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Resolving Puzzles of Monetary Policy Transmission in Emerging Markets

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Abstract

Conventional empirical models of monetary policy transmission in emerging market economies produce puzzling results: monetary tightening often leads to an increase in prices (the price puzzle) and depreciation of the currency (the FX puzzle). We show that incorporating forward-looking expectations into standard open economy structural VAR models resolves these puzzles. Specifically, we augment the models with novel survey-based measures of expectations based on consumer, business, and professional forecasts. We find that the rise in prices following monetary tightening is related to currency depreciation, so eliminating the FX puzzle helps solve the price puzzle.

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JEL Classification

E31, E32, Q43

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Resolving Puzzles of Monetary Policy Transmission in Emerging Markets

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I. Introduction

Monetary policy transmission in emerging market economies (EMEs) is confounded by the puzzling behavior of prices and exchange rates in response to changes in policy interest rates. Evidence that monetary policy tightening leads to an increase in prices has been characterized as a "price puzzle." In a survey of 70 studies spanning 31 countries, Rusnák et al. (2013) find that half of the studies find evidence of the price puzzle. Country-specific studies have confirmed the existence of this puzzle. Another curious empirical feature in many EMEs is that monetary policy tightening leads to domestic currency depreciation (*foreign exchange rate puzzle or FX puzzle*) or gradual appreciation over a prolonged period (*delayed overshooting)*.[2]

These empirical puzzles may partly reflect the complications EME central banks face in stabilizing business and financial cycles. The channels through which monetary policy influences economic activity and financial markets—including interest rates, exchange rates, asset prices, and credit (and bank lending)—appear not to operate properly in EMEs due to the incompleteness of and imperfections in financial markets or due to the procyclical nature of monetary policy.[3] Alternatively, standard empirical models may fail to capture the true effects of monetary policy shocks because macroeconomic and financial variables in EMEs are highly volatile.

In the case of advanced economies, an appealing explanation for the price puzzle is that their central banks have more information about future inflation than can be captured by a simple VAR model (Sims 1992; Grilli and Roubini 1996). This omission implies that a policy tightening in anticipation of a jump in future inflation would be misinterpreted in conventional models as a policy shock. If monetary policy only partially offsets inflationary pressures, such models would deliver a spurious positive correlation between policy rates and inflation.[4] Prior resolutions of the price puzzle have focused largely on advanced economies (e.g., Barth and Ramey 2002; Blanchard 2004; Rabanal 2007; Castelnuovo and Surico 2010). A few studies have looked at individual EMEs and generally find mixed results (Minella 2003; Cysne 2004; Luporini 2008; Céspedes et al. 2008; Carvalho and Rossi Júnior 2009; Kohlscheen 2014; Costa Filho 2017).[5]

The main contribution of our paper is to systematically assess the ability of those proposed solutions to resolve the puzzles within a unified framework for a set of EMEs. We find that incorporating forward-looking expectations into the model helps to simultaneously

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[2] Using a meta-analysis, for instance, Hnatkovska et al. (2012, 2016) find that the exchange rate depreciates in response to positive shocks to the interest rate differential in 37 out of 49 developing countries.

[3] See Hammond et al. (2009), Frankel (2010), Mishra et al. (2012), and De Leo et al. (2023).

[4] Other explanations of the price puzzle include: cost-push channel of monetary policy transmission (Barth and Ramey 2002; Rabanal 2007), currency depreciation and its pass-through to inflation (Blanchard 2004) or Indeterminacy—passive monetary policies by central banks (Castelnuovo and Surico 2010). More detailed theoretical discussions of the price puzzle and the literature review are provided in Appendix II.

[5] Some recent papers, such as Choi et al. (2024) and Deb et al. (2023), have attempted to better identify exogenous monetary policy shocks for EMEs and have provided evidence of monetary policy transmission without encountering the price puzzle. By contrast, we explore various approaches proposed in the literature and examine cross-country evidence alongside country-specific analyses. Additionally, we address both the price and FX puzzles simultaneously.

resolve the prize and FX puzzles in many EMEs. We first confirm that a standard VAR model controlling for commodity prices as well as global demand and supply shocks produces the price and FX puzzles in EMEs (but not in advanced economies). Alternative variable orderings, identification via high-frequency external instruments, and a factor-augmented VAR, do not resolve these puzzles. Our key result is that the puzzles disappear or are mitigated when we include forward-looking variables. When we incorporate survey-based expectations from professional forecasters, consumers, and firms (as proxies for central bank forecasts) into the model, the empirical results align with theoretical predictions of monetary policy transmission in EMEs.

The critical role of expectations is confirmed through proxy VAR models, which use instrumental variables for monetary policy shocks based on single-equation policy reaction functions. Our results point to an *omitted variable* problem: standard VAR models fail to capture future inflation developments, reflecting the high volatility of macroeconomic and financial variables in EMEs (Castelnuovo and Surico 2010). In addition, the opposite directional responses of output and inflation to monetary policy shocks (based on the mis-specified models) suggest that the omitted variables may mainly reflect the supply-driven shocks, which are more prevalent in EMEs.[6]

Based on estimation of a model augmented with the survey data—to identify "true" monetary policy shocks in EMEs—a one percentage point contractionary monetary policy shock is followed by declines in output and prices (of around 0.9 and 0.3 percent, respectively), along with an increase in short-term interest rates (roughly 0.5-0.6 percentage point), currency appreciation (0.6 percent), and a fall in stock prices (nearly 2 percent). The significant transmission of monetary policy shocks into different financial markets (bond, stock, and currency) and macroeconomic outcomes (output and prices) are observed in a majority of EMEs.

We also find that, in many EMEs, the price puzzle disappears when the FX channel is controlled using sign restrictions in the model.[7] This is also consistent with the view that the cost-push (or supply-driven) channel of monetary policy transmission can contribute to the price puzzle if the FX puzzle (i.e., currency depreciation) leads to inflation. Our analysis suggests that the two puzzles in EMEs are interconnected, whereas previous literature has tended to address them separately.

[6] Jarociński and Karadi (2020) argue that the price puzzle observed in the United States and the Euro area may reflect a bias stemming from central bank information effects. Central bank information shocks often resemble demand shocks, as output and prices tend to comove following such shocks. If similar information effects are at play in EMEs, our results might imply that central bank information in these economies conveys signals of adverse supply shocks. This would indicate that central banks in EMEs are confronted with a difficult trade-off: whether to "look through" supply shocks, or respond to them in an effort to anchor inflation expectations. Such a dilemma is well-documented in the literature, particularly in EMEs, where monetary policy responses to supply shocks tend to be more procyclical. For example, Ocampo and Ojeda-Joya (2022) find that supply shocks present significant challenges for EMEs, often forcing central banks to adopt a procyclical stance in response to temporary supply disruptions.

[7] This is consistent with Kim and Lim (2018), who show that the price puzzle disappears in four small open economies (UK, Canada, Sweden, and Australia) once the FX puzzle is resolved through sign restrictions.

II. A simple theoretical framework

We first introduce a New Keynesian model, following Clarida et al. (1999) and Woodford (2003), to motivate our empirical exercise. The model consists of the following system of equations:

$$R_t = \emptyset E_t \pi_{t+1} + r_t, \tag{1}$$

$$y_t = E_t y_{t+1} - (R_t - E_t \pi_{t+1}) + d_t, \tag{2}$$

$$\pi_t = k y_t + \beta E_t \pi_{t+1} + s_t, \tag{3}$$

where $x_t \equiv [r_t, d_t, s_t]^T$ is a vector of exogenous driving processes that follow the normal distribution of zero mean and a diagonal covariance matrix. y_t is defined as the deviation of output from its trend-path, π_t represents inflation, and R_t is the nominal interest rate. π_t and R_t are expressed in percentage deviations from their steady state values.

Equation (1) posits that the central bank adjusts the policy rate in response to inflation. r_t stands for the monetary policy shock, representing an unexpected deviation from the policy rule. Equation (2) is the IS curve derived from the household's intertemporal problem driven by consumption and bond holdings. The exogenous process, d_t, captures aggregate demand shocks such as changes in government spending. Equation (3) implies Calvo-type price setting, with firms adjusting prices with a constant probability in each period and independently of the time elapsed from the previous adjustment. The discrete price setting leads to larger price adjustments in response to higher expected future inflation. The parameter $0 < \beta < 1$ is the firms' discount factor. Inflation is driven by an exogenous process, s_t, typically associated with aggregate supply shocks such as changes in commodity prices or exchange rates. The literature presents various approaches to address the price puzzle arising in this framework, as discussed below.

Model misspecification. Many studies claim that the forward-looking component of monetary policy shocks is not correctly identified in standard empirical models, which typically exclude variables that help central bankers forecast inflation. Equations (1)-(3) imply that standard VAR models do not incorporate expectations for inflation and output gap. These models typically assume that the lagged output, prices, and financial variables—including interest rates, stock prices, and FX rates, which tend to incorporate news shocks on future economic developments—adequately capture inflation and output expectations. However, if the central bank considers a larger information set than VAR models capture, the estimated policy shock is then a combination of a genuine policy shock and an endogenous policy response. If the policy response only partially offsets current inflationary pressures, the VAR would deliver a spurious correlation between policy tightening and a rise in inflation.

The standard solution to this price puzzle was to include commodity prices in models estimated with U.S. data, as they help forecast inflation (e.g., Sims 1992). Other variables considered as potential correlates of future inflation include the output gap, house prices, and global variables. The inclusion of these variables does not always resolve the puzzle, leading to the inclusion of inflation expectations as additional explanatory variables (Castelnuovo and Surico 2010).

A major advance in recent literature is the use of external instruments, estimated outside the VAR system, based on narrative evidence (Romer and Romer 2004; Cloyne and Hürtgen 2016; Champagne and Sekkel 2018) or high-frequency data (Gertler and Karadi 2015; Nakamura and Steinsson 2018a). Coibion (2012) and Ramey (2016) document that the results of this approach can be sensitive to the choice of instrument, sample, and empirical specification. Miranda-Agrippino and Ricco (2021) address these instabilities by developing a new high-frequency instrument that accounts for informational rigidities, highlighting the "Fed information effect." Similarly, Bauer and Swanson (2023) propose that economic news released before an FOMC announcement is a key omitted variable, as both the Fed and market participants respond to such publicly available information.

Cost-push channel. Another strand of literature emphasizes the importance of the supply-driven or cost-push channel of monetary policy transmission in resolving the price puzzle (Ravenna and Walsh 2006; Chowdhury et al. 2006). These studies argue that prices can rise in response to a monetary tightening because an increase in interest rates pushes up production costs. In the short run, this translates into an increase in inflation, which can decline over time as aggregate demand decreases due to higher interest rates. Compared with the model as summarized in equations (1)-(3), this produces an extra link between monetary policy and inflation if the inflationary impact of monetary policies via the supply channel is stronger than the one operating via the standard demand channel.

Exchange rate pass-through. Monetary policy influences inflation through its impact on exchange rates, a critical transmission channel in EMEs. In theory, higher interest rates attract capital inflows, leading to an exchange rate appreciation and lower prices. However, exchange rate movements often deviate from theoretical predictions (Clarida et al. 2001; Scholl and Uhlig 2008). For instance, when a country has a high level of public debt, a tightening of monetary policy can raise real interest rates, increasing default risk and raising the risk premium (Blanchard 2004; Favero and Giavazzi 2004). This in turn can trigger capital outflows and lead to currency depreciation. If the exchange rate pass-through to domestic prices is large enough, this depreciation can result in higher inflation. Goodfriend (1993) link such price puzzles to autonomous increases in inflation expectations, particularly in countries where expectations are not well anchored.[8]

III. Methodology and data

Our baseline model is a standard structural vector-autoregressive (SVAR) model. The model assumes the economy is described by the following equation:

$$AY_t = \sum_{i=1}^{p} B_i Y_{t-i} + \sum_{j=0}^{q} C_j X_{t-j} + \varepsilon_t , \tag{4}$$

[8] Some studies focusing on the U.S. argue that the prize puzzle is driven by indeterminacy of monetary policies—i.e., violation of the Taylor rule (Lubik and Schorfheide 2004; Castelnuovo and Surico 2010). See Appendix II for details. Ramey (2016) offers an extensive review of studies on monetary policy and prices.

where Y_t is an $n \times 1$ vector of endogenous macroeconomic and financial variables. X_t is a vector of exogenous regressors. A, $B_i (\forall i \geq 1)$, and $C_j (\forall j \geq 0)$ are nonsingular coefficient matrices. ε_t is an $n \times 1$ vector of serially uncorrelated structural disturbances. $E(\varepsilon_t \varepsilon_t') = I$, where I is the identity matrix implying that the structural disturbances are also mutually uncorrelated. Pre-multiplying each side of the equation by A^{-1} yields the reduced form representation:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{j=1}^{q} \beta_j X_{t-j} + e_t, \tag{5}$$

where $\alpha_i = A^{-1} B_i$, and e_t are the reduced form residuals related to the structural shocks:

$$e_t = \begin{bmatrix} e_t^p \\ e_t^q \end{bmatrix} = S\varepsilon_t = [s^p s^q] \begin{bmatrix} \varepsilon_t^p \\ \varepsilon_t^q \end{bmatrix}, \tag{6}$$

with $S = A^{-1}$. e_t^p is a vector for the residuals of domestic monetary policy instruments and e_t^q is a vector for the residuals of the other variables. The analogous definition applies to structural shocks, ε_t^p and ε_t^q. s^p and s^q denote the column in matrix S that corresponds to the impact of structural policy shocks, ε_t^p and ε_t^q, respectively, on the vector of reduced-form residuals (e_t). The variance-covariance matrix of the reduced-form VAR is $\Sigma = E[e_t e_t'] = E[SS']$. The structural moving average representation as a function of structural shocks is then given by:

$$Y_t = \sum_{j=0}^{\infty} C_j S \, \varepsilon_{t-j} = \sum_{j=0}^{\infty} C_j s^p \, \varepsilon_{t-j}^p + \sum_{j=0}^{\infty} C_j s^q \, \varepsilon_{t-j}^q, \tag{7}$$

where C_j denotes the coefficients of the structural MA form. If an endogenous variable responds to monetary policy innovations, the relevant impulse responses (IRF), the dynamic response of the k[th] element of vector $Y (Y_k)$ to a unit shock (ε_t^p) at time $t+j$, can be obtained by:

$$IRF_{k,j} = \frac{\partial Y_{k,t+j}}{\partial \varepsilon_{k,t}^p} = C_{k,j} s^p, \tag{8}$$

where $C_{k,j}$ is the k-th row of C_j.

