^*), China's economic growth (y_t^{chn}), and the growth of the terms of trade (tot_t). The domestic block comprises the domestic GDP growth (y_t^{per}),[4] inflation (π_t), and the local interest rate (i_t), which is constructed by combining the interbank interest rate until 2003Q3 and the reference interest rate from 2003Q4 until the end of the sample.

Figure 1 presents the seven variables used in the base model. The y_t^{per} series reveals three significant declines: the first occurred in 1998, primarily attributed to the country's recession resulting from the El Niño phenomenon and the global context, including the Asian, Russian, and Brazilian crises; the second one, in 2001, was due to reduced domestic demand and capital inflows; and the third one, in 2008, resulted from the onset of the Global Financial Crisis (GFC); see Winkelried (2017). During the period 1994-2001, π_t decelerated due to weak domestic demand and the BCRP's expansionary policy. Subsequently, during 2002-2013, π_t decreased to 2.9%, primarily as a consequence of IT adoption, which strengthened Peru's macroeconomic policy. The i_t series

[4]The domestic GDP series has been seasonally adjusted using the TRAMO/SEATS software developed by Gómez and Maravall (1996).

exhibited high levels in the pre-IT period, peaking in 1998 due to depreciatory expectations in the face of adverse economic conditions (i.e., El Niño phenomenon and international financial crises).

On the external front, Figure 1 shows that y_t^{usa} remained relatively stable throughout most of the sample, with sharp declines in 2001 and 2010. The 2001 decline was attributed to the bursting of the dot-com bubble[5] and the terrorist attacks that occurred that year. The 2010 decline was a consequence of the global recession that began in 2008, triggered by the bursting of the housing bubble. The y_t^{chn} series exhibited higher volatility during the 1994-2010 period, primarily due to China's industrial expansion, increased investments, and export demand. After 2008, the volatility of y_t^{chn} decreased due to the onset of the GFC that year. Moreover, after the Asian financial crisis in 1998 and the GFC in 2008, the i_t^* series remained at levels below 2% to stabilize the financial system and prevent economic recession; see Recio and Egea (2015). Finally, in 2008, tot_t experienced a significant decline associated with the GFC. Its rapid recovery post-2009 was due to the macroeconomic stimulus emanating from China.

4.2 Prior Values

To calibrate the hyperparameters, we estimate a CVAR model using fifteen quarters as a training sample (1994Q1-1997Q3). This allows us to obtain the coefficients, $\widehat{\beta}_{OLS}$, and the variance-covariance matrix can be decomposed to produce $\widehat{A}_{QLS}$ and $\widehat{\sigma}_0$. We also obtain the variance-covariance matrices of $\widehat{\beta}_{OLS}$ and $\widehat{A}_{OLS}$, denoted as $V(\widehat{\beta}_{OLS})$ y $V(\widehat{A}_{OLS})$, respectively. Using these values, the priors for the initial conditions of each of the state equations are: $B_0 \sim \mathcal{N}(\widehat{B}_{OLS}, 4V(\widehat{B}_{OLS}))$, $A_0 \sim \mathcal{N}(\widehat{A}_{OLS}, 4V(\widehat{A}_{OLS}))$, and $\log(\widehat{\sigma}_0) \sim \mathcal{N}(\log(\widehat{\sigma}_0), 4I_n)$. The priors are then determined by the variances of the errors in the state equation, allowing these priors to depend on the priors that determine the number of breakpoints that can occur. It is important to note that the Beta prior we use for p_j implies that $E(p_j) = \frac{\underline{\beta}_{1j}}{\underline{\beta}_{1j}+\underline{\beta}_{2j}}$, where $\underline{\beta}_{1j} = 1$ y $\underline{\beta}_{2j} = 1$ for $j = 1, 2, 3$. Thus, $E(p_j) = 0.5$, i.e., there is a 50% probability of a breakpoint occurring in the parameter block in any given time period. Therefore, the following prior is established for the error of the variances in the state equation: $v_Q= 37$, $Q = (k_Q)^2 V(\widehat{B}_{OLS})(1/E(p_1)), v_Q= 5$, $W = 4(k_W)^2(I_3)(1/E(p_2)), v_{Sj}= j + 1$, and $S_j = (j + 1)(k_S)^2 V(\widehat{A}_{m,OLS})(1/E(p_3))$ for $j = 1, 2, 3$. Finally, it is worth noting that k_Q, k_W and k_S are the prior values for time variation; and $k_Q^2= 0.5 \text{ x } 10^{-4}$, $k_W^2= 1 \text{ x } 10^{-4}$ and $k_S^2= 1 \text{ x } 10^{-3}$ as in Canova and Pérez Forero (2015).

4.3 Empirical Results

The estimates are based on 70,000 iterations of Gibbs sampling, discarding the first 20,000. The identification strategy is carried out through recursive restrictions (Sims, 1980), where the matrix of contemporaneous relationships adopts a lower triangular form, meaning the variables are ordered from the most exogenous to the most endogenous y_t: $[y_t^{usa}, i_t^*, y_t^{chn}, tot_t, y_t^{per}, \pi_t, i_t]'$.

In the external block, the proposed ordering assumes that i_t^* responds to y_t^{usa}. In turn, fluctuations in y_t^{usa} and i_t^* influence decisions about trade and investment in China, affecting y_t^{chn}. These global demand fluctuations directly impact tot_t through changes in commodity prices. In the domestic block, variations in y_t^{per} imply changes in π_t, and depending on the dynamics of both variables, the monetary authority reacts by increasing or decreasing i_t.

[5]The dot-com bubble refers to the speculative phenomenon that took place between 1997 and 2001 in the technology sector, specifically internet-related companies. The surge in stock prices for these firms, combined with speculation and ample capital availability, fostered a favorable environment. The bursting of the dot-com bubble marked the onset of a moderate and protracted recession in Western countries.

Each structural shock is identified as follows: the errors of the equations for y_t^{usa}, i_t^*, y_t^{chn} and tot_t represent external shocks; the error of the equation for y_t^{per} represents the aggregate demand (AD) shock; the error of the equation for π_t represents the aggregate supply (AS) shock; and the error of the equation for i_t represents the monetary policy (MP) shock. This model is estimated using one lag, selected according to the Bayesian Information Criterion (BIC), so the results cover the period from 1998Q1 to 2019Q4.

4.3.1 Parameter Evolution

To assess the evolution of parameters over time, we employ the Trace test, the Kolmogorov-Smirnov (K-S) test, and the t-test. These tests are directly applied to the coefficients, variances, and contemporaneous effect coefficients of the TVP-VAR-SV model. The results are summarized in Table 1. The Trace test examines the trace of the prior variance matrix, yielding a value of 0.28 in this case. This value falls below the mean bound of 0.30 but exceeds the lower bound of 0.22 (which is estimated for the trace of posterior variances), indicating the presence of changing volatility over time. The K-S test checks whether each parameter can be drawn from the same continuous distribution, while the t-test assesses if these distributions have the same mean at two different time points. Initially, we divide the sample into two regimes (1998Q1-2002Q4 and 2003Q1-2019Q4). The results for the variance matrix of innovations, Σ_t, indicate a 100% variability, supporting the inclusion of stochastic volatility for better model specification. However, the results for the remaining two parameter blocks yield different insights. For the coefficients of lagged variables, B_t, the K-S test reveals a variability range between 73% and 86%, while the t-test suggests a range of 71% to 84%. As for the contemporaneous effects, the K-S test points to variability between 62% and 76%, while the t-test suggests that the entire parameter block should vary over time. Similar results are obtained when these statistics are calculated by splitting the total sample in half.

The empirical findings concerning breaks in all three parameter blocks and the model that gains the strongest support from the data are summarized in Table 2. The expected log-likelihood function value, denoted as $E(\log L)$, is used to gauge each model's performance. In the Benchmark model, both expected probabilities of variability, $E(p_1|Data)$ and $E(p_2|Data)$, related to B_t and Σ_t, exceed 95%. This indicates a high likelihood that the coefficients of the SVAR model and error volatilities change over time. Conversely, the estimated probability of variability for $E(p_3|Data)$, associated with A_t, stands at 10%. This result suggests a low probability of the contemporaneous effect coefficients changing over time.

As a result, the Benchmark A_t constant model ($K_{3t} = 0$) outperforms the others, showing the highest expected log-likelihood function value, followed by the Benchmark and Primiceri (2005) models. The Benchmark A_t and B_t constant, B_t constant, and A_t and Σ_t constant models receive little support from the data, and the CVAR model receives the least support. Therefore, we conclude that the evolution of parameters over time is crucial, particularly for parameter blocks containing SVAR model coefficients and error variances. Consequently, the subsequent sections prioritize the analysis of the results from the Benchmark A_t constant model.

4.3.2 Volatilities

Figure 2 shows how the standard deviation of errors changes over time for all the models. The results indicate that models considering time-varying B_t follow a similar pattern for both domestic and external shocks. It is important to note that the Primiceri (2005) model tends to estimate higher volatility compared to the other models. For the Benchmark and Benchmark A_t constant models, the standard deviations of errors are quite similar, which aligns with these models fitting the data best.

In the external block, there is a period of increased error volatility in y_t^{chn} (1998-2002), linked to the Asian financial crisis and China's growing integration into the global economy. A similar pattern is seen in the volatility of errors in tot_t which reflects China's role as the world's largest consumer of commodities and its significant trade relationship with Peru. Additionally, the errors in y_t^{usa} and i_t^* show high volatility during 2008-2009, which coincides with the GFC triggered by Lehman Brothers' bankruptcy. These findings are consistent with Rodriguez et al. (2023a), who found through a set of TVP-VAR-SV models that the standard deviation of external shocks increased until mid-2008 before leveling off.

In the domestic block, the dynamics of standard deviations are similar: episodes of high volatility between 1998-2002, followed by a significant decline. Armas and Grippa (2006) explain that this decline is due to IT adoption by the BCRP to maintain price stability, enhance the effectiveness of monetary policy, and strengthen the role of the local currency. Additionally, in 2008, there is a slight increase in the volatility of domestic shocks, which was caused by the onset of the GFC. Portilla et al. (2022) suggest that while Peru experienced capital flow slowdowns and a significant decline in terms of trade during both the 1998 and 2008 international financial crises, the macroeconomic response during the latter was more effective due to the implementation of an expansionary policy by the BCRP, which helped alleviate the impact of the external context.

Finally, in both the external and domestic blocks, it is evident that the CVAR model fails to capture the uncertainty in standard deviations of errors because it assumes constant variances. This aligns with the CVAR model ranking lowest in Table 2, indicating that it provides the poorest fit to the data.

4.3.3 Impulse Response Functions (IRFs)

This section examines the IRFs for y_t^{per}, π_t and i_t in response to various external shocks. We categorize the IRFs into two types: 3D IRFs, which illustrate the evolution of domestic variables' responses to external shocks over time (from Figure 3 to Figure 6), and 2D IRFs, which present the median IRFs in response to positive external shocks along with their corresponding confidence intervals (from Figure 7 to Figure 10).

In Figure 3 (positive shock to y_t^{usa}), we observe a positive impact on y_t^{per} lasting for three quarters. However, this effect diminishes over the years, declining from 0.37% in 2001 to 0.19% in 2019. Furthermore, both π_t and i_t exhibit a positive response to the shock originating from y_t^{usa}.

Figure 4 (increase in i_t^*) demonstrates a negative impact on y_t^{per}, with a relatively stable effect over time, shifting from -0.53% in 2001 to -0.48% in 2019. Similarly, π_t and i_t respond in alignment with US monetary policy.

In Figure 5 (positive shock to y_t^{chn}), the response of y_t^{per} is positive and grows over time. The impact in 2001 is 0.60%, rising to 0.87% in 2019. In the medium term, both π_t and i_t display positive responses.

Figure 6 (positive shock to tot_t) reveals a positive and transitory impact on y_t^{per} throughout all years, with a duration of two quarters. The magnitude displays moderate temporal variation, with the effect reaching 0.33% in 2001 and peaking at 0.39% in 2012.