III.1 Data

Our baseline analysis covers 14 EMEs with flexible exchange regimes and inflation targeting—Brazil, Chile, Hungary, Indonesia, India, Mexico, Peru, the Philippines, Poland, Romania, Russia, Thailand, Türkiye, and Ukraine. We also examine 7 advanced economies—Canada, Germany, Japan, Korea, Sweden, the United Kingdom, and the United States—and EMEs with managed exchange rate regimes, such as China and Malaysia, for comparison when necessary. Our dataset covers the period January 2000 through December 2019.

We employ six monthly macroeconomic and financial variables in the SVAR model, ordered as follows: logs of seasonally adjusted industrial production (*Y*, output hereafter), logs of seasonally adjusted consumer price index (*P*, 'price'), domestic policy interest rates (*MP*), overnight interest rates or 3-month or one-year government bond yields (*Int*), logs of the nominal exchange rate relative to the US dollar (*FX*), and the equity price index (*S*).[9] We also include four exogenous variables to account for latent factors that can simultaneously affect endogenous variables: the international commodity price index (*Cmdt*), U.S. federal funds rates (*FFR*), the CBOE volatility index (*VIX*), and a deterministic trend component (*Trend*).[10] These data are sourced from Haver Analytics, national central banks, or Federal Reserve Economic Data (FRED).

A novel aspect of this paper is the use of survey-based expectations for future inflation, output growth, FX rates, and interest rates. Consumer and business expectations are sourced from monthly surveys conducted by national central banks or statistical offices, while professional forecasters' expectations come from Consensus Economics surveys.[11] The availability of expectations data varies across EMEs. As a baseline, we prioritize consumer or business expectations, which tend to show greater variability, and supplement with professional forecasters' surveys when national consumer and business surveys are unavailable or too short for some EMEs. In the SVAR model, we incorporate one-year-ahead expectations.[12]

III.2 Identification and estimation

The baseline identification follows the standard recursive scheme using the Cholesky decomposition of the variance-covariance matrix, as in Christiano et al. (1999) and many others. The monetary policy instrument (i.e., policy interest rates) is placed after the output and price variables, in line with the Taylor-rule type monetary policy reaction function, and before financial variables—interest rates, exchange rates, and stock price—to reflect the transmission channel of monetary policy shocks through financial markets. Despite using monthly data, endogeneity issues may still persist. To address this, our model includes several exogenous variables (SVAR-X) that account for global demand and supply shocks, capturing the simultaneous movements of variables in small open economies. In addition, the main model is augmented with economic and financial forecasts by consumers, businesses, and professional forecasters.

We first estimate the SVAR models for each country using a Bayesian approach, where the routine aims to find 1,000 successful draws from at least 2,000 iterations with 1,000 burn-ins. The impulse response functions for each individual country are derived as the medians of these 1,000 successful draws, with posterior bands constructed using the 16th

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[9] These are the endogenous variables typically included in VAR models of monetary policy transmission (Rey 2015; 2016, Passari and Rey 2015, Bjørnland 2009). Summary statistics are shown in Table A1.

[10] While our main interest in this paper is in the transmission of domestic monetary policy shocks into EMEs, we also summarize the results on the transmission of U.S. monetary policy shocks in Appendix III.

[11] See Table A2 in appendix I for further details.

[12] For instance, Consensus surveys report annual growth rates or expected inflation for the current and the next year on a monthly basis. We obtain one-year-ahead inflation expectation as a linear combination of the inflation expectations for the current ($E\pi_t$) and next years ($E\pi_{t+1}$). Specifically, we calculate it as $E\pi_{1year}$ = (12-m)/12* $E\pi_t$+m/12* $E\pi_{t+1}$, where m represents the number of the month.

and 84th percentiles, following a one percentage point increase in the identified structural (monetary policy) shocks. For the group-level analysis, we use the mean group estimator from Pesaran and Smith (1995).[13] Specifically, we average the impulse response functions across individual countries to compute the mean group response and use bootstrapping to construct 90 percent confidence bands.

IV. Empirical results

We now present our key empirical results. First, we demonstrate that the standard VAR model, which controls for commodity prices and other global variables, gives rise to the price and FX puzzles in EMEs but not in AEs. Next, we show that incorporating forward-looking expectations into the model effectively resolves these puzzles in EMEs, while other solutions proposed in the literature do not. Table 1 summarizes the effects of monetary policy shocks on prices and exchange rates across different models.

IV.1 The baseline model

Figure 1.A presents the impulse responses of the variables to a one percentage point contractionary monetary policy shock for EMEs. The responses of output, the interest rate, and equity prices are in accord with conventional theories. But, for most EMEs, the responses of prices and foreign exchange rates are not.[14] Following a contractionary monetary policy shock, output and equity prices decline, and short-term interest rates rise, as expected. However, prices increase and foreign exchange rates depreciate against the U.S. dollar. Advanced economies do not exhibit these price and FX puzzles (Figure 1.B). Foreign exchange rates initially appreciate and then exhibit volatile responses during the first 12 months (in accord with Dornbusch's 1976).

IV.2 Alternative models

To resolve the price puzzle, we test each of the following approaches: (i) SVAR with recursive identification of alternative Cholesky ordering of the variables (labeled as "Alt"), placing monetary policy last; (ii) factor-augmented SVAR that included global variables of output, prices, monetary policy, market interest rates, and stock prices ("FAVAR"); (iii) Proxy SVAR with high-frequency identification ("Proxy")[15]; and (iv) SVAR-X model incorporating economic and financial forecasts (inflation, output, interest rate, and FX) by consumers, businesses, and professional forecasters ("EXP").[16] Figure 2 summarizes the impulse responses of prices to a contractionary monetary policy shock. While the average price response declines in some models, the median response still exhibits puzzling behavior, indicating that the responses of prices remain puzzling or at least statistically

[13] Cesa-Bianchi et al. (2024) and Gambacorta et al. (2014) use the same approach.
[14] Including exogenous variables one by one or adding variables such as Caldara and Iacoviello's (2022) geopolitical risk index and Baker et al's (2016) economic policy uncertainty index did not alter our results.
[15] Due to data limitations, our application of the high-frequency identification method is restricted to using daily movements of overnight rates and is limited to 7 EMEs.
[16] The identification strategies in Miranda-Agrippino and Ricco (2021) and Bauer and Swanson (2023) cannot be applied to EMEs with as they have less developed financial markets and lack central bank economic projection data.

insignificant in many EMEs.[17] Notably, Figure 2 shows both the median and mean impulse responses decline only in the model incorporating expectations.

Figure 3 compares impulse responses between the base model (red dashed lines) and the model augmented with forward-looking variables (navy lines with confidence bands). The inclusion of expectation variables significantly affects the responses of prices, FX, and equity prices. The price and FX puzzles are resolved in the model with expectations, unlike in the base model. The price response turns negative immediately after the shock and reaches its peak, with a decline of approximately 0.3 percent, around 20 months. The foreign exchange rate appreciates by 0.6 percent, though it briefly depreciates immediately following the shock.

Our results support the hypothesis that central banks possess more information about future inflation than a simple VAR could capture, leading to the price puzzle when policy tightening anticipates future inflation. In AEs, adding a commodity price index to the VAR, as suggested by Sims (1992) and Hanson (2004), helps resolve the puzzle. However, in EMEs, commodity prices and other global variables are insufficient. This aligns with Castelnuovo and Surico (2010), who find that including expected inflation resolves the price puzzle, and Fermo (2009), who shows that adding inflation expectations eliminate puzzling responses of prices, output, stock prices, and exchange rates to monetary policy in the Philippines.

IV.3 Models with external instruments of monetary policy shocks

We have shown that incorporating expectations data resolves the price and FX puzzles when estimating the Cholesky VAR model. To check the robustness of this conclusion, we now identify monetary policy shocks outside the VAR system using the expectations data. To this end, we follow the single-equation approach of Romer and Romer (2004). Central bank forecasts are not publicly available for the entire sample period at a monthly frequency. We therefore use forecasts from market participants as proxies for central bank forecasts.[18] By regressing the change in the policy rate on market forecasts of macroeconomic variables, we estimate the systemic or anticipated component of monetary policy. The residuals from this regression represent the unpredictable component of policy given the available information about current and future economic conditions and serve as an instrument for monetary policy shocks.

We construct a series of monetary policy shocks by estimating the following regression:

$$\begin{aligned}\Delta i_t = {} & c + \alpha_1 i_{t-1} + \alpha_2 \Delta i_{t-1} + \beta_1 E_t[y_{t+12}] + \beta_2 (E_t[y_{t+12}] - E_{t-1}[y_{t+11}]) + \beta_3 E_t[\pi_{t+12}] \\ & + \beta_4 (E_t[\pi_{t+12}] - E_{t-1}[\pi_{t+11}]) + \beta_5 E_t[u_{t+12}] + \beta_6 (E_t[u_{t+12}] - E_{t-1}[u_{t+11}]) \\ & + \beta_7 E_t[R_{FX3M}] + \beta_8 E_t[R_{FX12M}] + \gamma_1 i^*_{us,t-1} + \gamma_2 \Delta i^*_{us,t-1} + \varepsilon_t^{mps}, \qquad (9)\end{aligned}$$

[17] Appendix Figures A1-A3 present the impulse responses of all endogenous variables with confidence bands, showing that the price and FX puzzles are not resolved for these models.

[18] Cloyne and Hürtgen (2016) and Holm et al. (2021) show that market participants' forecasts are good proxies for official forecasts for the U.K. and Norway, respectively.

where i is the domestic policy rate, $E_t[x_{t+j}]$ indicates the j months ahead market forecasts of the variable x made at time t, y, π, and u are the real GDP growth, inflation rates, and unemployment rates, R_{FX3M} and R_{FX12M} represent the investment returns on domestic currency against US dollars over the next 3-month and 12-month, respectively, and i_{us}^{*} is the US policy rate.[19] Forecast changes are included because changes in the policy rate are likely to be associated with changes in expectations driven by recent updates on economic conditions. A variant of Equation (9) is estimated for each country depending on data availability.[20]

The identified monetary policy shocks are first used in the framework of the SVAR model based on the external instrument identification scheme, also known as a proxy SVAR.[21] We then complement the SVAR model by estimating impulse responses of the variable of interest following a single equation approach and employing the Jordá (2005) local projections method.[22] We use a panel local projection for 14 EMEs and the specification is as follows:

$$x_{i,t+h} - x_{i,t} = c + \alpha_{i,h} + \beta_h \hat{\varepsilon}_{i,t}^{mps} + \sum_{k=1}^{K} \beta_h^k \hat{\varepsilon}_{i,t-k}^{mps} + \sum_{j=0}^{J} \mu_j^h Z_{i,t-j} + \epsilon_{i,t+h}, \text{ for } h = 0,1,2,\dots,H \quad ,(10)$$

where x is the logarithm of variables of interest, Z is a vector of control variables, $\alpha_{i,h}$ is a country fixed effect to capture time-invariant country characteristics, and $\hat{\varepsilon}^{mps}$ refers to the measure of a monetary policy shock estimated from Equation (9).[23]

We first discuss the results using the proxy SVAR. The impulse responses in Figure 4 indicate that the external identification scheme, which incorporates forward-looking expectations, resolves both the price and FX puzzles. Following a contractionary monetary policy shock, statistically significant price declines are observed after several months. Although the FX response shows some variability initially, the exchange rate appreciates thereafter. Overall, the model produces impulse responses similar to those in the model with expectation variables (Figure 3), though it generates larger responses in output, prices, and the foreign exchange rate.

Figure 5 presents impulse responses estimated using the panel local projection, comparing two models: (i) one with identified monetary policy shocks in the spirit of Romer and Romer (2004) (blue lines with dots) and (ii) another using actual policy rate changes

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[19] Unlike Romer and Romer (2004), we rely on one-year-ahead forecasts instead of quarterly ones because of data limitations. Holm et al. (2021) and Brandão-Marques et al. (2020) follow a similar approach.

[20] When central bank meeting dates are available, estimation is done at a meeting-by-meeting frequency.

[21] The external instrument identification VAR estimates the parameters by applying the instrumental variables of monetary policy shocks to two-stage least squares, without imposing any assumptions on the contemporaneous interactions among endogenous variables (Mertens and Ravn 2013; Stock and Watson 2018). The first-stage F-statistics are substantially above 10 for all countries, except Türkiye.

[22] One criticism of VAR models is that they require the VAR to be a correct representation of all the endogenous variables, an assumption that is unlikely to hold in practice (Nakamura and Steinsson 2018b).

[23] We include 12 lags for the interest variable, 4 lags for the control, and 36 lags for the shock (see, e.g., Romer and Romer 2004; Cloyne and Hürtgen 2016; Champagne and Sekkel 2018; and Holm et al. 2021).

(solid grey lines). The output response to a one percentage point contractionary monetary policy shock is smaller than that to a one percentage point rate increase. The estimated shock response bottoms out at 1 percent after three quarters, while the policy rate innovation remains negative at around 1.5 percent. Crucially, isolating the systemic component of monetary policy based on expectations mitigates both the price and FX puzzles. Although the inflation response still shows a price puzzle for 12–15 months, it becomes negative over time, unlike the consistently positive response to rate changes. The FX puzzle nearly disappears, with a depreciation of 1 percent after 6 months. Thus, including forward-looking expectations helps resolve both the price and FX puzzles.