Figure 7 presents the median IRFs (black line) in response to a positive shock in y_t^{usa} along with their 14% and 86% confidence intervals (shaded area). This visual indicates a positive and transitory response of y_t^{per}, with a magnitude of 0.24%. This response is attributed to the influence of the US economy on Peruvian trade.[6] Studies by Chávez and Rodríguez (2023), and Rodríguez et

[6] An improvement in economic conditions in China and the US strengthens Peru's economy through higher export revenues. See Urbina and Rodriguez (2023).

al. (2023a, 2023b) yield similar results, confirming the positive impact and transitory nature of the external shock. As for π_t and i_t, their responses are also positive and transitory, with magnitudes of 0.2% and 0.1%, respectively. The increase in π_t is due to the possibility that the shock from y_t^{usa} may induce inflationary pressures through increased domestic demand resulting from higher export income and investment flows. The response of i_t aligns with the BCRP's countercyclical stance against external shocks and its commitment to inflation stabilization.

Figure 8 illustrates the response of domestic variables to a positive shock in i_t^*. The impact on y_t^{per} is contractionary, with a magnitude of -0.15% in the third quarter. This is because a shock in i_t^* negatively affects exchange rates, international reserves, and stock prices, leading to reduced credit, investment, and domestic demand. This, in turn, results in higher external financing costs for small, open economies like Peru; see Eichengreen and Gupta (2015), Flores (2015), Nolazco et al. (2016), and Quispe et al. (2017). Furthermore, the responses of π_t and i_t are positive, with magnitudes of 0.14% and 0.6%, respectively, corroborating the synchronization of Peru's monetary policy with Fed decisions. The increase in π_t can be attributed to the exchange rate pass-through effect resulting from the depreciation of the domestic currency against the dollar, caused by capital outflows seeking higher returns in the US Likewise, the positive response of i_t results from the BCRP's adoption of a countercyclical policy aimed at meeting the inflation target, indicating a pass-through effect from i_t^* to i_t.

Figure 9 showcases the response of domestic variables to a positive shock in y_t^{chn}. The impact on y_t^{per} is significant, with a magnitude of 0.65% and a duration of eight quarters. China, being one of the world's largest consumers of raw materials, is a key factor in understanding why fluctuations in Peru's economy are closely tied to China's growth; see Xu et al. (2019). Furthermore, there is a 0.24% impact on π_t in the second quarter, and a 0.12% impact on i_t in the fourth quarter. These results indicate an increase in the momentum of domestic demand due to higher exports, foreign direct investment, and portfolio flows.

Figure 10 presents the impact of a positive shock in tot_t on domestic variables. The effect on y_t^{per} is positive and transitory, increasing by 0.28% in the first quarter, consistent with the findings of Ojeda Cunya and Rodríguez (2022). This reflects that tot_t is a source of prosperity for the Peruvian economy, as the globalization process reduces import and export restrictions, directly impacting y_t^{per}; see Loser (2013). Furthermore, the impact on π_t and i_t is -0.13% and 0.27%, respectively, attributable to the higher dynamism of exports, resulting in an appreciation of the local currency and a decrease in inflation due to the exchange rate pass-through effect.

4.3.4 Forecast Error Variance Decomposition (FEVD)

Figure 11 shows the evolution of the FEVD over time for the domestic variables y_t^{per}, π_t, and i_t in the short term ($h = 2$ quarters) and long term ($h = 20$ quarters). Additionally, Table 3 presents the FEVD results for y_t^{per} from the Benchmark A_t constant model.

The results indicate that until the end of 2001, external shocks accounted for 34.8% of the long-term FEVD of y_t^{per}, relatively small share compared to domestic shocks. This aligns with Raddatz (2007), who suggests that external shocks explained only 11% of GDP growth in emerging economies. Chávez and Rodríguez (2023), and Rodríguez et al. (2023a, 2023b) also found that external shocks contributed between 17% and 38% to fluctuations in domestic output before IT adoption. During this period, the domestic shocks with the most substantial impact on the variability of y_t^{per} were the AD and MP shocks, accounting for 25.6% and 34.1%, respectively. The limited contribution of the AS shock can be attributed to the macroeconomic policies implemented to address the adverse effects of the 1997 El Niño phenomenon and the international financial crisis.[7] Portilla et al. (2022) note that the BCRP responded more rapidly to external and AS shocks but more gradually to AD shocks.

Based on the results in Table 3, it becomes evident that between 2002-2011, the contribution of external shocks increased compared to the previous period, accounting for around 57% of the variability of y_t^{per}. This was driven by greater trade openness, IT adoption, and elevated commodity prices, which reduced the volatility of domestic variables relative to external ones. Loser (2013) and Mendoza (2014) argue that trade openness, which began in 2003, was one of the primary factors contributing to the increased role of external shocks on y_t^{per}, as it allowed the domestic economy to benefit from the economic growth of its main trading partners. On the external side, the most significant factors were shocks originating from tot_t and global demand shocks, contributing an average of 27% and 19.7%, respectively. These results align with Souza and de Mattos (2022), who emphasize the importance of international commodity prices and external demand for economic growth uncertainty in South American countries following a primary-export model, such as Brazil and Chile. Additionally, the contribution of MP shocks decreased after IT adoption, averaging 7.2%, and ceased to be a major source of uncertainty due to changes in monetary policy.

For the period 2012-2019, the share of external shocks in the variability of y_t^{per} increased from 57% in 2012 to 64.4% in 2019 (Table 3), despite a 5.2% decline in tot between 2012-2015 and global trade issues arising from trade tensions between the US and China. The increased uncertainty in y_t^{per} was associated with shocks originating from tot_t (averaging 31%) and y_t^{chn} (averaging 12%). Furthermore, Table 3 indicates that shocks from y_t^{usa} and i_t^* made a lower contribution of 11.5% and 10.6%, respectively, which is consistent with findings by Mendoza and Collantes Goicochea (2017). These results are also in line with Rodriguez et al. (2023a), who found that external shocks contributed between 65% and 85% to the variability of y_t^{per}.

The results from the CVAR model suggest some differences. Firstly, they indicate that external shocks contribute 69% to the uncertainty of y_t^{per} over the entire sample period, which is 4 percentage points higher than the results from the Benchmark A_t constant model for 2012-2019. Secondly, they show that the external shocks contributing the most to the variability of y_t^{per} are shocks from tot_t (averaging 52%) and y_t^{usa} (averaging 10%), whereas in the Benchmark A_t constant model, the shock from y_t^{chn} is the second most important. Thirdly, compared to the Benchmark A_t constant model, the results underestimate the contribution of the MP shock by 23.6 percentage points and 2.5 percentage points during the periods 1998-2001 and 2002-2019, respectively.

Regarding π_t, between 1998-2001, external shocks accounted for an average of 41% of its variability. This is consistent with Canova (2005), who shows that in Latin American countries, external shocks contribute an average of 38% to the FEVD of π_t. For the period 2002-2011, the contribution of external shocks increased to 58.2%, and between 2002-2019, it rose to 65.1%, on average. On the external side, shocks from tot_t had the largest share (averaging 33%), followed by shocks from y_t^{usa} (averaging 14%), i_t^* (averaging 10%), and y_t^{chn} (averaging 7.8%). Among domestic variables, the AS shock stood out (averaging 26.8%), which is in line with the findings of Armas and Grippa (2006), who argue that fluctuations in π_t have been primarily driven by AS shocks and imported inflation.

As for i_t, during 1998-2001, external shocks explained only 31.5% of its variability, with MP shocks being the most relevant, accounting for approximately 50%. This reflects the financing constraints faced by the domestic economy due to public sector deficits and high indebtedness relative to private sector capital. After IT adoption, the contribution of external shocks increased

[7] Between 1998-1999, Peru experienced capital outflows due to the Asian, Russian, and Brazilian crises. However, due to Peru's strong macroeconomic stability, it was possible to mitigate their adverse effects via countercyclical policies.

significantly (from 38% in 2002 to 67% in 2019), with shocks from tot_t being the major source of uncertainty, contributing 30%. This finding is similar to that of Chávez and Rodríguez (2023).

There are some differences when comparing the results for π_t and i_t between the Benchmark A_t constant and CVAR models. For π_t, the CVAR model underestimates the contribution of the trade and financial channels by 4 percentage points and 7 percentage points, respectively. Regarding i_t, the CVAR results underestimate contributions by 8 and 9 percentage points. Furthermore, models that do not allow volatility and contemporaneous effects coefficients to vary over time exhibit constant FEVD, which does not adequately approximate reality.

4.3.5 Historical Decomposition (HD)

To quantify the contribution of external and domestic shocks to Peru's economic fluctuations, Figure 12 presents the findings from the HDs of domestic variables. Additionally, Table 4 displays the results of the HD for y_t^{per} from the Benchmark A_t constant model.

Between 1998-2002, domestic shocks made the largest contribution to y_t^{per}. According to the results, the average output growth (1.1%) is explained by external factors in 34%, while domestic factors contribute 59%. Recall that the low level of economic output during this period was primarily associated with internal factors, especially AD shocks due to a decrease in public and private investment, as well as AS shocks related to the El Niño phenomenon, which affected the fishing and agriculture sectors; see Velarde and Rodríguez (2001).

The results in Table 4 show that during the 2002-2011 period, 57.8% of the increase in average output growth (6.2%) is explained by external shocks, with 30% attributed to tot_t, 15% to y_t^{chn}, 5% to y_t^{usa}, and 8% to i_t^* shocks. This predominance of external shocks is related to the surge in commodity prices experienced from 2002 to 2008, which led to annual economic growth of up to 9.2% during that period. These results align with Oladunni (2020), who argues that commodity price shocks and global demand shocks are the main sources of output growth for small open economies. On the other hand, during the GFC, external shocks largely explained the deceleration of y_t^{per}, which dropped to 1.1% in 2009. According to the results, 34.3% of the economic downturn was explained by tot_t and 15% by y_t^{usa} shocks, as unfavorable conditions prevailed in financial markets, with contractions in developed countries and slowdowns in emerging economies.

From 2012 onward, y_t^{per} experienced an average increase of 3.8%, with 46% of this increase attributed to external shocks. Shocks from tot_t contributed 30%, and shocks from the commercial channel (y_t^{chn} and y_t^{usa}) contributed 14% (Table 4). In that same year, the country went through an economic slowdown, primarily due to deteriorating terms of trade and trade tensions between the US and China. On the domestic front, AD, AS, and MP shocks explained 38%, 2%, and 9%, respectively, of the increase in y_t^{per}. These results were driven by a decrease in private investment, the impact of the El Niño Costero in 2017, and political uncertainty caused by the Lava Jato corruption scandal.[8]

When comparing the results with the CVAR model, 45% of the increase in y_t^{per} is attributed to external shocks, which is 4 percentage points lower than the results obtained with the Benchmark A_t constant model. Both models concur that shocks from tot_t are the primary contributors to the increase in y_t^{per}, but the CVAR model's results emphasize that shocks from y_t^{usa} (averaging 21%) constitute the second most significant source. This diverges from the Benchmark A_t constant model's findings, which suggest that shocks from y_t^{chn} are the second most substantial contributors to the increase in y_t^{per}.

[8]The Lava Jato scandal refers to the corruption cases uncovered in 2017, involving companies accused of paying bribes to high-ranking public officials with the aim of winning tenders for public works.

Between 1998 and 2001, π_t witnessed an average output growth of 4.1%, with 81% of this increase attributed to domestic shocks, particularly those related to MP and AS. In the subsequent period, the significance of domestic shocks declined in comparison to external shocks, which accounted for 58% of the average increase in π_t (2.7%), with the shock from y_t^{chn} emerging as the most significant channel. These findings diverge from those of Rodríguez et al. (2023), who noted that from IT adoption until the end of the sample period, shocks from the nominal channel played the most substantial role. However, this discrepancy could be attributed to the use of a different external variable (global commodity price index). Regarding i_t, during the 1998-2001 period, MP shocks had the most significant impact, explaining 85% of the average increase in i_t. Subsequently, external shocks gained prominence, accounting for over 57%, with the tot_t channel being the most prominent contributor. Lastly, the CVAR model underestimated the influence of external shocks by 18 percentage points for π_t and 19 percentage points for i_t, in comparison to the results of the Benchmark A_t constant model.

5 Robustness Exercises

To validate the previous estimations, four robustness exercises are conducted, introducing changes to the baseline model: (i) an external variable from the nominal channel is modified; (ii) the baseline model is extended by adding the public investment variable in the domestic block; (iii) the baseline model is extended by adding the nominal exchange rate variable as the most endogenous variable in the domestic block; (iv) the model is estimated with four, five, and six variables. Figures are available in an Appendix upon request.

5.1 Change of External Variable

The variable tot_t is replaced by the growth of the export price index (epi_t henceforth). Panel (a) of Table 5 indicates that the model that best fits the data is, once again, the Benchmark A_t constant model, and the models with the most support are those that incorporate stochastic volatility. On the other hand, the CVAR model is the one that fits the data the least.

The results of the IRFs show that for the Benchmark A_t constant model, a positive shock from y_t^{usa} expands y_t^{per} by 0.13% in the third quarter, while in the baseline model, the expansion is 0.2% for the same period. The response of y_t^{per} to a shock in i_t^* is negative, with a magnitude of -0.16%, which is similar to the baseline model, where i_t^* causes a drop of 0.15% in y_t^{per}. Likewise, the shock from y_t^{chn} and epi_t has a positive effect of 0.63% and 0.25%, respectively, on y_t^{per}, matching the baseline model's result, which estimates that both external shocks generate an impact of 0.65% and 0.28%, respectively.

The findings from the FEVD are in panel (a) of Table 6. First, during the period 2002-2019, the Benchmark A_t constant model shows a high contribution of external shocks to y_t^{per}, with epi_t and y_t^{chn} shocks being the greatest source of uncertainty (25% and 18%, respectively). Similarly, during the period 2012-2019, the shocks with the most influence are epi_t and y_t^{chn}, and the participation of all external shocks during that period is 55.1%, which coincides with the baseline model's results. Finally, panel (a) of Table 7 shows that the results obtained for the HD are also similar to those obtained in the previous model. The Benchmark A_t constant model indicates that during 1998-2001, domestic shocks explained 49.5% of the increase in y_t^{per} (1.1%). Between 2002-2011, the contribution of external shocks increases, especially from y_t^{chn} (41.3%) and epi_t (13.2%), and between 2012-2019, external shocks explained 68.4% of the increase in y_t^{per}.

5.2 Extending the Baseline Model with Fiscal Policy

The purpose of this section is to integrate Peru's fiscal policy into the baseline model. To achieve this, we introduce the growth rate of public investment (g_t^{pub}) as an exogenous domestic variable, as its increase is a result of public policy decisions. Furthermore, g_t^{pub} inmediately stimulates economic activity by positively affecting the country's productive capacity, as outlined in Palacios Tovar (2018). In this case, once again, the Benchmark A_t constant model shows the best empirical fit, reaffirming the model's robustness in capturing the dynamics of the Peruvian economy. Conversely, the CVAR model exhibits the weakest fit with the data, underscoring the significance of parameter evolution over time, as shown in panel (b) of Table 5.

The time evolution of the IRFs suggests that the impact of a 1% change in g_t^{pub} on y_t^{per} has been steadily increasing, particularly since the 2000s when the National Public Investment System (SNIP) was established to optimize the utilization of public resources allocated to investment. According to the Benchmark A_t constant model, the effect of a g_t^{pub} shock on y_t^{per} has risen from 0.05% in 1998 to 0.15% in 2019, confirming the growing influence of public investment on economic activity since the SNIP's inception. Concerning the median of the IRFs derived from the Benchmark A_t constant model, a positive g_t^{pub} shock exerts a favorable and sustained impact on y_t^{per}, with a magnitude of 0.15% in the first quarter. This outcome is linked to enhancements in healthcare and education, subsequently boosting labor productivity; see Mariátegui-Orbegozo (2019).

Regarding the FEVD, as shown in panel (b) of Table 6, the inclusion of the g_t^{pub} variable results in a 50% reduction in the contribution of external factors to the variability of domestic variables. The Benchmark A_t constant model indicates that the contribution of g_t^{pub} accounts for 30% of the variability during the 2012-2019 period, becoming the primary source of uncertainty. These findings deviate from those obtained in the baseline model, where external shocks accounted for 62% of the variability in 2009, while in the model including g_t^{pub} it amounted to 32% in the same year. According to Rodríguez et al. (2023), this discrepancy can be attributed to the high volatility of g_t^{pub}, resulting in increased uncertainty in determining y_t^{per}.

In terms of the Historical Decomposition (HD) results, panel (b) of Table 7 reveals that, in the Benchmark A_t constant model, the contribution of external shocks to y_t^{per} increases as the years progress. Consequently, external shocks explain 8.5% of the increase in y_t^{per} during 1998-2001 and 19.6% during 2002-2011. Additionally, g_t^{pub} accounts for approximately 31.2% of the increase in y_t^{per}, making it the second most significant variable contributing to growth. Finally, as in the baseline model, the HD presents an unclear and diffuse representation of the impact of both external and domestic shocks in the CVAR model.

5.3 Extending the Baseline Model with the Nominal Exchange Rate

In this Section, we introduce the annual variation of the nominal exchange rate (e_t) as the primary domestic variable in our model, driven by the uncovered interest rate parity condition. This variable is also influenced by monetary policy and serves as a buffer against external shocks, affecting bond risk premiums in emerging markets and domestic competitiveness; see Nolazco et al. (2016). Our results indicate that the Benchmark model provides the best fit to the data, closely followed by the Benchmark A_t constant model, while the CVAR model exhibits the poorest fit (Table 5, panel c).

The IRFs of the Benchmark model generally follow the patterns observed in our baseline model, with one noteworthy exception: the response of y_t^{per} to the tot_t shock. In this case, the initial impact is positive; however, economic output contracts starting in the third quarter before gradually recovering over the course of the second year. This complex behavior can be attributed to conflicting forces. On one hand, the expansion of tot_t has a positive effect on export income, while on the other hand, it is influenced by the BCRP's response to inflationary pressures and exchange rate fluctuations.

Turning our attention to the FEVD, as shown in Table 6 (panel c), we observe a shift in the contribution of external shocks to the uncertainty surrounding y_t^{per}. Here, external shocks account for 26% of the uncertainty, demonstrating a decrease relative to domestic shocks. This trend aligns with our earlier findings when public spending was included in the model, indicating that the intervention of economic policymakers reduces the uncertainty arising from external shocks. Notably, the impact of the e_t shock appears relatively subdued compared to the influence of the g_t^{pub} shock in the previous model. This muted impact may be attributed to the indirect nature of e_t effects. Finally, the HD results in Table 7 (panel c) also emphasize the significant role of domestic shocks in explaining variations in y_t^{per} across the entire sample period. The largest external shock contribution occurred during 2002-2011, explaining 19% of the growth in y_t^{per}, with y_t^{usa} having the most substantial impact at 6.8%, while i_t^* had the smallest influence at 0.4%.

5.4 Lower-Dimensional Models

To analyze the contribution of external shocks to the domestic block progressively, we present results with 4-variable, 5-variable, and 6-variable model specifications.

5.4.1 4-Variable Model

In this model, the external block includes only one variable: epi_t. For the domestic block, we used the classic macroeconomic order: y_t^{per}, π_t, and i_t. The results in Table 5 (panel d) show that the Benchmark A_t constant model fits the data best, consistent with our earlier findings. Conversely, the CVAR model is the least suitable.

The FEVD results for y_t^{per} (Table 6, panel d) show that during 1998-2002, domestic factors contribute roughly 90%. However, their importance wanes as we move forward, with external shocks gradually becoming more prominent, eventually dominating variability in y_t^{per} with an 80% contribution, in line with Chávez and Rodríguez (2023). The HD findings for y_t^{per} indicate that during 1998-2001, domestic shocks account for about 57% of fluctuations. From 2002 onward, shocks related to epi_t gain importance, explaining 52.9% of growth in y_t^{per} during 2001-2019 (Table 7, panel d).

5.4.2 5-Variable Model

In this model, we add two more variables, y_t^{chn} and tot_t, to the external block, while the domestic block retains y_t^{per}, π_t, and i_t. Table 5 (panel e) underscores the Benchmark A_t constant model as the most empirically robust, with the CVAR model as the least supported.

Reviewing the FEVD results for y_t^{per} variability, we find that external shocks dominate, contributing an average of 62.4% over the analysis period. This aligns with our prior findings. Specifically, during 2002-2011, external shocks drive 77.3% of uncertainty, decreasing to 59.7% from 2012 onward (Table 6, panel e). Meanwhile, variations in the domestic block are mainly tied to tot_t shocks. Furthermore, the HD results (Table 7, panel e) reveal that external shocks explain the majority of the average 1.1% growth in y_t^{per} during 2002-2011 (45.4%).

5.4.3 6-Variable Model

In this model, we expand the external block to include i_t^*, y_t^{chn} and tot_t, while the domestic block still features y_t^{per}, π_t, and i_t. Table 5 (panel f) confirms the Benchmark A_t constant model as the most empirically supported, with the CVAR model receiving the least support.

Much like the baseline model, the FEVD results indicate that external factors represent an average of 47% of the variation in y_t^{per} over the analysis period. Between 1998-2011, y_t^{chn} shocks are the primary source of external uncertainty (Table 6, panel f). The HD results (Table 7, panel f) show that approximately 45% of the average increase in y_t^{per} is attributed to external factors across the analysis period. Additionally, during 2012-2019, the contribution of tot_t shocks increases in comparison to other external factors, explaining 17.5%, in line with the baseline model.

6 Conclusions

This research quantifies the importance and evolution of the effects of external shocks on the Peruvian economy during 1998Q1-2019Q4 using a family of mixture innovation TVP VAR models with SV (TVP-VAR-SV) following Koop et al. (2009). The model specification includes an external block comprising the trade, financial, and nominal channels, and a domestic block comprising output, inflation, and interest rates under recursive identification assumptions.

The results suggest that the model with the best empirical fit is one where the coefficients associated with the SVAR model (B_t) and volatilities (Σ_t) vary over time, with probabilities of variability exceeding 95%. This indicates a high likelihood of gradual changes in these parameter blocks.

Based on the findings from the IRFs, three conclusions can be drawn. Firstly, external shocks in the trade and nominal channels have positive short-term effects on the Peruvian economy, while financial shocks have a negative impact. Secondly, shocks related to fluctuations in the Chinese economy increase Peruvian output by 0.65%, making them the most impactful external shocks. Thirdly, the impacts of terms of trade growth and Chinese growth have increased in the post-IT period.

Regarding the FEVD, the findings indicate that external shocks account for 56.5% of output variability between 2002-2011 and 64.4% between 2012-2019, with price-related external shocks being the primary source of uncertainty. In the HD results, external shocks play a significant role in driving economic cycle fluctuations, explaining 58% of Peruvian output growth during 2002-2011.

In terms of robustness exercises, external shocks stemming from US monetary policy have a lower contribution to output growth uncertainty. Furthermore, the participation of global demand shocks in the HD of output growth has increased compared to price-related external shocks. Another critical result is that including fiscal policy (using public investment growth) and the nominal exchange rate reduces external factors' uncertainty regarding output growth.

The results of this study pose two challenges for Peruvian policymakers. The first challenge is to strengthen macroeconomic policies to mitigate the effects of external shocks on the domestic economy. This could involve promoting fiscal savings by the Ministry of Economy and accumulating international reserves by the BCRP. The second challenge is to diversify Peru's economic structure, given its dependence on external nominal channels. While the primary sector plays a significant role in output growth, it has limited integration with other productive sectors.

Lastly, it is worth noting potential extensions of this study for future research: (i) applying structural identification using sign restrictions, as in Canova (2005), or long-run restrictions, as in Blanchard and Quah (1993) and Galí (1992); and (ii) imposing restrictions on the error variance decomposition, as proposed in Barsky and Sims (2011).