IV.4 Additional results on the roles played by economic expectations

We now delve deeper into the role of expectations in identifying monetary policy shocks.

Type of expectations. To examine the significance of each type of expectations, we regress the residual of the monetary policy instrument—i.e. Taylor-rule residuals based on typical SVAR models—on (i) expected inflation $(E\pi_t)$, (ii) expected GDP growth (Ey_t), and (iii) expected foreign exchange rates (EFX_t) for each country. The results, shown in Table 2, indicate that inflation expectations are correlated with the residuals in a majority of countries, suggesting that the omitted variables are associated with inflation expectations. In some countries (Peru, Poland, and Russia), where the expectation data are available, FX expectations also exhibit a statistically significant correlation with the residuals.[24]

Information content. To understand the information content of the expectations data, we decompose inflation expectations $(E\pi_t)$ into (i) the surprise in inflation expectations at time t $(E\pi_t - E\pi_{t-1})$, (ii) the deviation of inflation expectations from the long-term average inflation (as a proxy for inflation target) $(E\pi_{t-1} - \pi^*)$, and (iii) long-term inflation (π^*). Specifically,

$$E\pi_t = (E\pi_t - E\pi_{t-1}) + (E\pi_{t-1} - \pi^*) + \pi^*, \tag{11}$$

where $E\pi_t$ indicates one-year-ahead inflation expectations at month t by households, firms, or professional forecasters (depending on data availability across countries).

The results are shown in Table 3. For some countries (e.g., Brazil, Chile, and Hungary), the deviation of current expectations from the long-term average inflation ("Level") appears to be more influential than the differential effect (surprise in the expectations at time t, denoted as "Difference"). For others such as Russia, the time t shifts in inflation expectations appear to play a more significant role in the identification of monetary policy shocks. Finally, both components show significant coefficients in the case of Hungary, Peru, and Thailand. These findings collectively suggest that while inflation expectations are critical variables in the identification of monetary policy shocks in EMEs, there are

[24] We also examine if the price puzzle can be resolved by including each type of expectations one by one. Inflation expectations consistently emerge as the most influential factor.

cross-country differences in what information contents account for the (omitted) role of inflation expectations in the SVAR model.[25]

Omitted variables. Our results suggest that the incorrectly identified policy shock has the flavor of an *adverse supply shock*, as it moves inflation and output in opposite directions. Given that the incorporation of commodity prices did not significantly contribute to resolving the price puzzles, other types of supply shocks—such as potential future adverse productivity shocks, financial crises, or future expected currency depreciation—seem to still be omitted in the VAR system. Our analysis shows that inflation expectations can control for these omitted factors.[26] Absent this control, the positive correlation between expectations and both prices and policy rates can lead to an upward bias in the estimated effect of monetary policy on prices. This bias may even reverse the expected sign, particularly under a passive monetary policy regime in which the central bank does not fully offset inflationary pressures, a situation that is widely prevalent among EMEs. This logic also suggests that the estimated response of output could be biased towards zero or even turn positive if anticipatory policy measures respond to positive demand shocks. In our analysis, however, the responses of output are mainly negative and statistically significant.

Response of expectations to monetary policy shocks. We include the expectations variables as control (exogenous) variables partly to reduce the number of coefficients estimated in the VAR estimation. This assumes that the inflation expectations at time t are pre-determined. Alternatively, we can test a model considering such expectations as being endogenous and as responding to monetary policy and other shocks. Figure A4 shows that inflation expectations do react to monetary policy shocks (see the rows named "inflation expectation"), and the impulse responses are consistent with theoretical expectations. In other words, these variables serve as a transmission channel—an "expectations channel" of monetary policy to the macroeconomy.

Use of expectations with the data of advanced economies. The empirical results for the U.S. did not exhibit the price and FX puzzles, even without incorporating expectations data. Still, controlling for central bank information shocks could enhance the transmission of monetary policy. To illustrate this point, we utilize the (pure) monetary policy shocks of Jarociński and Karadi (2020), where the information contents from central bank news shocks are taken out. This yields more pronounced and statistically significant responses (third column in Figure A5). This finding aligns well with those of Jarociński and Karadi (2020) and Bu et al. (2020).

[25] These results gain support when each component is incorporated into the SVAR identification, as the impulse responses notably differ (overcoming the price and FX puzzles) when the control variables include separately the "level" or "difference" component of inflation expectations (not shown here).

[26] To examine the possibility that global risk shocks could be the omitted variables, we conducted a panel local projection analysis to explore how the residuals from our baseline SVAR model respond to the global financial cycle measure of Miranda-Agrippino and Rey (2020), the risk aversion index from Bekaert et al. (2021), global economic policy uncertainty from Baker et al. (2016), and the geopolitical risk index from Caldara and Iacoviello (2022). The residuals do not show any systematic response to these global variables. Incorporating these variables into the baseline model did not resolve the price and FX puzzles, although they were somewhat mitigated.

V. Further considerations: the relation between price and FX puzzles

To better understand the role of omitted variables in influencing the transmission of monetary policy shocks, we undertake two independent but closely related exercises within the unified SVAR framework: a VAR dynamics accounting analysis under a recursive SVAR and a SVAR analysis with sign restrictions.

V.1 VAR dynamics accounting

We conduct two exercises to disentangle the role of transmission channels of monetary policy shocks. First, we simulate the effects of domestic monetary policy shocks by deactivating each transmission channel in the baseline model, setting the impulse responses of key variables to zero at all horizons (Cesa-Bianchi and Sokol 2022; Davis and Zlate 2019). This allows us to measure the contribution of each channel as the difference from the baseline model. Second, we treat the variables representing each transmission channel as exogenous, preventing them from responding to policy shocks. Comparing the impulse response functions from this model with the baseline provides a quantitative measure of each channels' strength.

The results suggest that the price puzzle observed in the baseline model is primarily driven by the positive contribution of foreign exchange rates (i.e., currency depreciation).[27] Other variables such as output, interest rates, and equity prices exhibit contractionary effects. Similar results are obtained from the second exercise. While the price puzzle is resolved in most EMEs when the exchange rate is considered as a control variable, incorporating other control variables does not alter the impulse responses.[28] Overall, these two analyses suggest that the foreign exchange rate puzzle is linked to the emergence of the price puzzle.

V.2 Sign-restricted SVAR

We now turn to the SVAR model that imposes a sign restriction on the impulse response of the foreign exchange rate, resolving the FX puzzle by construction.[29] Figure 6 shows that, following a contractionary monetary policy shock, both output and prices decline, while the foreign exchange rate appreciates (by design). Notably, the price and FX puzzles appear to be interconnected, suggesting that resolving the FX puzzle helps address the price puzzle as well. Kim and Lim (2018) report similar results for four small, advanced open economies.

[27] The results are presented in appendix Figure A6 for selected countries.
[28] The results are presented in appendix Figure A7 for selected countries.
[29] The sign restriction method, which identifies shocks based on sign restrictions on the responses of other variables, gained prominence after Uhlig (2005) challenged conventional identification strategies that imposed zero restrictions on the contemporaneous responses of key variables, such as output, to a monetary policy shock.

We tested two additional sign restrictions.[30] First, we imposed sign restrictions on output and prices to directly address the price puzzle. Although the signs of all responses were theoretically consistent, the magnitudes of the output and price responses were implausibly large (Figure A8 in Appendix I).[31] Second, we applied a sign restriction to interest rates to resolve the liquidity puzzle, but both the price and liquidity puzzles persisted (Figure A9 in Appendix I).[32]

V.3 Discussion: Exchange rate as a propagation mechanism

We have established that exchange rates play a pivotal role in the genesis of the price puzzle. Conventional open economy models, which integrate an uncovered interest parity condition with rational expectations, predict that an unexpected monetary contraction initially triggers currency appreciation (Dornbusch 1976). This sets the stage for subsequent depreciation at a rate equivalent to the interest rate differential. This link between interest rate hikes and currency appreciation is a standard feature in other workhorse models of international macroeconomics. However, the conditional movements of foreign exchange rates deviate from these theoretical predictions (Clarida et al. 2001; Scholl and Uhlig 2008). For instance, in response to a contractionary domestic monetary shock, the currency either depreciates or appreciates only gradually over prolonged periods.[33]

The evidence of this FX puzzle persists in recent literature, especially in the case of EMEs (Obstfeld et al. 2019; Kohlscheen 2014; Kim and Lim 2018; Hnatkovska et al. 2012, 2016). Importantly, this puzzle is not merely a byproduct of misspecification or poor identification. For instance, in a study of Brazil, Mexico, and Chile, Kohlscheen (2014) finds that even when focusing on 1-day exchange rate changes following policy events—which reduces the potential for reverse causality—there is no evidence that unexpected interest rate hikes result in immediate appreciations.[34] Brandão-Marques et al. (2020) find that the effects on prices of a contractionary monetary policy shock are more muted and only significant when accounting for the exchange-rate channel. They argue that the behavior of the exchange rate explains countries' heterogeneous responses to monetary policy shocks (Ehrmann et. al. 2011; Kim and Roubini 2000). The transmission of

[30] We also tested the Uhlig (2005) sign restrictions. This resolves the price puzzle by construction but yields insignificant output responses, possibly due to the compounding effects of positive supply shocks (leading to declines in prices and increases in output) and positive demand shocks (leading to declines in both).

[31] In addition, the impulse response of output and prices are not hump-shaped based on these sign restrictions, which is at odd with the typical results and predictions in the monetary economics literature.

[32] Recent advances in shock identification techniques provide more robust alternatives to traditional sign restrictions. For example, Arias et al. (2019) enhance the standard approach by imposing both sign and zero restrictions on the systematic component of monetary policy, while Antolín-Díaz and Rubio-Ramírez (2018) introduce narrative sign restrictions that integrate narrative methods with sign restrictions. These approaches generate impulse responses that better align with theoretical predictions. We leave the implementing of such sophisticated methods in EMEs for future research.

[33] In the case of EMEs, earlier studies based on high-frequency data show that the currency response to monetary policy is low or nonexistent (Aktas et al. 2005; Duran et al. 2012; Pennings et al. 2015).

[34] The result is robust to the use of US dollar or effective exchange rates, the exclusion of policy rate changes followed by exchange rate interventions, and the dropping of "contaminated" events from the analysis.

monetary policy shocks to output and prices is statistically different from estimates obtained when excluding the amplification mechanism through exchange rates.

Consistent with this literature, our results indicate that FX puzzles are prevalent in most EMEs, where currency depreciation impinges on domestic financial stability. More notably, the price puzzle is most evident in EMEs which display the foreign exchange rate puzzle. In contrast, in advanced economies and a few other EMEs with managed foreign exchange regimes, neither the FX puzzle nor the price puzzle is evident.[35]

VI. Conclusion

The literature presents mixed results, at best, on the effectiveness of monetary policy in EMEs. This could stem from the challenges EME central banks face in stabilizing macroeconomic conditions or from limitations in accurately identifying the effects of monetary policy shocks due to the volatile nature of these economies. Our empirical findings, based on a standard SVAR model, suggest that in the major advanced economies monetary policy transmission operates effectively and in line with theoretical predictions. We document that in most EMEs, by contrast, monetary policy tightening often seems to result in rising prices (the price puzzle) and depreciating currencies (the FX puzzle).

We adopt a unified framework to appraise various solutions that have been proposed to address these empirical puzzles. We conclude that SVAR models augmented with forward-looking expectations show the most promise in resolving these puzzles. We also show that the two puzzles are closely related—eliminating the FX puzzle resolves the price puzzle. Our findings underscore the importance of modeling the forward-looking nature of monetary policy in EMEs when evaluating the effectiveness of their monetary transmission mechanisms.

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[35] The results for countries with managed fixed exchange regimes are presented in Figure A10.

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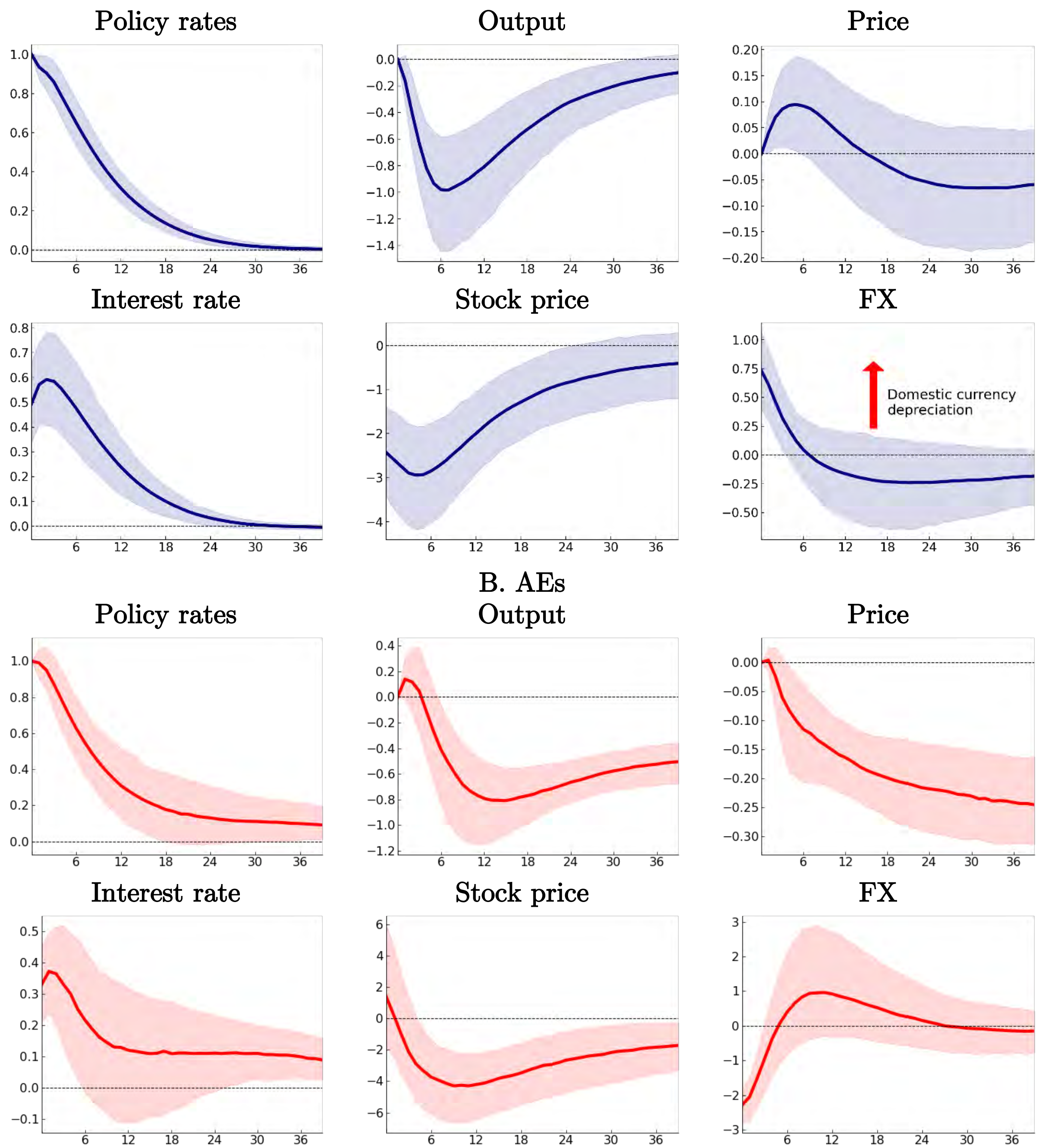
Figures

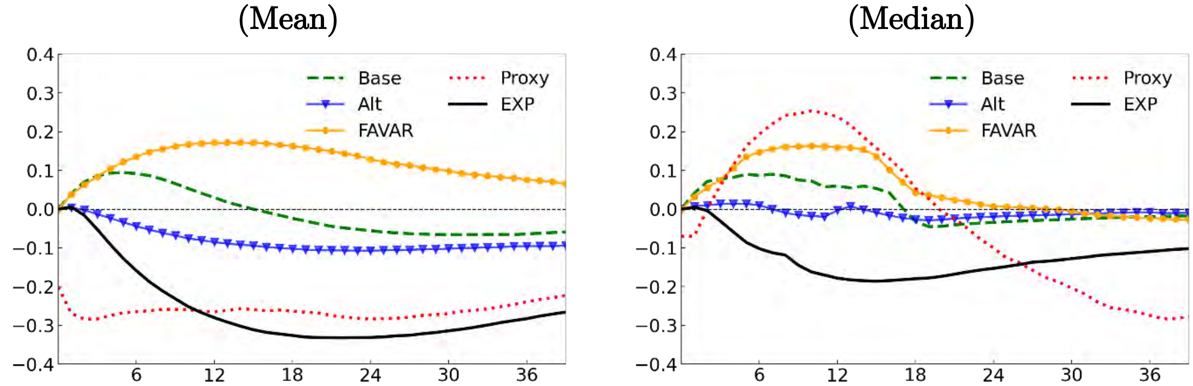
Figure 1. Impulse responses to a monetary policy tightening (Baseline SVAR model with conventional control variables)

A. EMEs



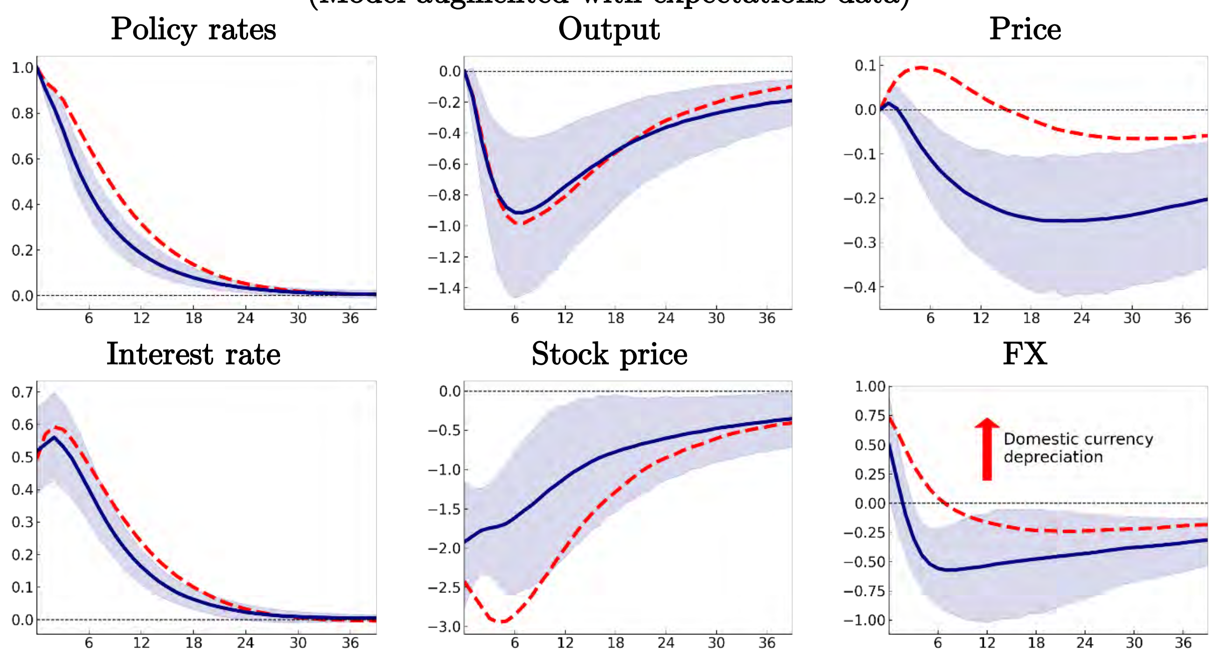
Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure 2. Impulse responses of price to a domestic monetary policy tightening (Comparison across different models)



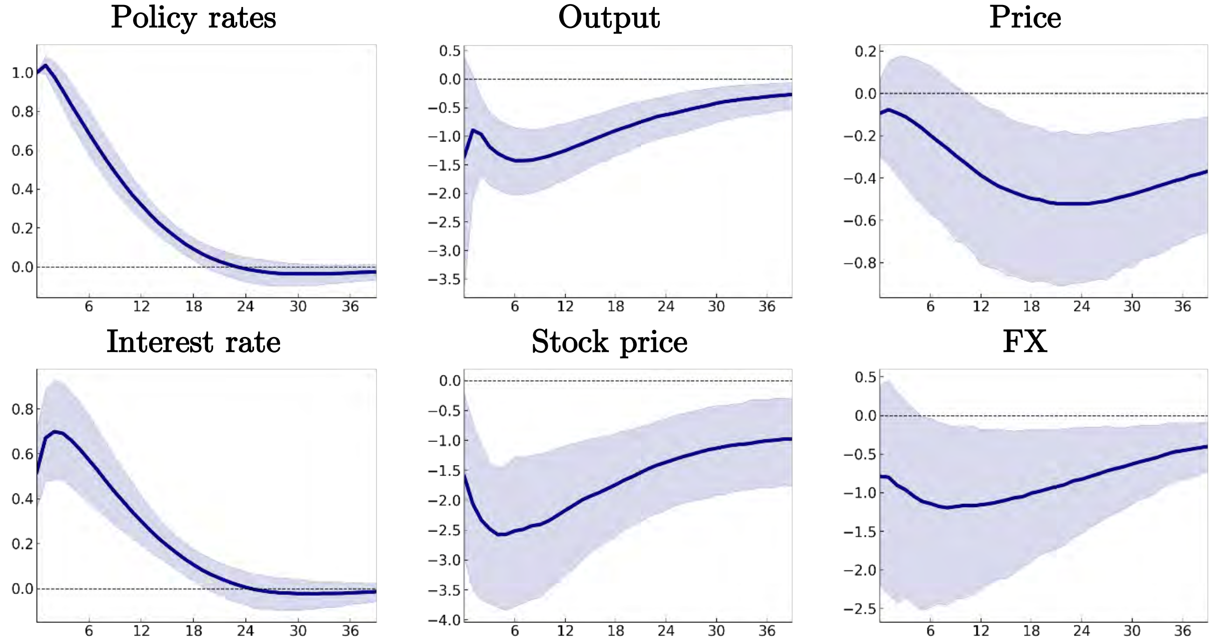
Note: Impulse response functions of prices, following a 1 percentage point contractionary monetary policy shock. “Base” refers to a model with standard control variables and Cholesky ordering of the variables, “Alt” is a SVAR model with recursive identification of alternative Cholesky ordering of the variables, “FAVAR” refers to a factor-augmented SVAR that includes global variables of output, prices, monetary policy, market interest rates, and stock prices, “Proxy VAR: High-frequency” is a SVAR-X model with alternative identification using high-frequency identification, and “EXP” is a SVAR-X model with economic and financial forecasts (Inflation, output, interest rate, and FX) by consumers, businesses, and professional forecasters. The Y-axis indicates percent, and the X-axis indicates months.

Figure 3. Impulse responses to a monetary policy tightening (Model augmented with expectations data)



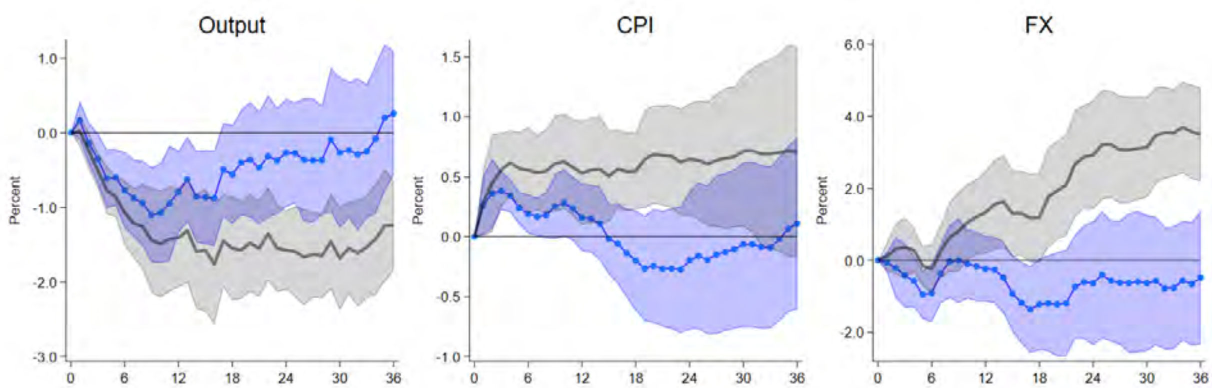
Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. The dashed line represents the impulse responses obtained from the baseline SVAR model with conventional control variables (Figure 1.A). The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure 4. Impulse responses to a monetary policy tightening (Model with external instruments)



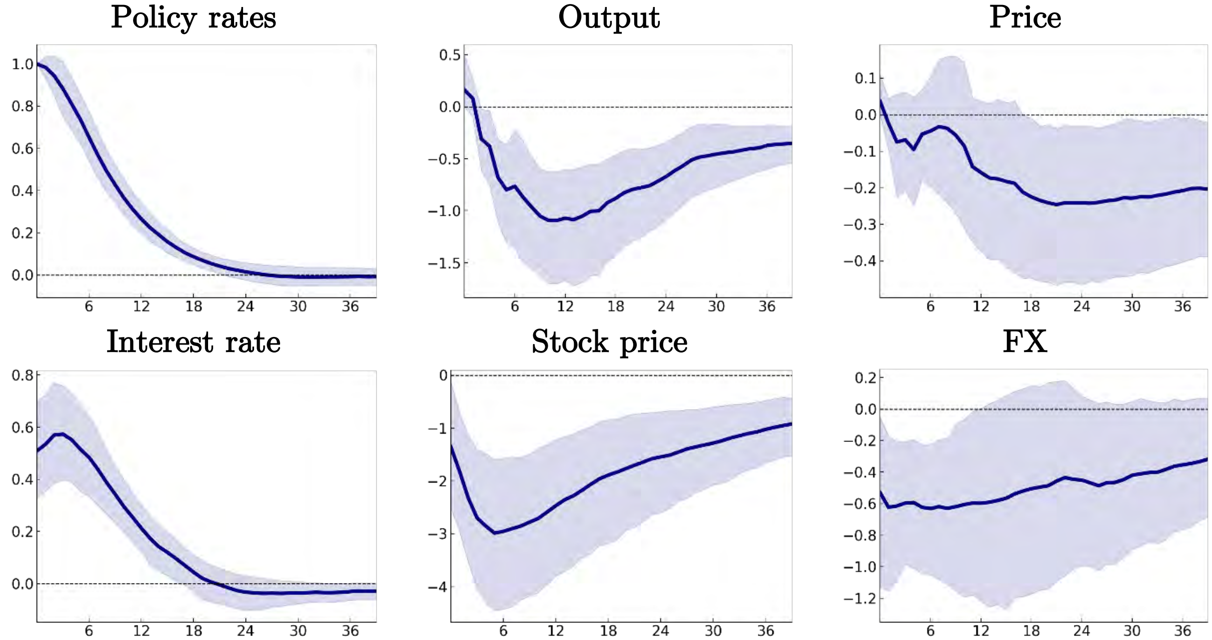
Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. Monetary policy shocks are identified using the single equation approach developed by Romer and Romer (2004). The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure 5. Impulse responses to a monetary policy tightening (Local Projections)



Note: Impulse response functions based on the local projections method. The blue dotted line represents the response to a 1 percentage point contractionary monetary policy shock, while the black line represents the response to a 1 percentage point increase in the policy rate. The shaded areas indicate the 90% confidence intervals, constructed with standard errors double-clustered by country and time. The X-axis indicates months.