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Table 1. Tests for Time Variation in the Coefficients of VAR, Volatility and Contemporaneous Relations

Tests	Coefficients	Sample			
		1998Q1-2002Q4	2003Q1-20190Q4	1998Q1-2008Q4	2008Q4-2019Q4
Kolgomorov-Smirnov	B_t	41/56	48/56	47/56	46/56
	Σ_t	7/7	7/7	7/7	7/7
	A_t	13/21	16/21	16/21	14/21
t-test	B_t	40/56	47/56	47/56	42/56
	Σ_t	7/7	7/7	7/7	7/7
	A_t	21/21	21/21	21/21	21/21
Trace Test					
Trace			16% perc.	50% perc.	84% perc.
0.28			0.22	0.30	0.42

The Table reports the number of time-varying parameters in each parameter block, according to the Kolgomorov-Smirnov test and the t-test. B_t contains the regression coefficients of VAR, Σ_t contains the volatilities of innovations and A_t contains the contemporaneously relations. In the Trace Test, the trace of the a priori variance matrix is reported, as well as the 16%, 50% and 84% percentiles of the trace of the posterior variance matrix

Table 2. Results using Benchmark Priors for Mixture Innovation TVP-VAR-SV Models

Model	$E(p_1\|Data)$	$E(p_2\|Data)$	$E(p_3\|Data)$	$E(logL)$	$Rank$
Benchmark	0.99 (0.01)	0.99 (0.02)	0.42 (0.07)	−45.30	2
Primiceri (2005)	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	−49.07	3
Benchmark A_t Constant	0.98 (0.02)	0.98 (0.02)	0.00 (0.01)	**−40.45**	**1**
Benchmark A_t and Σ_t Constant	0.98 (0.02)	0.00 (0.01)	0.00 (0.01)	−87.91	6
Benchmark A_t and B_t Constant	0.00 (0.01)	0.98 (0.02)	0.00 (0.01)	−73.03	4
Benchmark B_t Constant	0.00 (0.01)	0.98 (0.02)	0.36 (0.23)	−82.90	5
CVAR	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	−90.10	7

B_t, Σ_t and A_t are the parameters blocks of VAR coefficients, volatilities and contemporaneously relations, respectively. $E(p_1|data)$, $E(p_2|data)$ and $E(p_3|data)$ are the posterior means of transition that break occurs at time t and are related to B_t, Σ_t and A_t, respectively. Standard deviations are in parenthesis. $E(\log L)$ is the expected value of the log-likelihood function. The simulations are based on 70,000 Gibbs Sampler iterations, discarding the first 20,000 by convergence.

Table 3. FEVD of y_t^{per} at $h = 20$ quarters (mean values in %). Baseline Model - Benchmark A_t Constant Model.

Sample	Shock to:					
	y_t^{usa}	i_t^*	y_t^{chn}	tot_t	External	Domestic
Total Sample	10.4	9.8	9.3	26.0	55.4	44.6
1998-2001	7.6	6.3	4.9	15.9	34.8	65.2
2002-2011	10.7	10.5	9.0	26.3	56.5	43.5
2012-2019	11.5	10.6	11.7	30.5	64.4	35.6

Table 4. HD Contribution of Shocks to y_t^{per} (mean values in %). Baseline Model - Benchmark A_t Constant Model.

Sample	Shock to:						
	y_t^{usa}	i_t^*	y_t^{chn}	tot_t	External	Domestic	Deterministic
Total Sample	6.7	4.8	10.4	27.1	49.0	43.8	7.3
1998-2001	6.8	2.1	10.3	14.7	33.9	59.3	6.9
2002-2011	5.2	8.4	14.5	29.7	57.8	33.9	8.3
2012-2019	8.6	1.6	5.3	30.0	45.4	48.3	6.3

Table 5. Robustness Check

Models	$E(p_1\|Data)$	$E(p_2\|Data)$	$E(p_3\|Data)$	$E(logL)$	$Rank$	$E(p_1\|Data)$	$E(p_2\|Data)$	$E(p_3\|Data)$	$E(logL)$	$Rank$
	(a) 7-Variable model using epi_t					(b) 8-Variable model incorporating g_t^{pub}				
Benchmark	0.99 (0.01)	0.99 (0.02)	0.10 (0.07)	-26.70	1	0.99 (0.01)	0.99 (0.01)	0.48 (0.16)	-67.42	2
Primiceri (2005)	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-30.27	2	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-89.34	3
Benchmark A_t Constant	0.99 (0.01)	0.98 (0.02)	0.00 (0.01)	-30.63	3	0.99 (0.01)	0.99 (0.01)	0.00 (0.01)	-56.32	1
Benchmark A_t and Σ_t Constant	0.98 (0.02)	0.00 (0.01)	0.00 (0.01)	-31.97	4	0.99 (0.01)	0.00 (0.01)	0.00 (0.01)	-90.67	4
Benchmark A_t and B_t Constant	0.00 (0.01)	0.96 (0.02)	0.00 (0.01)	-73.03	7	0.00 (0.01)	0.98 (0.02)	0.00 (0.01)	-106.55	5
Benchmark B_t Constant	0.00 (0.01)	0.98 (0.02)	0.11 (0.23)	-70.93	5	0.00 (0.01)	0.98 (0.02)	0.55 (0.05)	-111.60	6
CVAR	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-71.56	6	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	-115.82	7
	(c) 8-Variable model incorporating e_t					(d) 4-Variable Model (epi_t, y_t^{per}, π_t, i_t)				
Benchmark	0.98 (0.01)	0.98 (0.01)	0.15 (0.14)	-63.3	1	0.99 (0.01)	0.99 (0.02)	0.10 (0.07)	-31.15	2
Primiceri (2005)	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-66.2	3	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-32.57	3
Benchmark A_t Constant	0.98 (0.01)	0.98 (0.01)	0.00 (0.00)	-64.5	2	0.99 (0.01)	0.98 (0.02)	0.00 (0.01)	-31.02	1
Benchmark A_t and Σ_t Constant	0.98 (0.01)	0.00 (0.00)	0.00 (0.00)	-95.5	6	0.98 (0.01)	0.00 (0.01)	0.00 (0.01)	-56.84	6
Benchmark A_t and B_t Constant	0.00 (0.00)	0.99 (0.01)	0.00 (0.00)	-65.73	4	0.00 (0.01)	0.96 (0.02)	0.00 (0.01)	-46.69	5
Benchmark B_t Constant	0.00 (0.00)	0.98 (0.02)	0.12 (0.10)	-67.6	5	0.00 (0.01)	0.98 (0.02)	0.11 (0.23)	-45.58	4
CVAR	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-100.0	7	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	-57.78	7

B_t, Σ_t and A_t are the parameters blocks of VAR coefficients, volatilities and contemporaneously relations, respectively. $E(p_1|data)$, $E(p_2|data)$ and $E(p_3|data)$ are the posterior means of transition that break occurs at time t and are related to B_t, Σ_t and A_t, respectively. Standard deviations are in parenthesis. $E(\log L)$ is the expected value of the log-likelihood function. The simulations are based on 70,000 Gibbs Sampler iterations, discarding the first 20,000 by convergence.

Table 5 (Continued). Robustness Check

Models	$E(p_1\|Data)$	$E(p_2\|Data)$	$E(p_3\|Data)$	$E(logL)$	$Rank$	$E(p_1\|Data)$	$E(p_2\|Data)$	$E(p_3\|Data)$	$E(logL)$	$Rank$
	(e) 5-Variable Model (y_t^{chn}, tot_t, y_t^{per}, π_t, i_t)					(f) 6-Variable Model (i_t^*, y_t^{chn}, tot_t, y_t^{per}, π_t, i_t)				
Benchmark	0.99 (0.01)	0.99 (0.01)	0.48 (0.16)	-24.33	2	0.99 (0.01)	0.99 (0.01)	0.15 (0.10)	-26.81	2
Primiceri (2005)	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-29.16	3	1.00 (0.01)	1.00 (0.01)	1.00 (0.01)	-35.66	3
Benchmark A_t Constant	0.99 (0.01)	0.99 (0.01)	0.00 (0.01)	-16.15	1	0.99 (0.01)	0.98 (0.02)	0.00 (0.01)	-20.70	1
Benchmark A_t and Σ_t Constant	0.99 (0.01)	0.00 (0.01)	0.00 (0.01)	-41.30	6	0.98 (0.02)	0.00 (0.01)	0.00 (0.01)	-44.89	4
Benchmark A_t and B_t Constant	0.00 (0.01)	0.98 (0.02)	0.00 (0.01)	-38.53	4	0.00 (0.01)	0.96 (0.02)	0.00 (0.01)	-54.45	6
Benchmark B_t Constant	0.00 (0.01)	0.98 (0.02)	0.55 (0.05)	39.11	5	0.00 (0.01)	0.98 (0.02)	0.11 (0.23)	-51.63	5
CVAR	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	-47.15	7	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-60.41	7

B_t, Σ_t and A_t are the parameters blocks of VAR coefficients, volatilities and contemporaneously relations, respectively. $E(p_1|data)$, $E(p_2|data)$ and $E(p_3|data)$ are the posterior means of transition that break occurs at time t and are related to B_t, Σ_t and A_t, respectively. Standard deviations are in parenthesis. $E(\log L)$ is the expected value of the log-likelihood function. The simulations are based on 70,000 Gibbs Sampler iterations, discarding the first 20,000 by convergence.

Table 6. Robustness Check: FEVD of y_t^{per} at $h = 20$ quartes (mean values in %)

Sample	Shock to:					
	y_t^{usa}	i_t^*	y_t^{chn}	tot_t	External	Domestic
(a) 7-Variable model using epi_t - Benchmark Model						
Total Sample	8.4	2.0	12.4	30.1	53.0	47.0
1998-2001	7.1	2.0	11.5	24.0	44.6	55.4
2002-2011	8.4	1.8	13.1	31.3	54.6	45.4
2012-2019	9.1	2.3	12.1	31.6	55.1	44.9
(b) 8-Variable model incorporating g_t^{pub} - Benchmark A_t Constant Model						
Total Sample	7.9	1.3	13.0	4.5	26.7	73.3
1998-2001	4.5	1.7	18.4	3.2	27.8	72.2
2002-2011	6.7	1.2	11.8	3.7	23.4	76.6
2012-2019	7.9	1.3	11.7	6.3	30.3	69.7
(c) 8-Variable model incorporating e_t- Benchmark Model						
Total Sample	8.2	0.7	5.0	12.0	26.0	74.0
1998-2001	8.7	0.7	10.9	14.3	34.8	65.2
2002-2011	8.0	0.7	5.5	11.3	25.5	74.5
2012-2019	8.1	0.7	1.5	11.8	22.1	77.9
(d) 4-Variable Model (epi_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model						
Total Sample				62.8	62.8	37.2
1998-2001				20.4	20.4	79.6
2002-2011				68.2	68.2	31.8
2012-2019				78.6	78.6	21.8
(e) 5-Variable Model (y_t^{chn}, tot_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model						
Total Sample			21.7	40.7	62.4	37.6
1998-2001			17.6	12.5	30.1	69.9
2002-2011			37.7	39.6	77.3	22.7
2012-2019			3.7	56.0	59.7	40.3
(f) 6-Variable Model (i_t^*, y_t^{chn}, tot_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model						
Total Sample		7.3	27.5	12.3	47.1	52.9
1998-2001		5.1	37.5	14.6	57.2	47.8
2002-2011		8.5	28.2	11.9	48.7	51.3
2012-2019		8.4	16.8	12.3	37.5	62.5

.