Figure 6. Impulse responses to a monetary policy tightening (SVAR with a sign restriction on FX)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. Monetary policy shocks are identified using a combination of zero and sign restrictions, which assume FX appreciation following monetary policy tightening. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Tables

Table 1. Summary of monetary policy shock effects on prices and FX across different models

Model (IRF figure)	Price puzzle	FX puzzle	Comments
Baseline SVAR with Cholesky identification (Fig. 1A)	Yes, prices initially rise by 0.1% at 6 months	Yes, exchange rates depreciate for 6 months (0.7% upon impact)	Puzzles are not observed for the sample of advanced economies (Fig. 1B)
SVAR augmented with forward-looking variables (Fig. 3)	No, prices fall by 0.3% at its peak (near 18 months)	Nearly disappeared; exchange rates depreciate upon impact but appreciate by 0.6% after 6 months	
RR-proxy SVAR: External instruments using Romer-Romer approach (Fig. 4)	No, prices fall by 0.5% at its peak (near 2 years)	No, exchange rates appreciate by 1.2% after 6 months	
Local Projections: External instruments from Romer-Romer methods (Fig. 5)	Yes, prices increase in the early period	No, exchange rates appreciate by 1% at 6 months	Puzzles are greatly mitigated compared to using actual changes in policy rates
SVAR with a sign restrictions on FX (Fig. 6)	No, prices fall by 0.2% after 18 months	No (by construction)	
Factor-augmented VAR (Fig. A1)	Yes, prices increase for 2 years but statistically insignificant and small	Yes, exchange rates depreciate for 3 years with initially significant depreciations	
HFI-proxy SVAR: External instruments using Gertler-Karadi approach (Fig. A2)	Responses are insignificant; the puzzle is observed in half of the sample	Yes, exchange rates appreciate shortly upon impact	
Cholesky VAR with alternative ordering (Fig. A3)	Yes, responses are insignificant; prices increase in the early period	Responses are insignificant	
SVAR with sign restrictions on output and prices (Fig. A8)	No (by construction)	No, exchange rates appreciate by 2% after 18 months	Output and price responses are implausibly large
SVAR with a sign restriction on interest rates (Fig. A9)	Yes, prices rise by 0.1% at 6 months	Yes, exchange rates depreciate for 18 months with initially significant deprecations	

Table 2. Regression of monetary policy residuals on different type of expectations

	$E\pi_t$ (Inflation expectations)	Ey_t (GDP expectations)	EFX_t (FX expectations)
BRA	0.05** (0.02)	-0.003 (0.009)	-0.009 (0.02)
CHL	0.10*** (0.02)	-0.000 (0.006)	0.05 (0.07)
HUN	-0.003 (0.003)	-0.001 (0.003)	
IDN	0.004 (0.007)	0.009 (0.018)	
IND	-0.02 (0.01)	0.004 (0.005)	
MEX	0.12*** (0.01)	0.01 (0.79)	-0.005* (0.003)
PER	0.03*** (0.003)	0.005*** (0.001)	0.02** (0.007)
PHL	0.02** (0.005)	-0.001 (0.005)	
POL	-0.006 (0.004)	0.00 (0.08)	0.002** (0.001)
ROU	0.01*** (0.002)	0.001 (0.005)	
RUS	0.03*** (0.003)	0.002 (0.003)	0.17** (0.07)
THA	0.02*** (0.006)		
TUR	0.05*** (0.003)	0.003 (0.008)	0.03* (0.02)
UKR	0.02*** (0.004)	-0.03*** (0.007)	

Note: This regression reports the coefficients of VAR residuals of monetary policy instruments on expectations for future output, inflation, and FX rates. *** ** * indicate statistically significant at the 1%, 5%, and 10%, respectively. The number in the parenthesis indicates robust standard errors.

Table 3. Regression of monetary policy residuals on decomposed inflation expectations

Terms	$E\pi_{t-1} - \pi^*$	$E\pi_t - E\pi_{t-1}$
countries	Deviation of inflation expectations from inflation level (LEVEL)	Time t surprise in inflation expectations (DIFFERENCE)
BRA	0.08*** (0.03)	0.24 (0.18)
CHL	0.15*** (0.04)	0.16 (0.10)
HUN	0.49*** (0.02)	0.24** (0.11)
IDN	-0.001 (0.007)	0.06*** (0.02)
IND	-0.005 (0.008)	0.04* (0.02)
MEX	-0.02 (0.04)	0.33 (0.32)
PER	0.09*** (0.02)	0.19*** (0.06)
PHL	0.003 (0.018)	-0.13 (0.09)
POL	-0.000 (0.001)	-0.002 (0.002)
ROU	0.02 (0.06)	0.38** (0.16)
RUS	0.003 (0.014)	0.52*** (0.16)
THA	0.020*** (0.006)	0.070** (0.032)
TUR	0.03 (0.02)	0.11 (0.10)
UKR	0.020* (0.011)	0.10 (0.06)

Note: *** ** * indicate statistically significant at the 1%, 5%, and 10%, respectively. The number in the parenthesis indicates robust standard errors.

SUPPLEMENTARY APPENDIX

NOT FOR PULICATION

Resolving Puzzles of Monetary Policy Transmission in Emerging Markets

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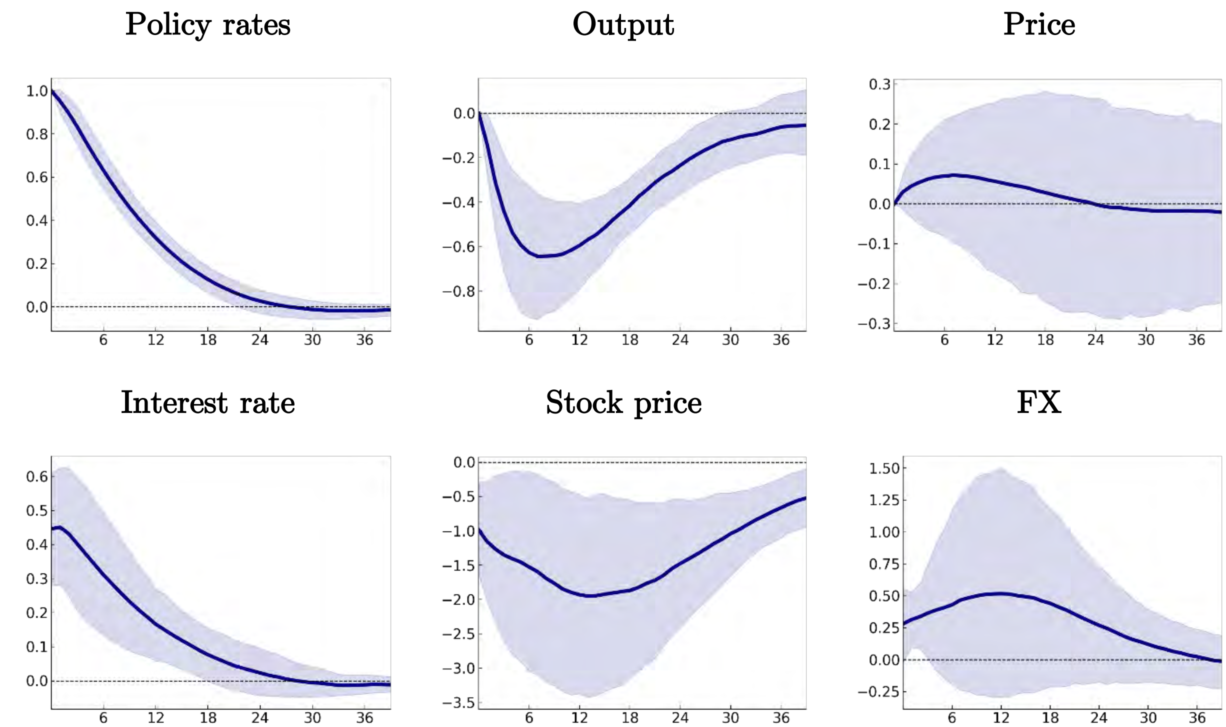
Appendix I. Additional Figures and Tables

Figure A1. Impulse responses to a monetary policy tightening

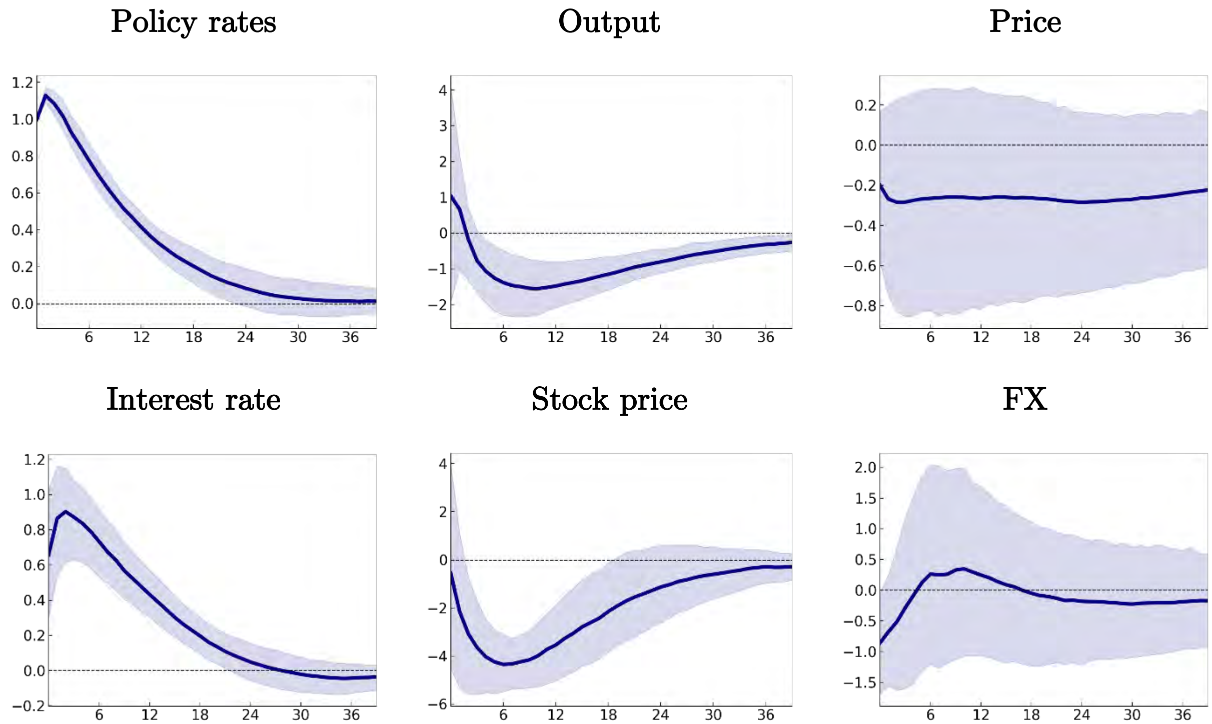
(FAVAR: Factor-augmented VAR model)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. The model includes global variables of output, prices, monetary policy, market interest rates, and stock prices. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A2. Impulse responses to a monetary policy tightening

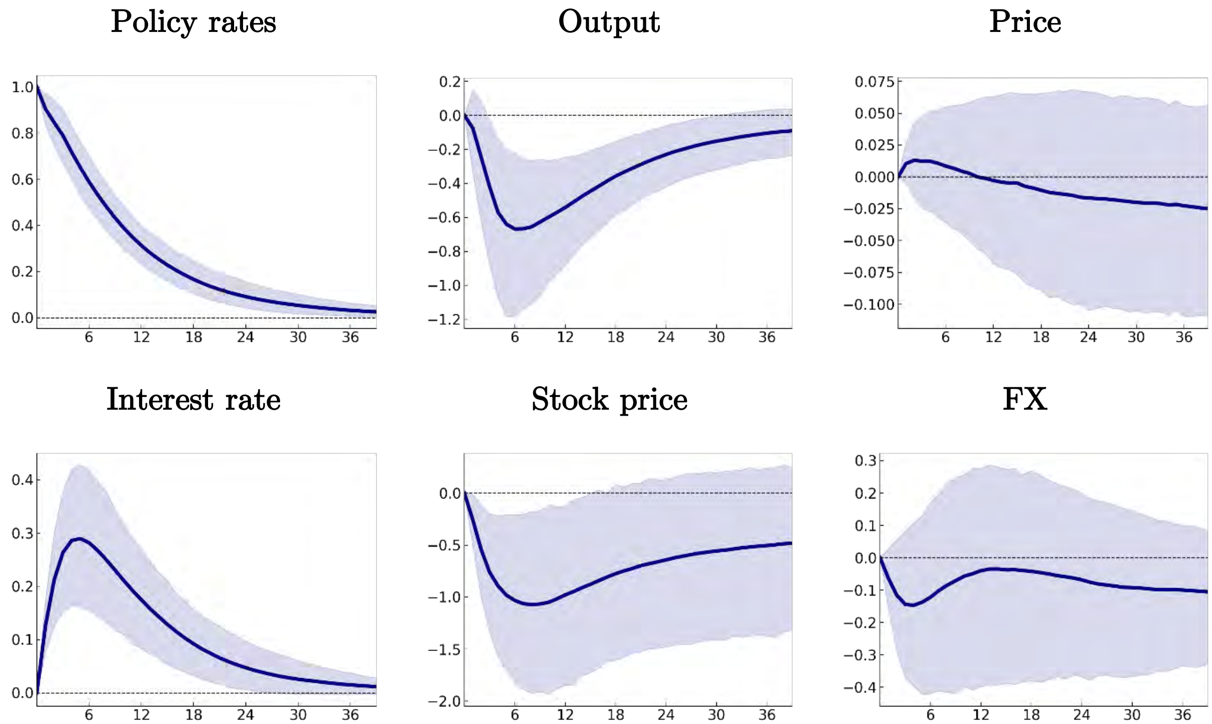
(Proxy SVAR: High frequency identification)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. Monetary policy shocks are identified using an external instrument (daily movements of overnight rates). The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A3. Impulse responses to a monetary policy tightening

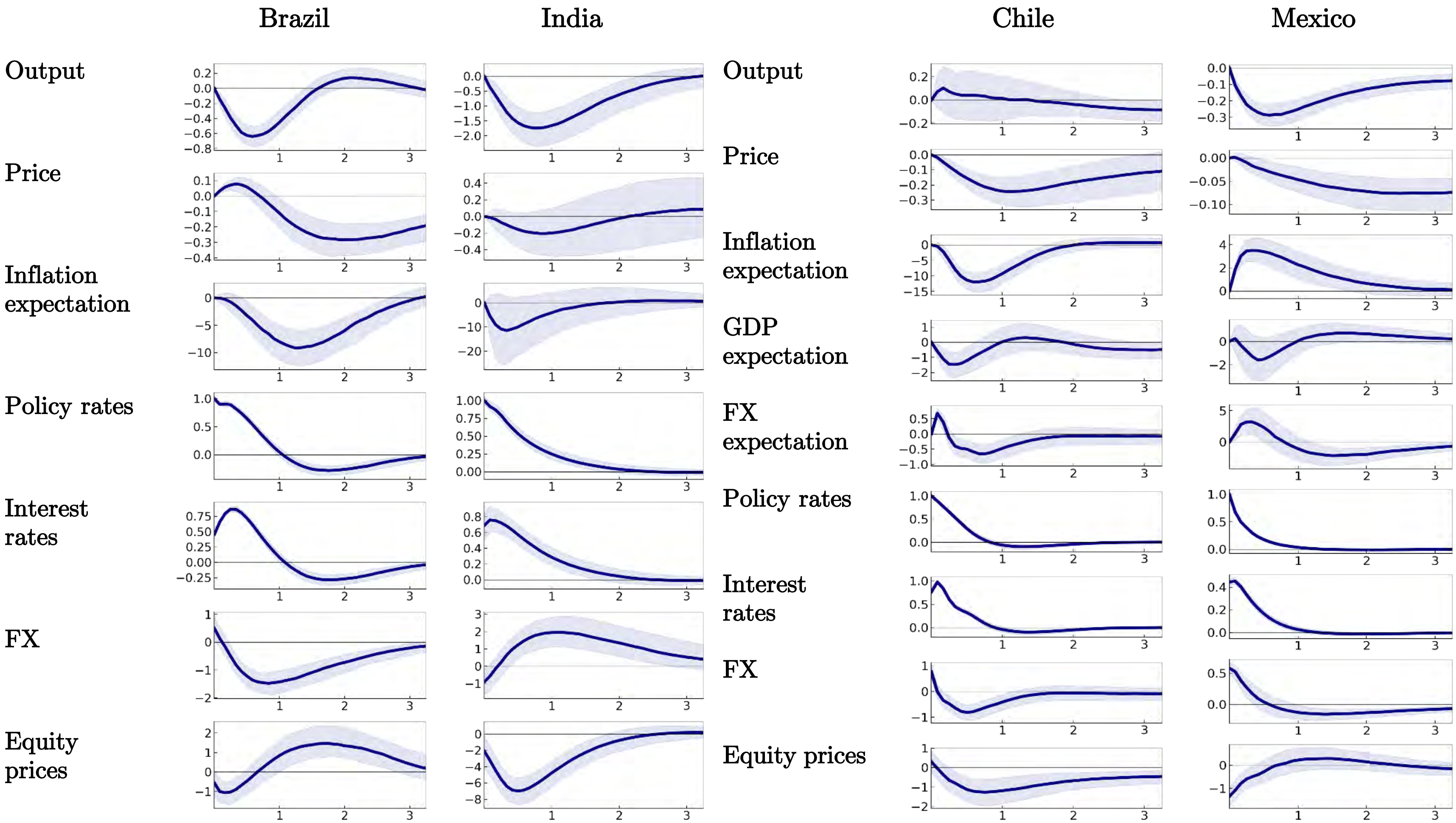
(Cholesky VAR with an alternative ordering)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. The variables are ordered as follows: output, price, short-term interest rates, exchange rates, stock prices, and monetary policy instruments. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A4. Impulse responses to a monetary policy tightening

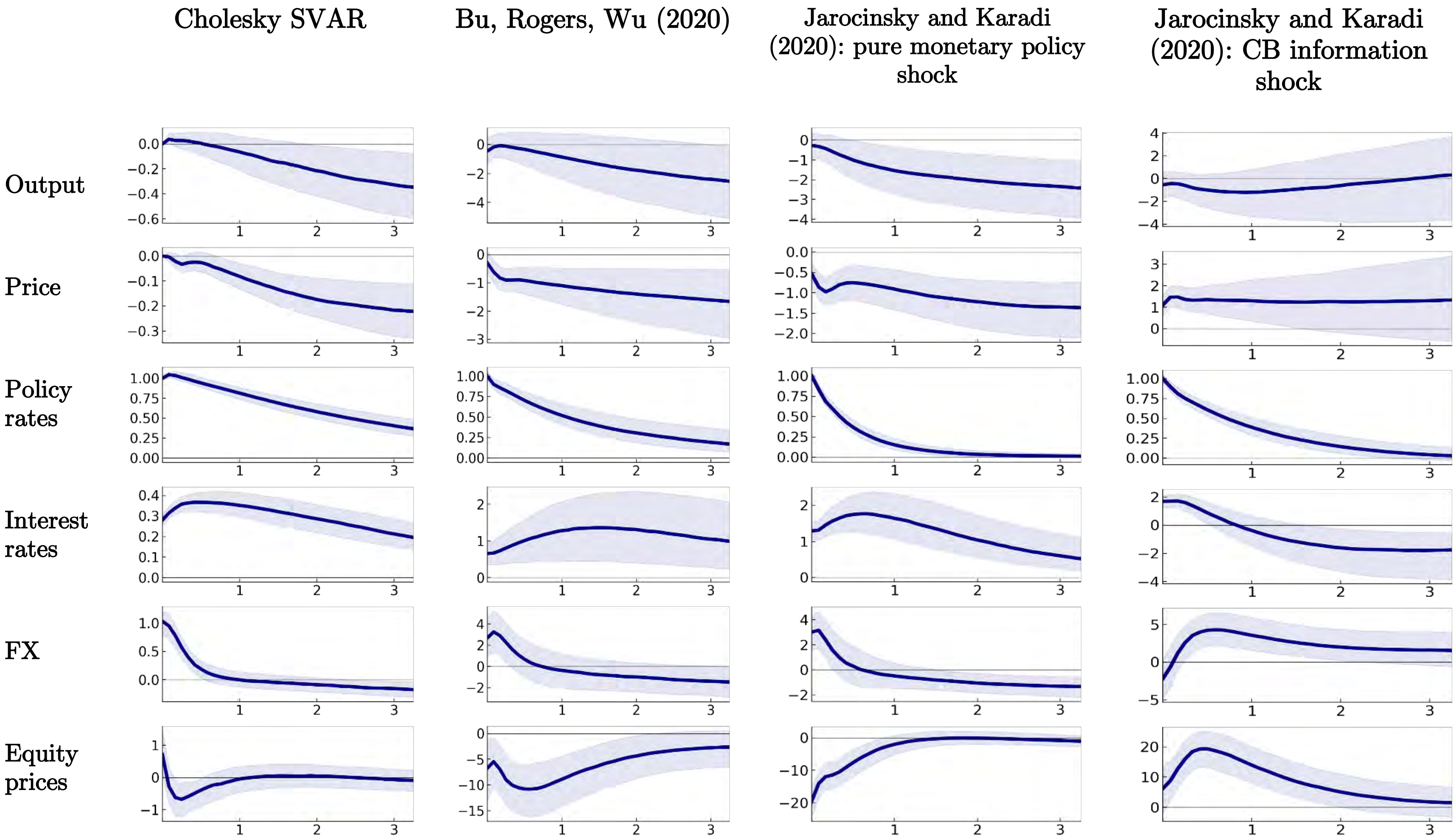
(SVAR-X model with expectations)



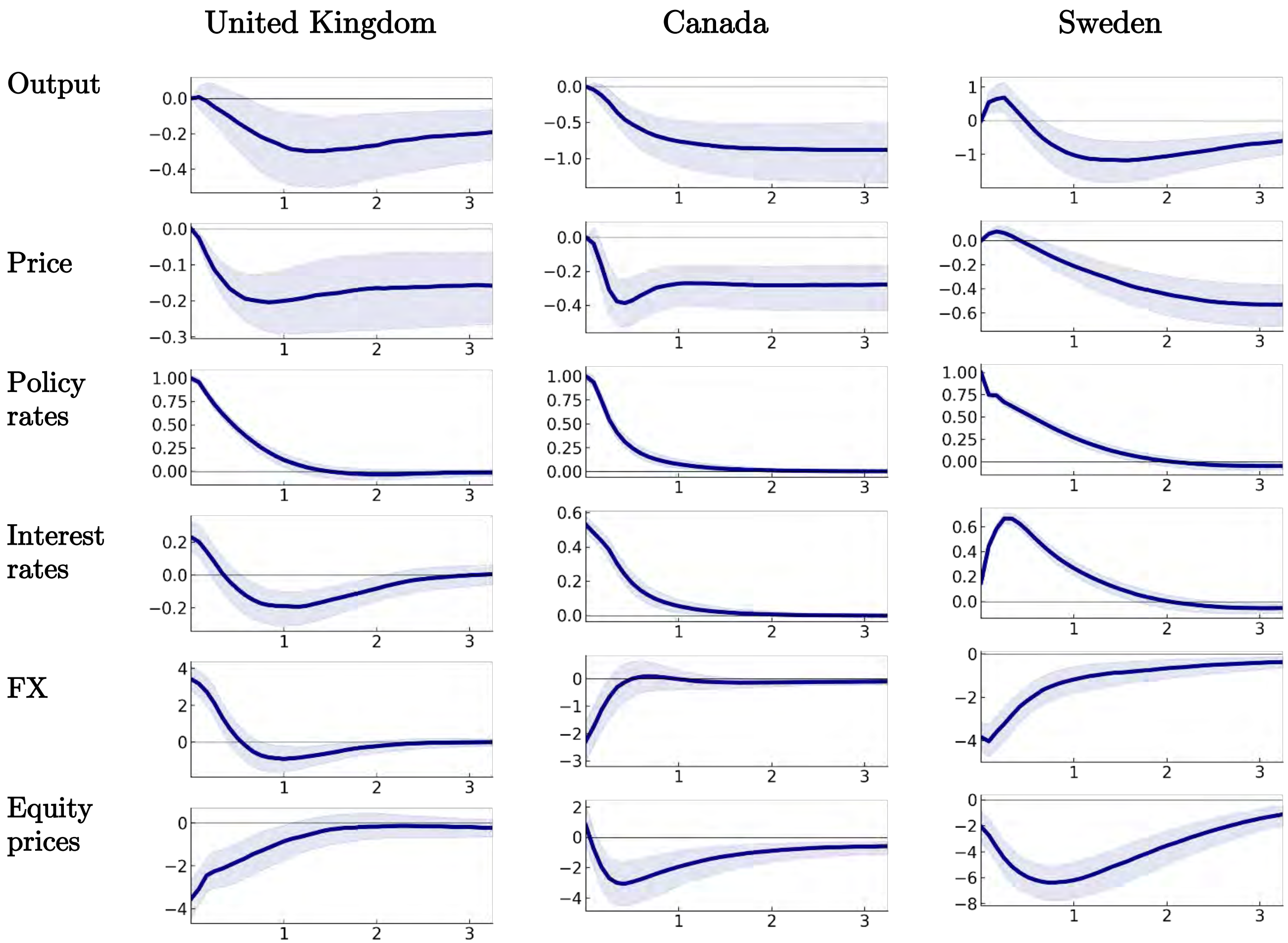
Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the median, and the shaded areas indicate the posterior bands using the 16th and 84th percentiles. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A5. Impulse responses to a monetary policy tightening: Cholesky VAR with expectations