Table 7. Robustness Check: HD Contribution of Shocks to y_t^{per} (mean values in %)

Sample	Shock to:						
	y_t^{usa}	i_t^*	y_t^{chn}	tot_t	External	Domestic	Deterministic
(a) 7-Variable model using epi_t - Benchmark Model							
Total Sample	4.9	1.6	42.2	12.9	61.6	33.5	5.0
1998-2001	2.6	0.3	35.7	10.8	49.5	33.9	16.6
2002-2011	4.8	1.7	41.3	13.2	60.9	37.2	1.9
2012-2019	6.1	2.2	46.5	13.6	68.4	28.7	3.0
(b) 8-Variable model incorporating g_t^{pub} - Benchmark A_t Constant Model							
Total Sample	4.3	1.3	5.1	4.6	15.4	82.8	1.8
1998-2001	1.5	0.5	3.2	3.2	8.4	87.3	4.3
2002-2011	3.8	1.4	6.2	5.3	16.7	82.3	1.0
2012-2019	6.2	1.7	4.8	4.5	17.2	81.2	1.6
(c) 8-Variable model incorporating e_t - Benchmark Model							
Total Sample	5.7	0.4	3.5	4.8	14.5	81.1	4.4
1998-2001	4.0	0.3	3.0	3.0	10.3	80.2	9.5
2002-2011	6.8	0.5	5.7	6.0	19.0	77.2	3.8
2012-2019	5.1	0.4	1.1	4.1	10.7	86.4	2.9
(d) 4-Variable Model (epi_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model							
Total Sample				46.8	46.8	52.4	0.8
1998-2001				38.8	38.8	57.3	3.9
2002-2011				45.7	45.7	54.2	0.1
2012-2019				52.3	52.3	47.6	0.1
(e) 5-Variable Model (y_t^{chn}, tot_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model							
Total Sample			23.6	9.6	45.1	49.0	5.9
1998-2001			15.6	5.7	21.3	76.0	2.7
2002-2011			33.4	9.7	53.7	42.1	4.1
2012-2019			23.8	22.3	46.1	44.1	9.8
(f) 6-Variable Model (i_t^*, y_t^{chn}, tot_t, y_t^{per}, π_t, i_t) - Benchmark A_t Constant Model							
Total Sample		13.9	16.7	14.5	45.1	52.7	3.2
1998-2001		5.7	13.0	6.7	25.4	66.2	8.4
2002-2011		15.9	20.9	14.9	51.8	46.9	1.3
2012-2019		15.3	12.3	17.5	45.1	51.9	3.0

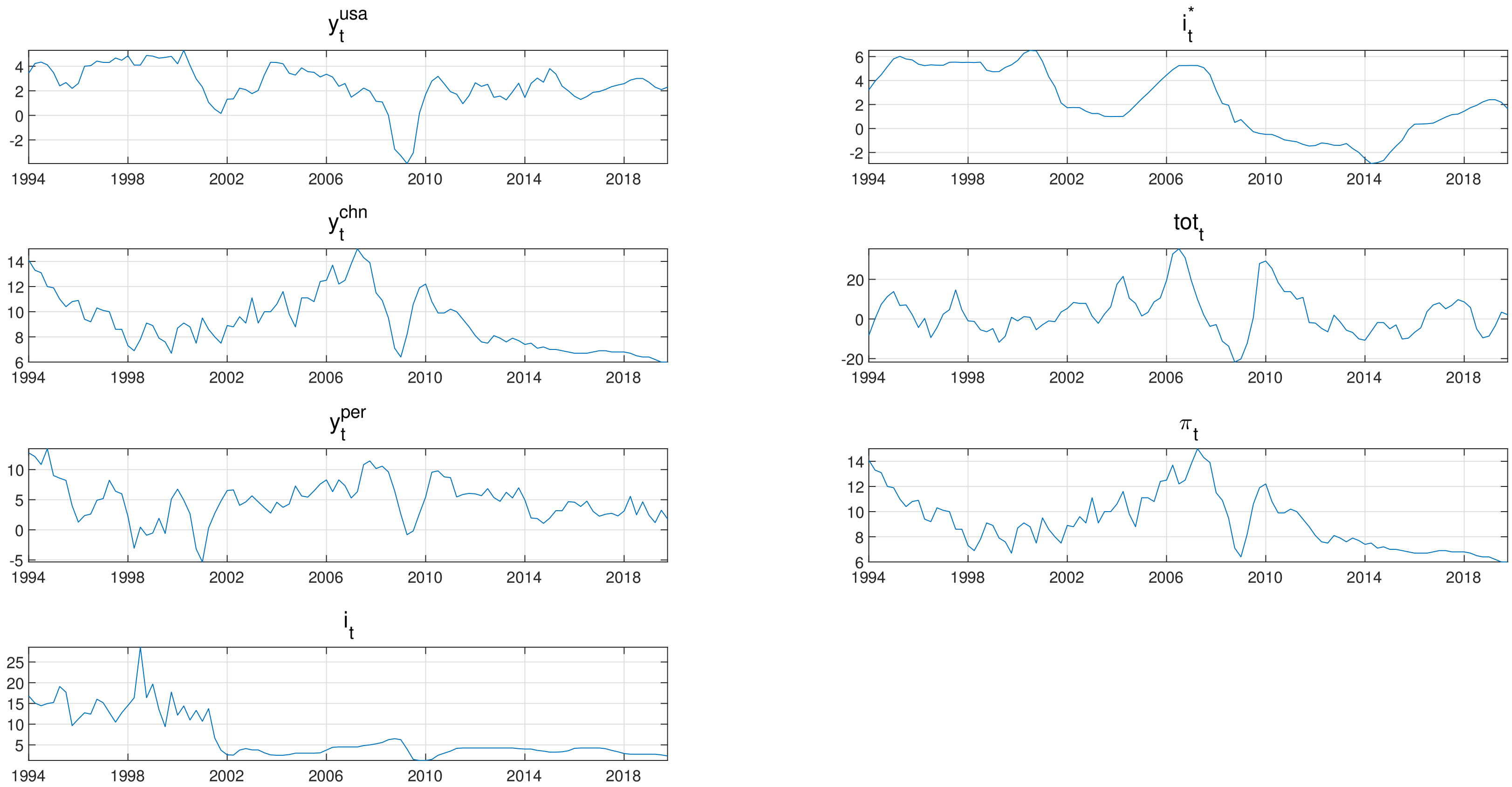

Figure 1. Time Series

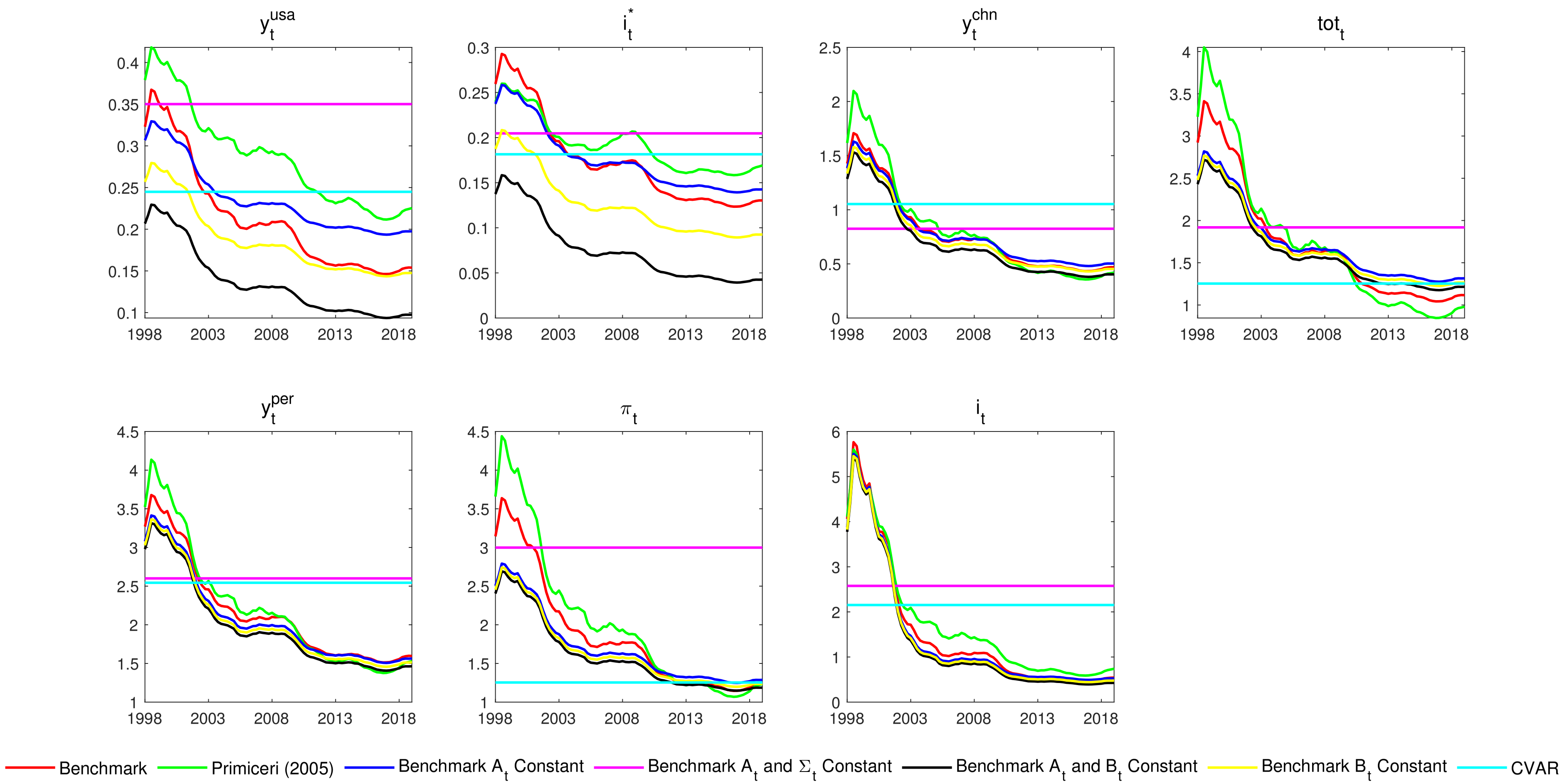

Figure 2. Median Standard Deviation of the Innovations in each Equation for all Models

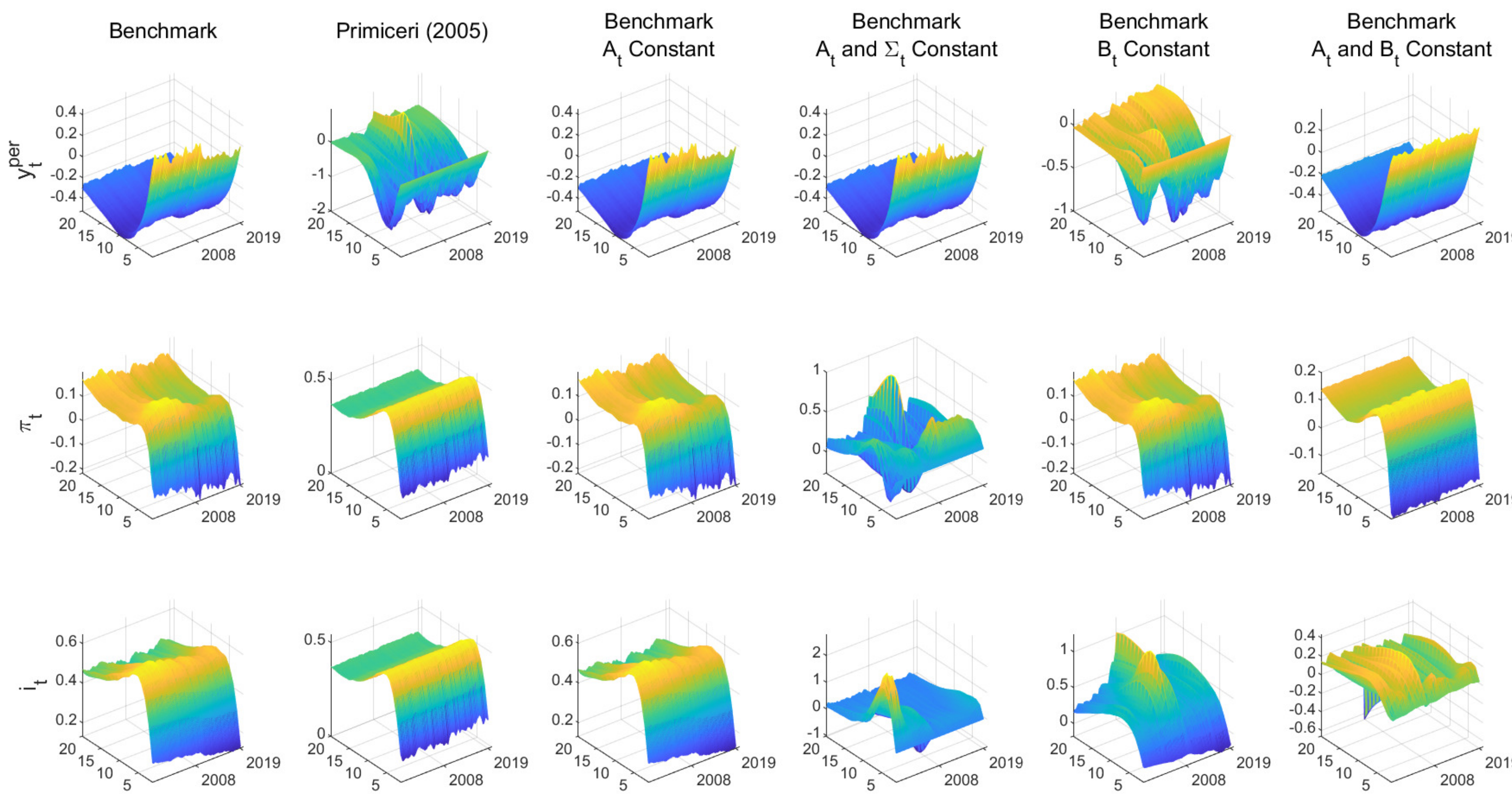

Figure 3. Median Time-Varying IRFs of y_t^{per}, π_t, i_t to a External Shock - y_t^{usa}. The shocks are normalized to increase the External Shock by 1%

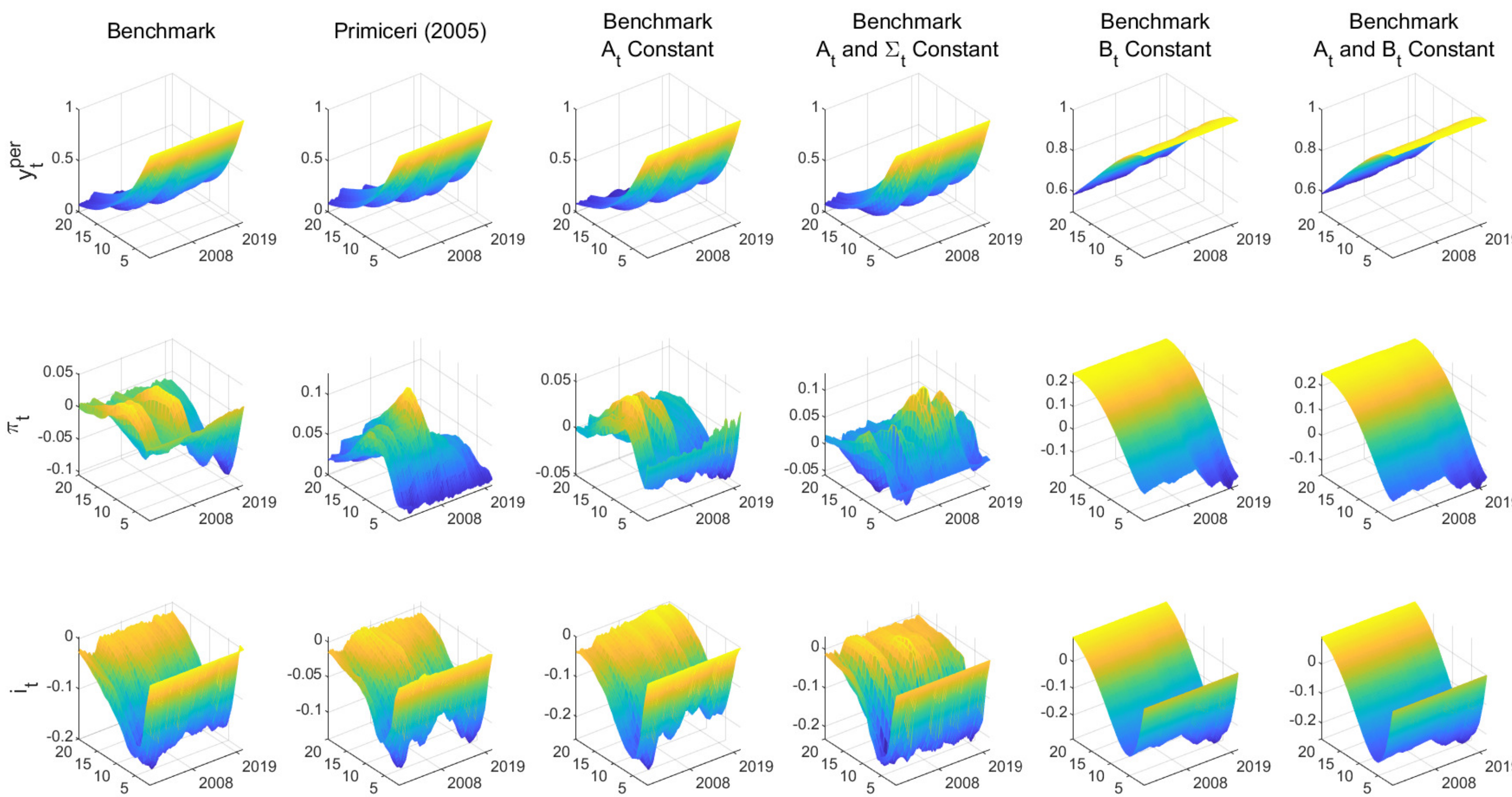

Figure 4. Median Time-Varying IRFs of y_t^{per}, π_t, i_t to a External Shock - i_t^{*}. The shocks are normalized to increase the External Shock by 1%

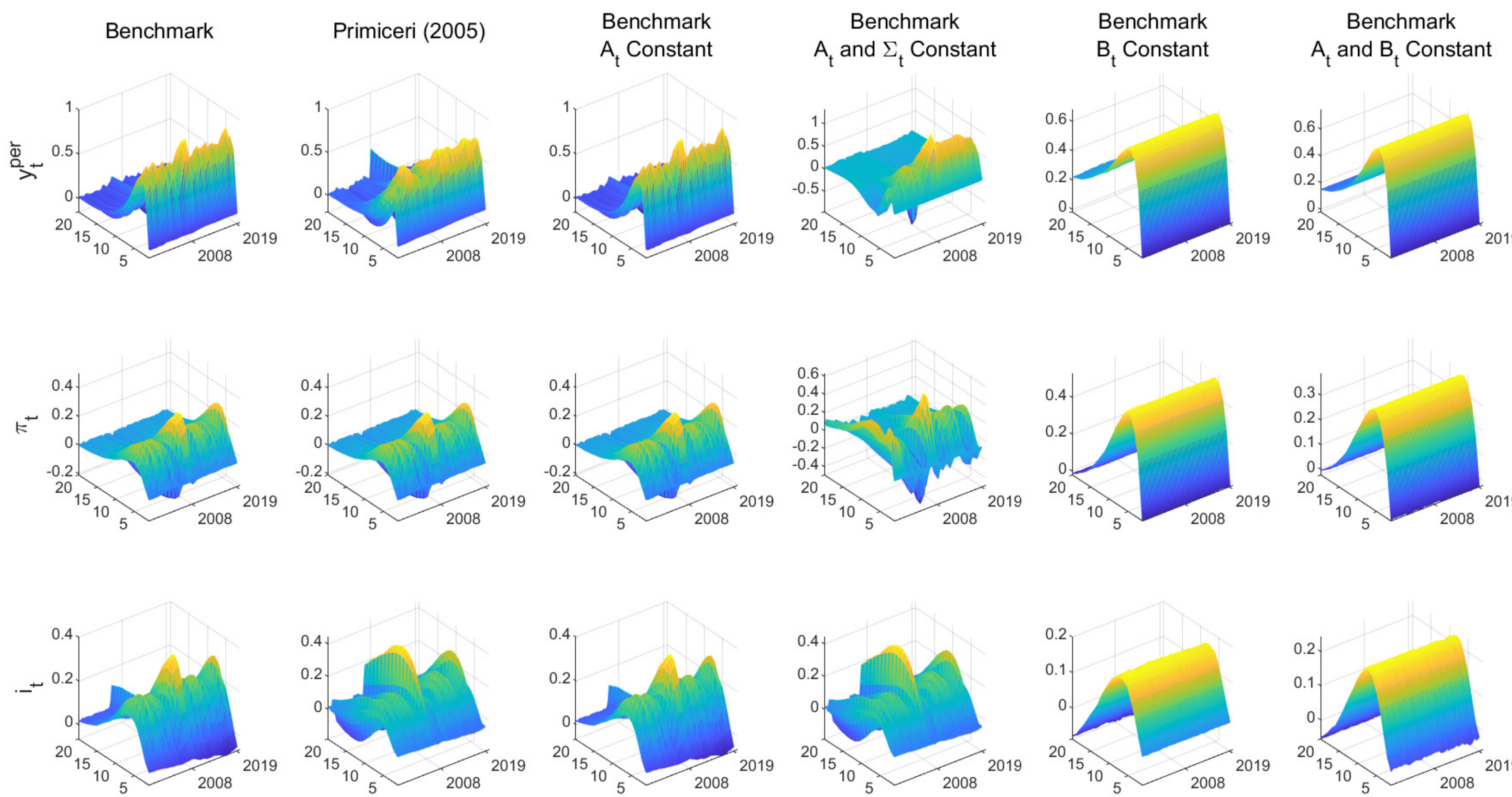

Figure 5. Median Time-Varying IRFs of y_t^{per}, π_t, i_t to a External Shock - y_t^{chn}. The shocks are normalized to increase the External Shock by 1%

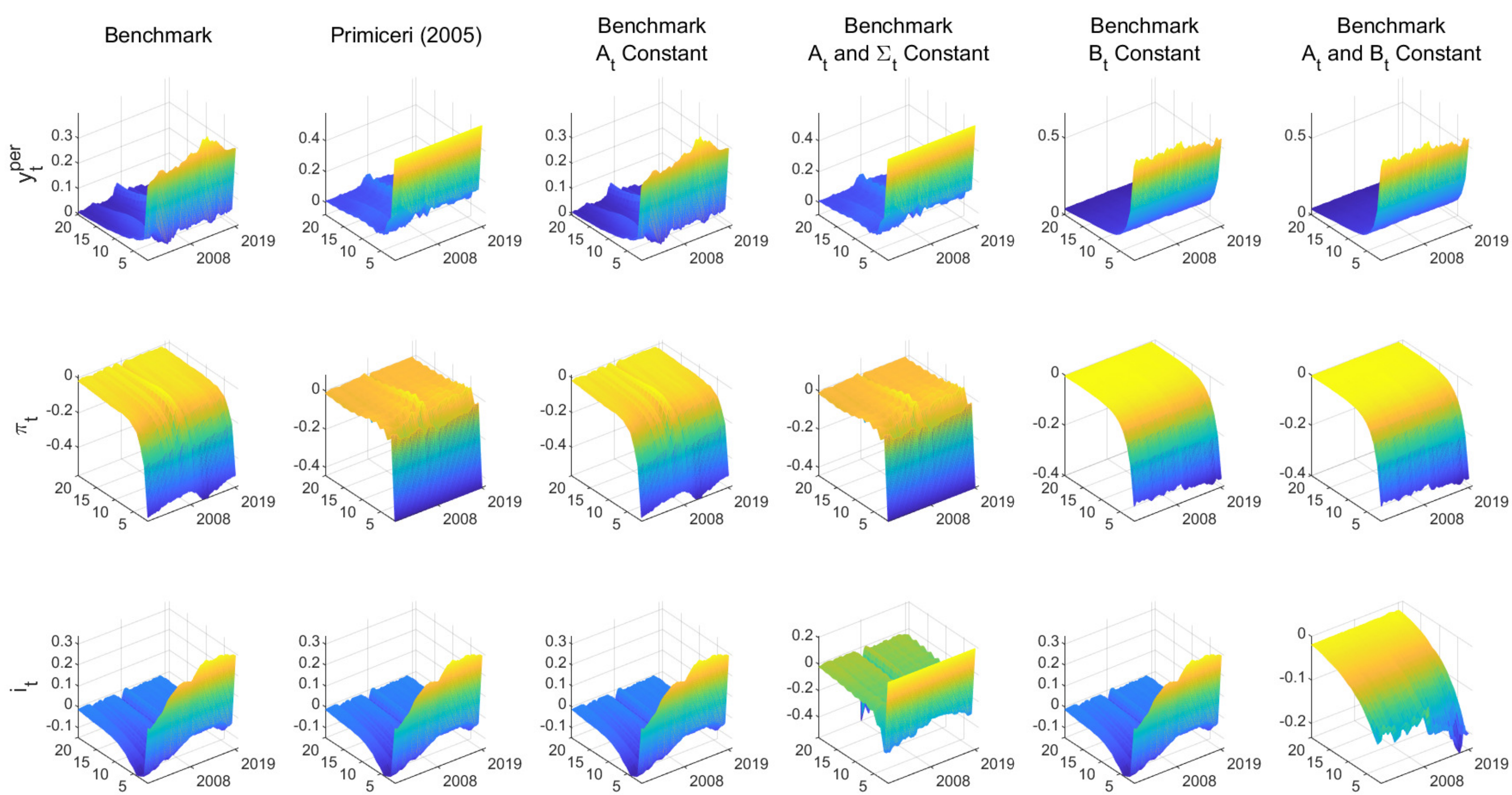

Figure 6. Median Time-Varying IRFs of y_t^{per}, π_t, i_t to a External Shock - tot_t. The shocks are normalized to increase the External Shock by 1%