A. United States

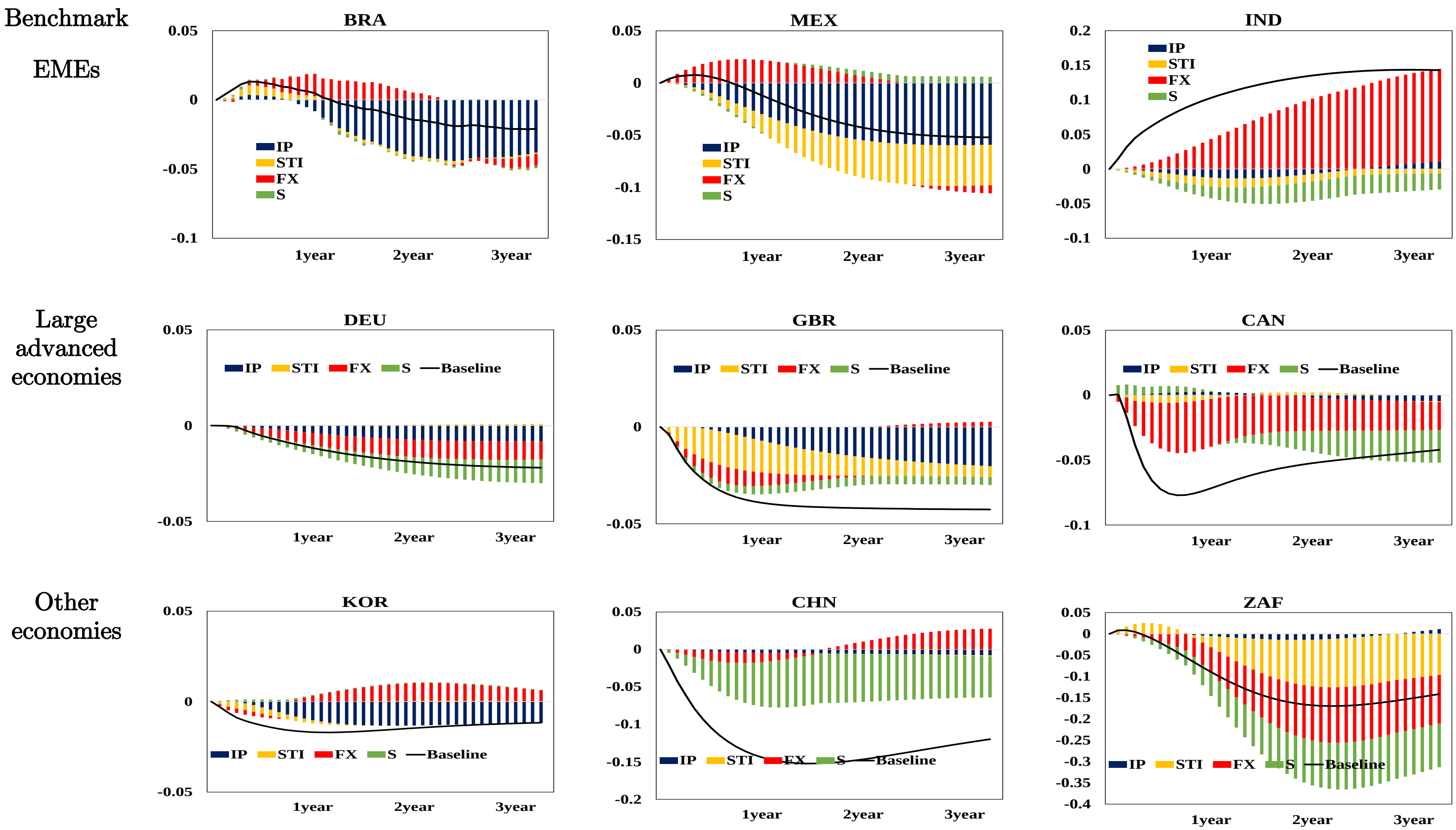


B. Other advanced economies



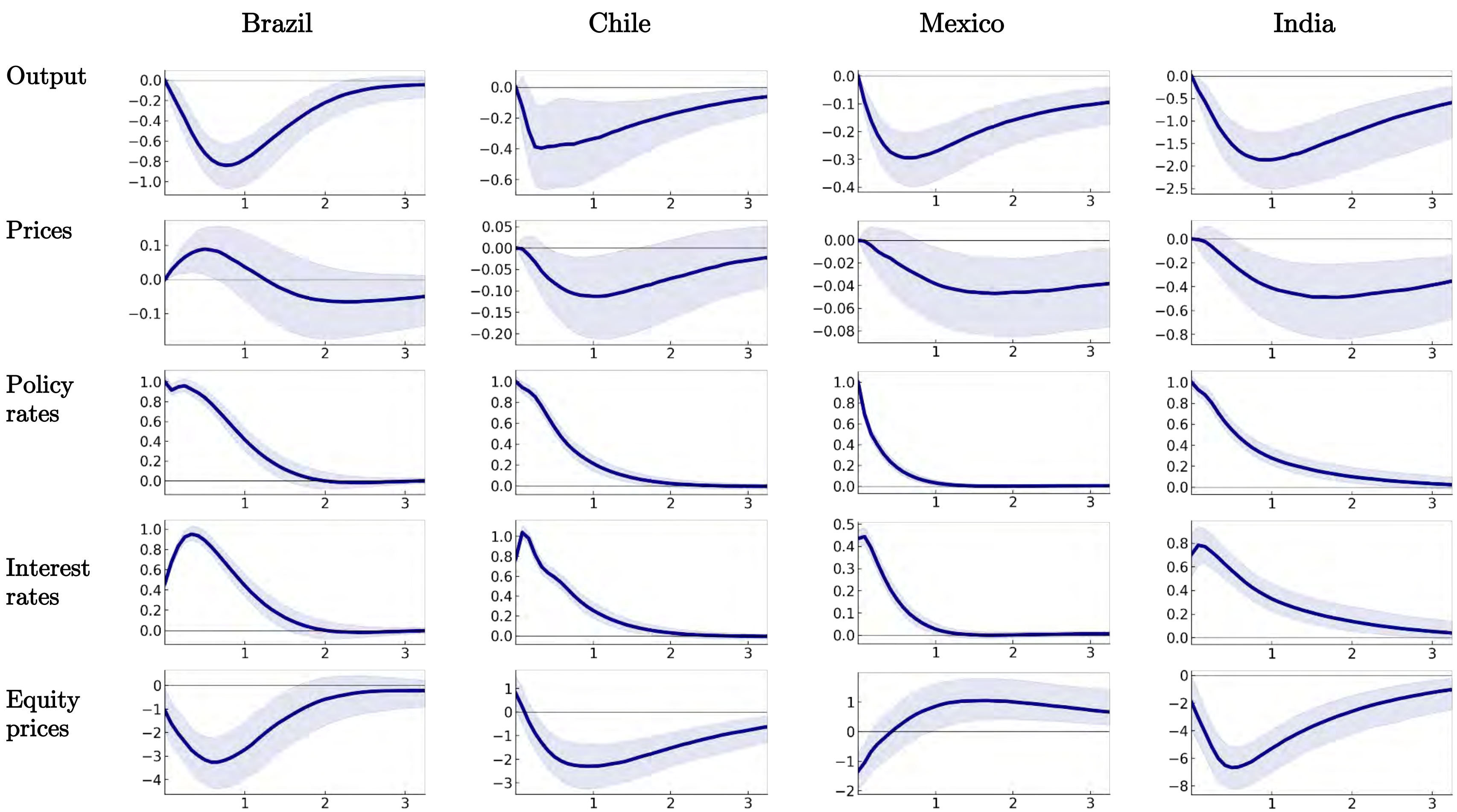
Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the median, and the shaded areas indicate the posterior bands using the 16th and 84th percentiles. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A6. VAR dynamic accounting: contribution to the IRFs of prices



Note: Contributions of variables to Impulse response functions of prices following a one-standard-deviation monetary policy shock. The Y-axis indicates the percentage point, and the X-axis indicates years.

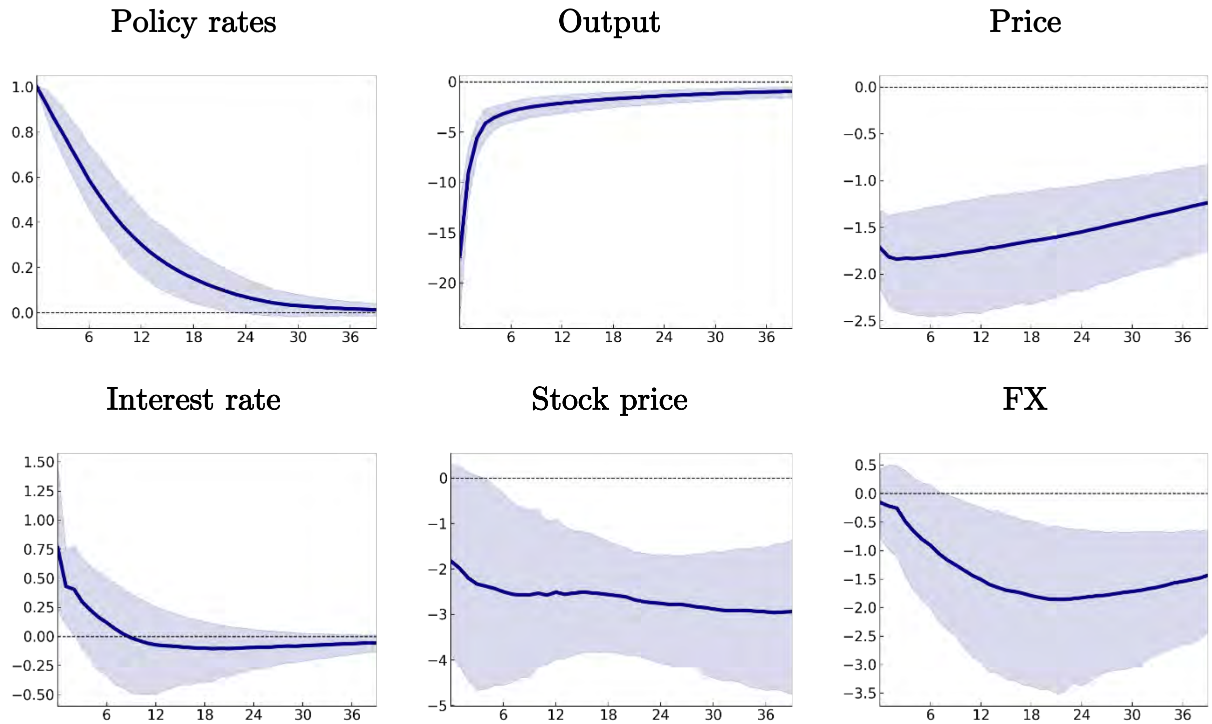
Figure A7. Impulse responses to a monetary policy tightening: SVAR-X with FX as a control variable



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the median, and the shaded areas indicate the posterior bands using the 16th and 84th percentiles. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A8. Impulse responses to a monetary policy tightening

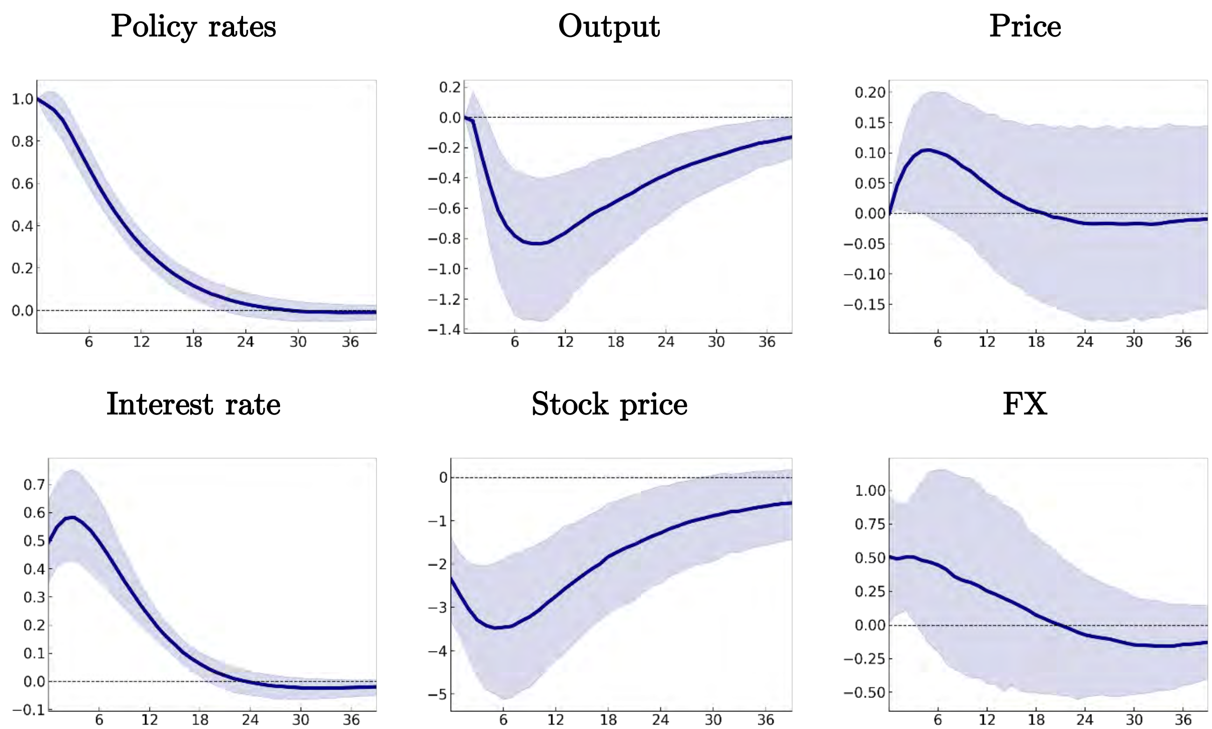
(SVAR with sign restrictions on output and price)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. Monetary policy shocks are identified using a combination of zero and sign restrictions, which assume a negative response of output and prices following a monetary policy tightening. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A9. Impulse responses to a monetary policy tightening

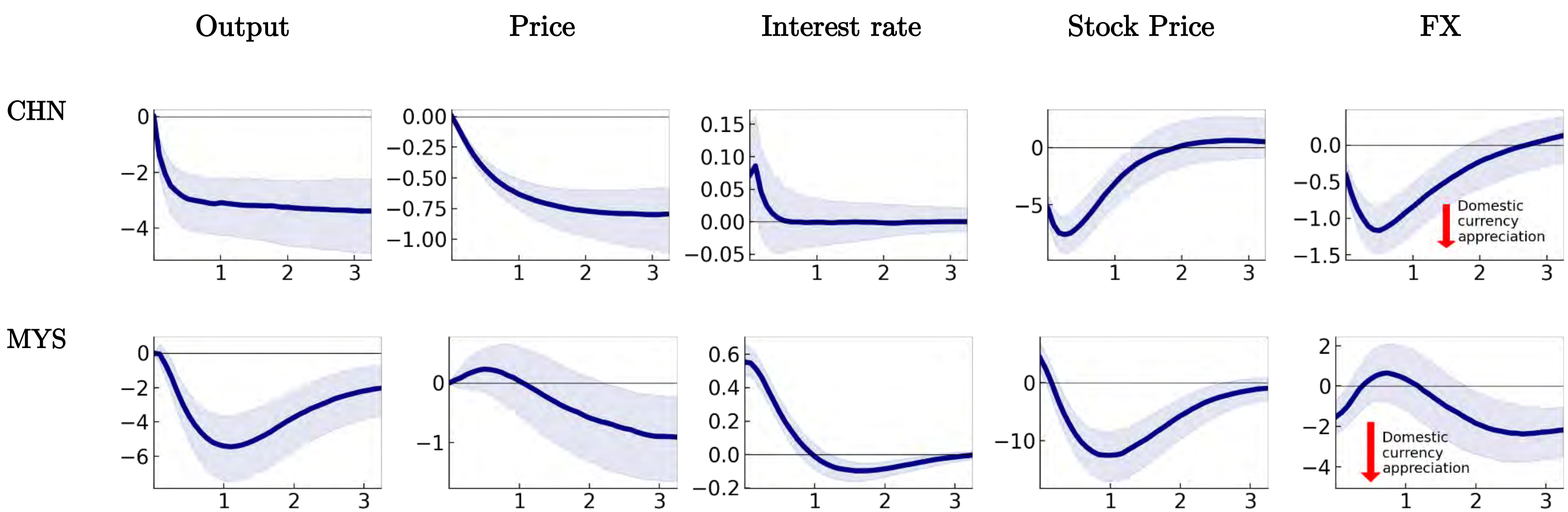
(SVAR with a sign restriction on interest rates)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the mean group estimate, and the shaded areas indicate the 90% bootstrap confidence intervals. Monetary policy shocks are identified using a combination of zero and sign restrictions, which assume a positive response of interest rates following a monetary policy tightening. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