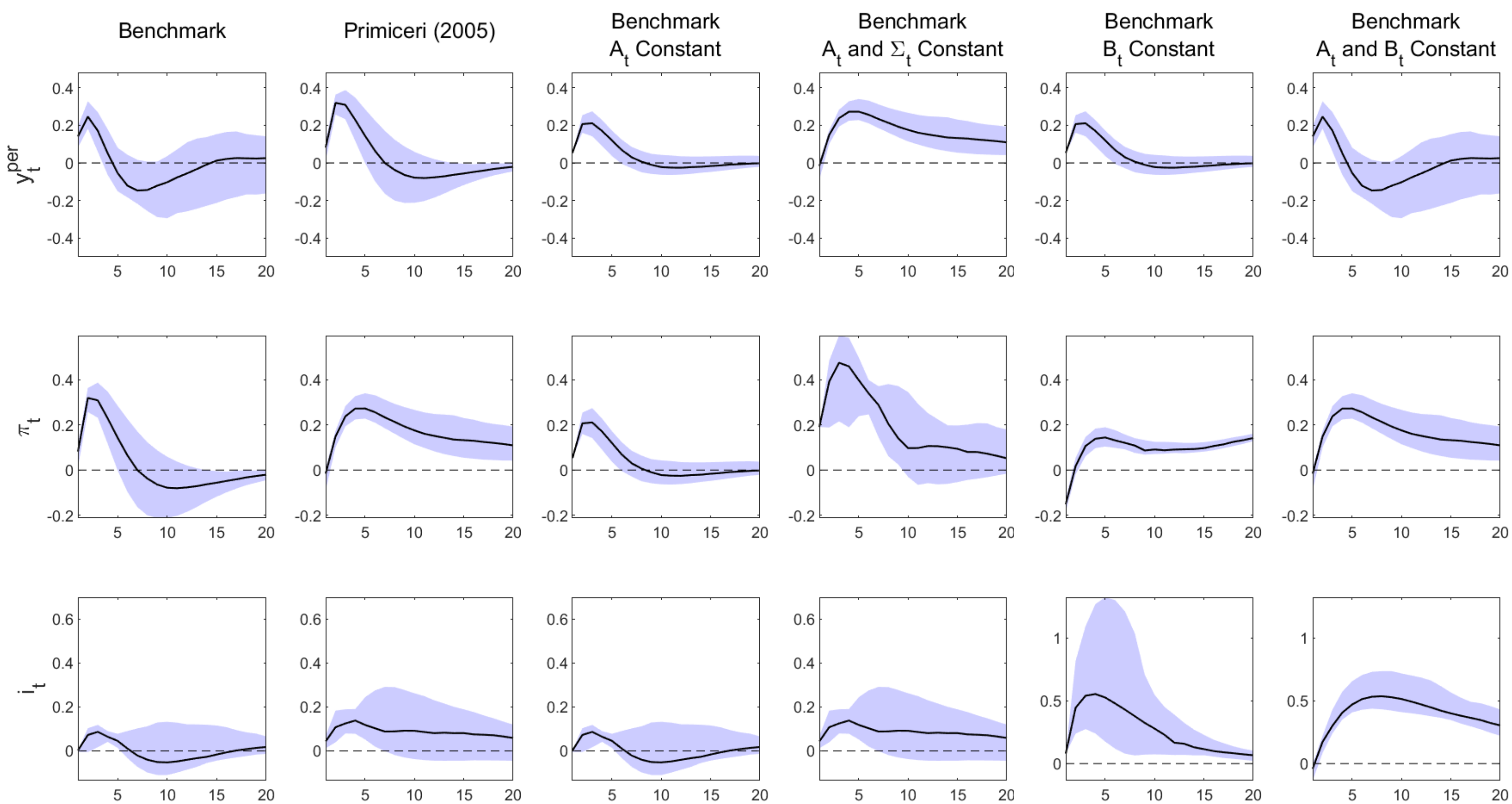

Figure 7. Median IRFs of y_t^{per}, π_t, i_t to a External Shock - y_t^{usa}. The solid black line represents the respective model by columns and the shaded area its 68% error band.

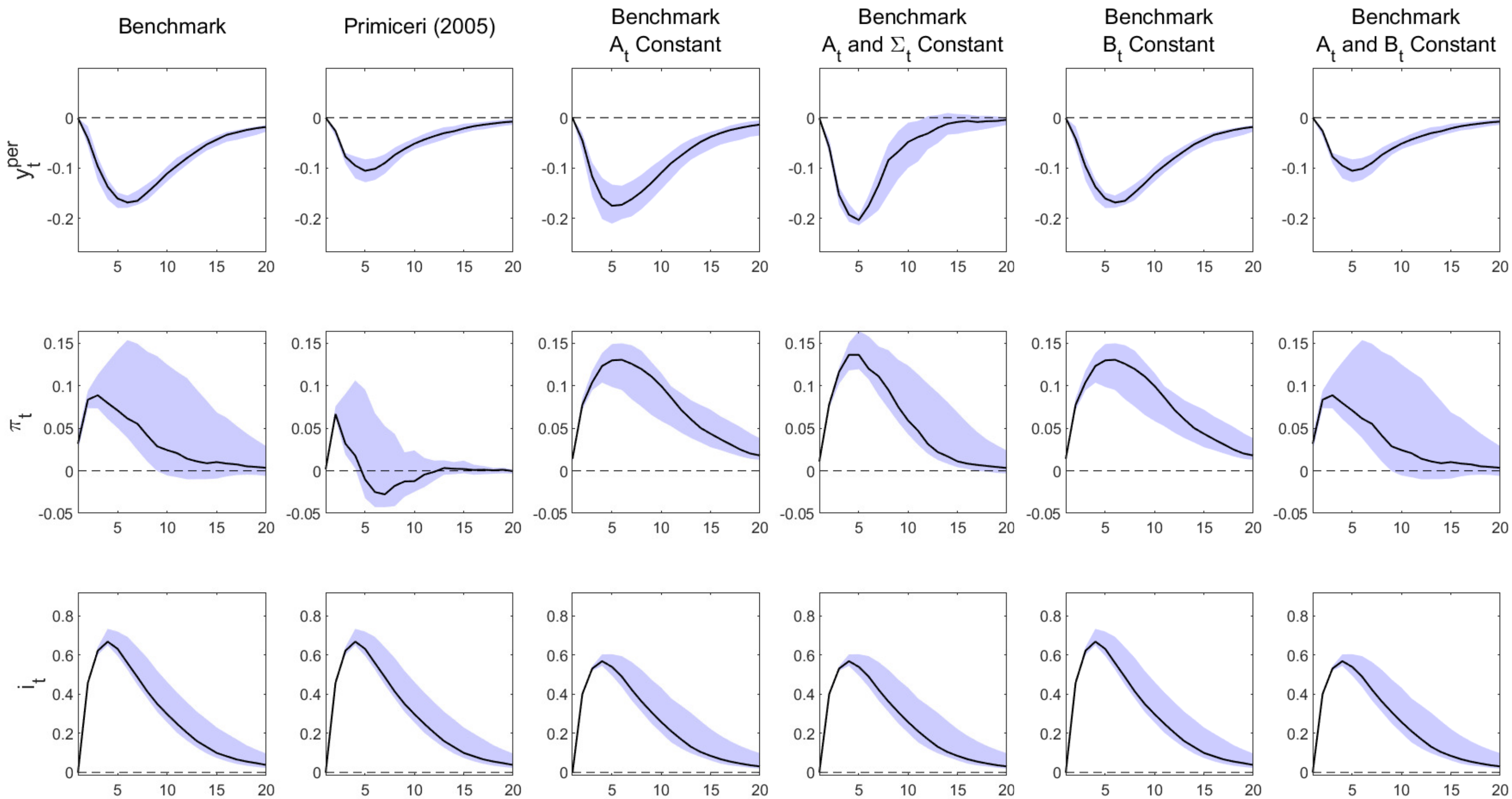

Figure 8. Median IRFs of y_t^{per}, π_t, i_t to a External Shock - i_t^*. The solid black line represents the respective model by columns and the shaded area its 68% error band.

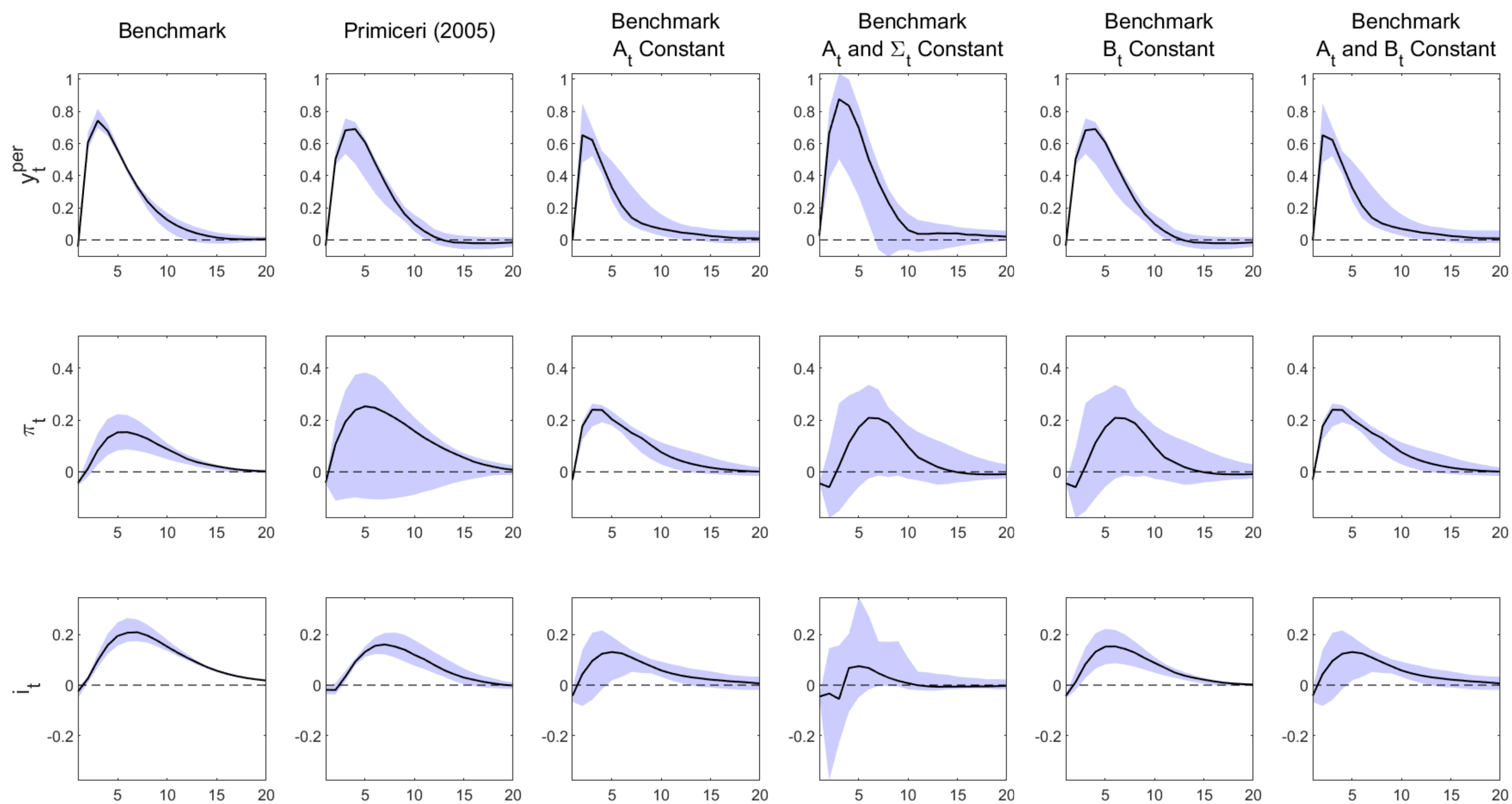

Figure 9. Median IRFs of y_t^{per}, π_t, i_t to a External Shock - y_t^{chn}. The solid black line represents the respective model by columns and the shaded area its 68% error band.

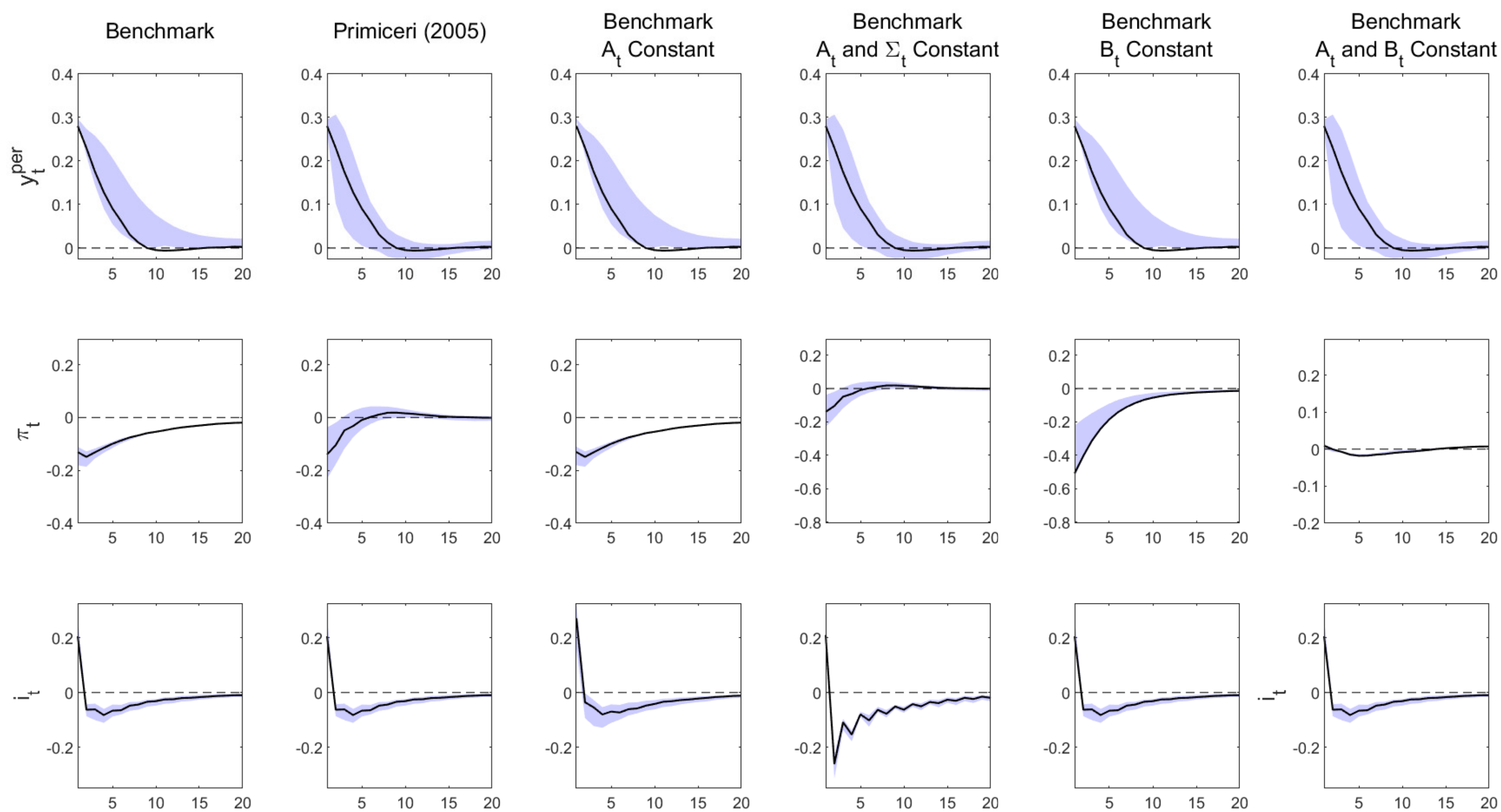

Figure 10. Median IRFs of y_t^{per}, π_t, i_t to a External Shock - tot_t. The solid black line represents the respective model by columns and the shaded area its 68% error band.

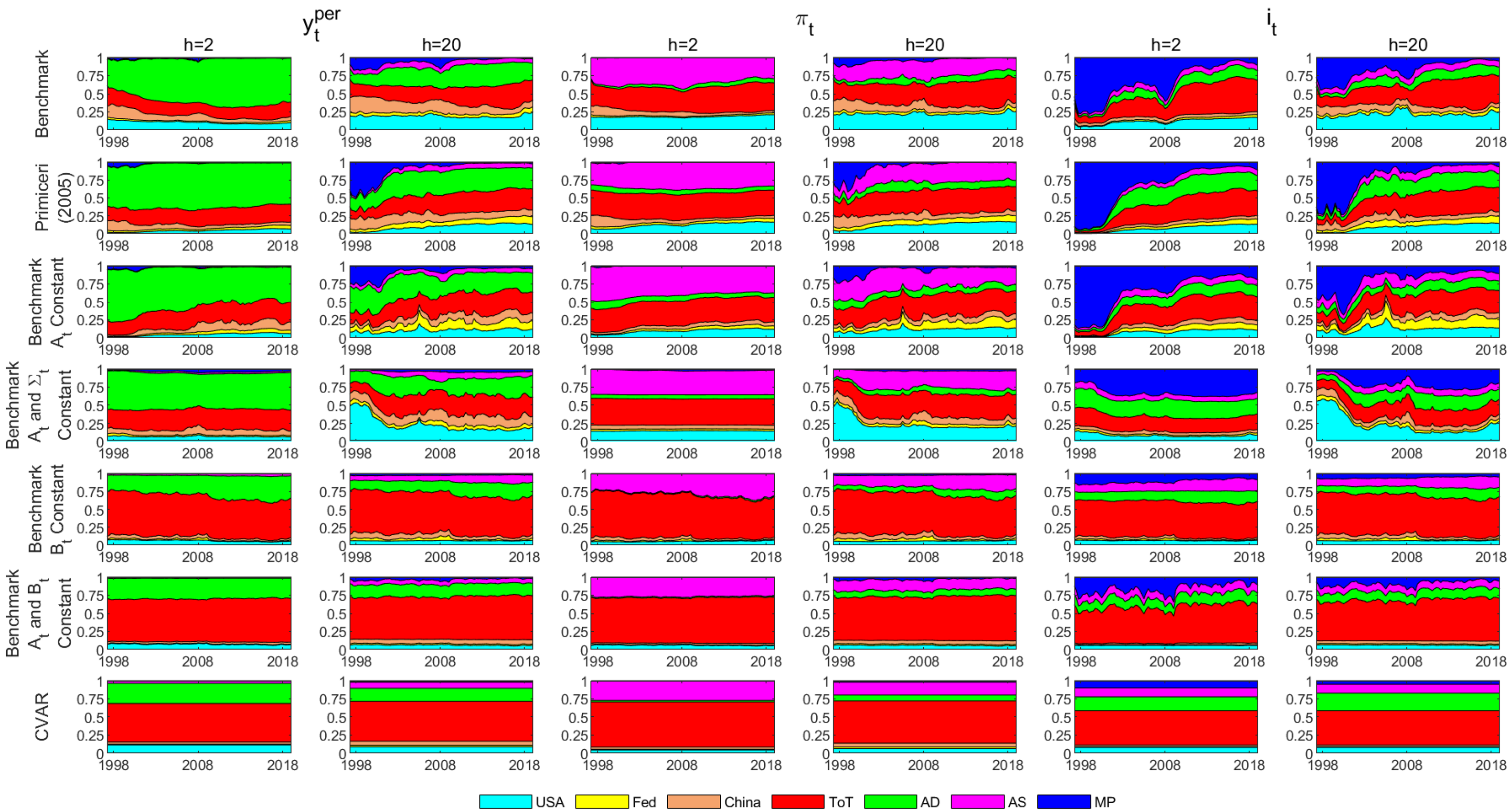

Figure 11. Time Evolution of the Mean FEVD of y_t^{per}, π_t, i_t at $h = 2,\ 20$ for all Models.

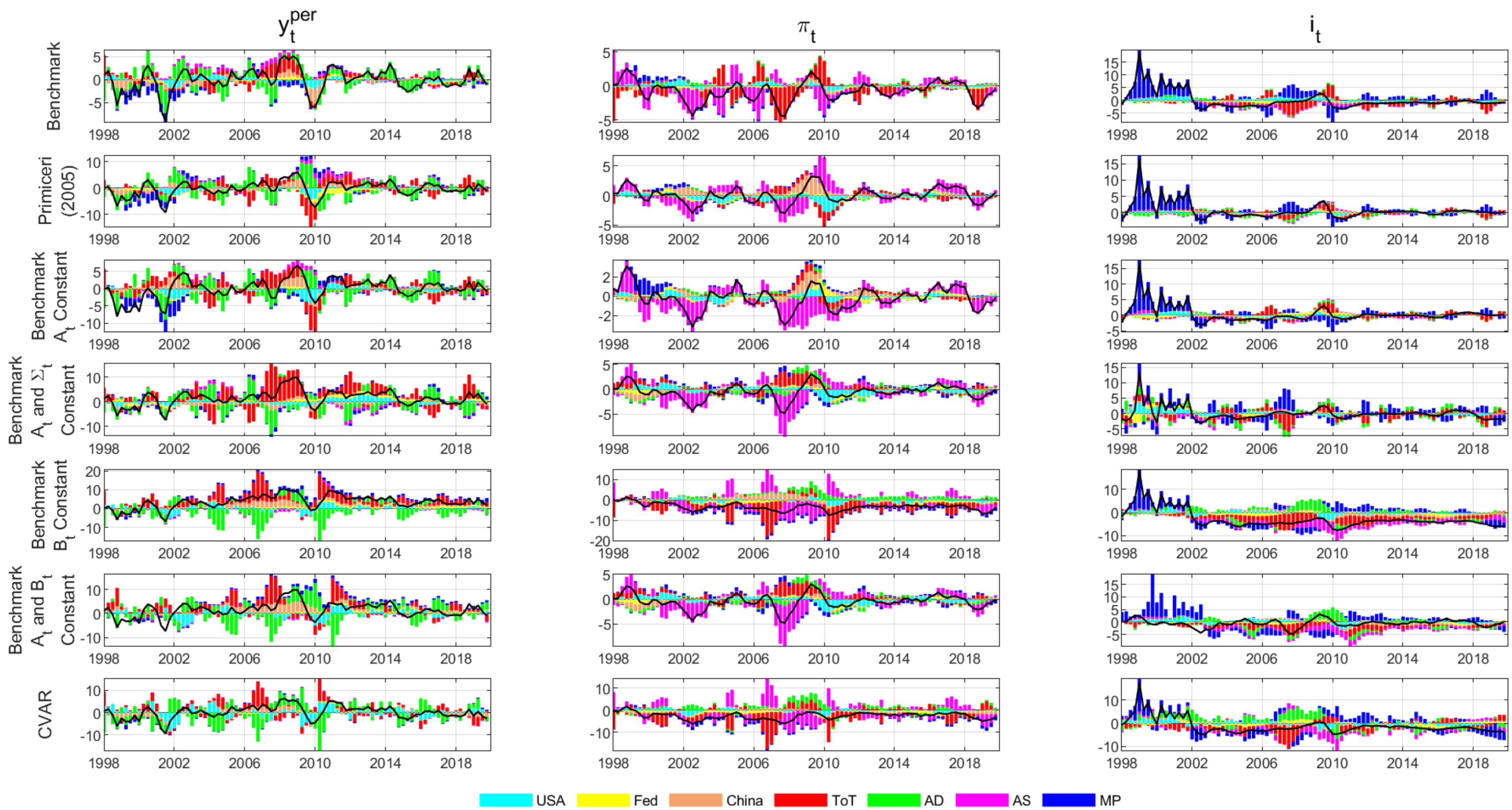

Figure 12. HD of Domestic Variables for all Models.

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