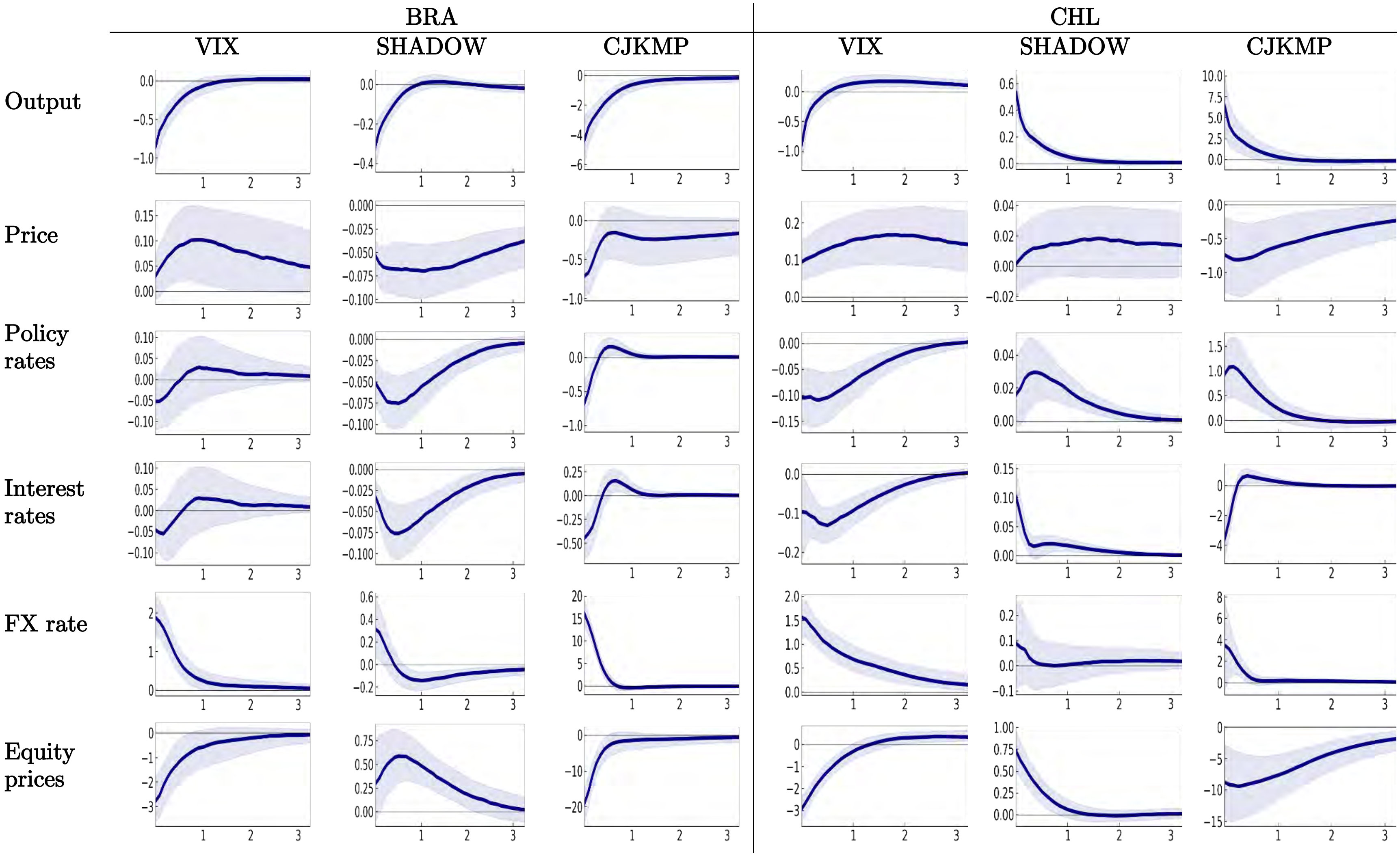
Figure A10. Impulse response following monetary policy shocks: EMEs with managed exchange rate regimes

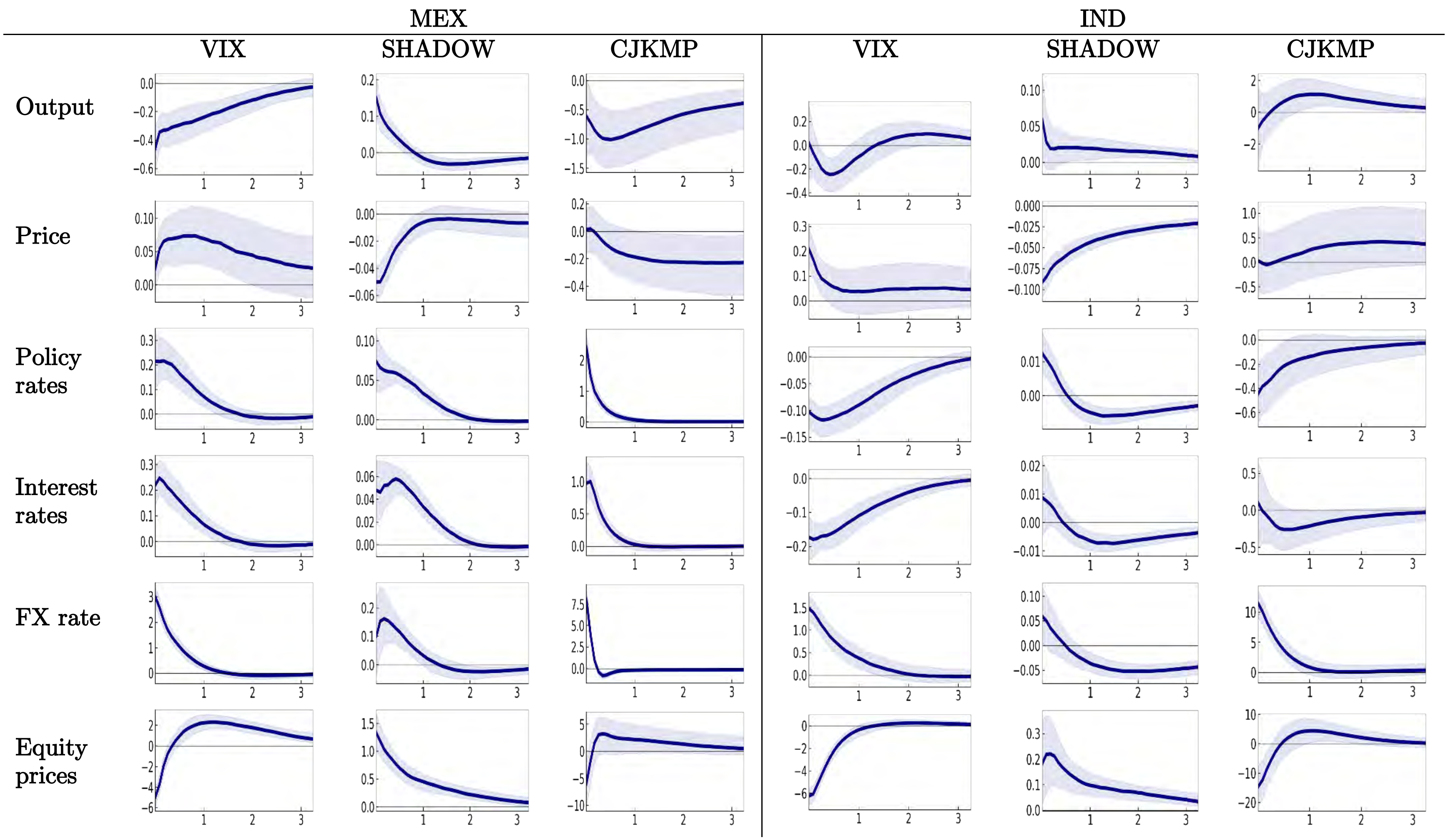
(Baseline SVAR model with conventional control variables)



Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the median, and the shaded areas indicate the posterior bands using the 16th and 84th percentiles. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Figure A11. Transmission of U.S. uncertainty and monetary policy shocks





Note: Impulse responses to a 1 percentage point contractionary monetary policy shock. The solid line represents the median, and the shaded areas indicate the posterior bands using the 16th and 84th percentiles. The Y-axis indicates percentages or percentage points, and the X-axis indicates months.

Table A1. Summary statistics of VAR variables

BRA	Var	Obs.	Mean	S.D.	CHL	Var	Obs.	Mean	S.D.	MEX	Var	Obs.	Mean	S.D.
	IP	216	4.67	0.08		IP	240	4.49	0.12		IP	240	4.57	0.06
	CPI	216	4.33	0.30		CPI	240	4.34	0.19		CPI	240	4.26	0.24
	MP	216	12.64	4.71		MP	240	3.79	1.62		MP	240	6.79	3.27
	R1D	216	12.58	4.70		R1D	240	4.13	2.27		R1D	240	7.07	3.31
	FX	216	0.92	0.28		FX	240	6.36	0.14		FX	240	2.55	0.24
	S	216	10.71	0.58		S	240	9.50	0.57		S	240	10.60	0.64
IND	IP	192	4.57	0.24	HUN	IP	240	4.43	0.20	IDN	IP	228	4.65	0.21
	CPI	192	4.53	0.33		CPI	240	6.90	0.23		CPI	228	4.17	0.35
	MP	192	6.77	1.04		MP	240	6.01	3.67		MP	228	8.21	3.24
	R1D	192	6.69	1.55		R1D	240	5.95	3.84		R3M	228	8.63	3.23
	FX	192	3.98	0.19		FX	240	5.45	0.17		FX	228	9.26	0.18
	S	192	8.59	0.53		S	240	9.80	0.52		S	228	7.72	0.92
PHL	IP	180	4.24	0.22	POL	IP	216	4.36	0.31	RUS	IP	180	4.52	0.12
	CPI	180	4.41	0.15		CPI	216	5.04	0.11		CPI	180	4.31	0.35
	MP	180	4.60	1.41		MP	216	3.79	1.95		MP	180	9.58	2.16
	R1D	180	4.52	3.25		R1D	216	5.37	3.60		R1D	180	6.50	3.17
	FX	180	3.85	0.09		FX	216	1.21	0.15		FX	180	3.64	0.37
	S	180	8.43	0.50		S	216	7.69	0.27		S	180	7.33	0.35
ROU	IP	204	4.43	0.21	TUR	IP	240	4.27	0.34	PER	IP	228	4.39	0.18
	CPI	204	4.57	0.21		CPI	240	5.07	0.61		CPI	228	4.43	0.13
	MP	204	7.15	5.48		MP	240	25.83	17.48		MP	228	3.67	1.09
	R1D	204	5.15	3.58		R1D	240	20.47	31.77		R1D	228	3.93	1.80
	FX	204	1.20	0.17		FX	240	0.61	0.51		FX	228	7.02	0.09
	S	204	8.64	0.43		S	240	6.03	0.77		S	228	10.11	0.71
UKR	IP	216	4.74	0.14	THA	IP	240	4.41	0.26	USA	GDP	240	9.66	0.11
	CPI	216	4.60	0.63		CPI	240	4.45	0.14		CPI	240	5.37	0.12
	MP	216	11.35	5.01		MP	240	2.20	0.97		MP	240	1.04	2.61
	R1D	216	5.37	3.60		R3M	240	2.54	0.96		R3M	240	1.67	1.83
	FX	216	2.25	0.65		FX	240	3.57	0.12		FX	240	4.70	0.09
	S	216	5.80	0.80		S	240	6.74	0.56		S	240	9.49	0.34
DEU	IP	240	4.53	0.09	GBP	GDP	240	4.44	0.09	JPN	IP	240	4.63	0.07
	CPI	240	4.47	0.08		CPI	240	4.49	0.13		CPI	240	4.57	0.02
	R1Y	230	1.66	1.86		MP	240	2.62	2.22		MP	240	1.49	0.13
	R10Y	235	2.71	1.73		R1Y	240	6.95	1.50		R10Y	240	0.96	0.62
	FX	240	0.18	0.14		FX	240	0.45	0.13		FX	240	4.66	0.13
	S	240	8.84	0.40		S	240	8.66	0.18		S	240	9.52	0.31
CAN	GDP	240	14.31	0.11	SWE	IP	240	4.67	0.07	KOR	IP	240	4.37	0.19
	CPI	240	4.75	0.10		CPI	240	5.70	0.07		CPI	240	4.42	0.15
	MP	240	1.81	1.70		MP	236	1.64	1.66		MP	240	3.06	1.27
	R3M	240	1.97	1.48		R3M	240	1.57	1.72		R10Y	240	4.35	1.76
	FX	240	0.20	0.15		FX	240	2.06	0.15		FX	240	7.02	0.09
	S	240	9.36	0.26		S	240	5.81	0.38		S	240	10.05	0.75
CHN	IP	240	5.11	0.67	MYS	IP	240	4.44	0.19	ZAF	IP	216	4.58	0.05
	CPI	240	4.35	0.15		CPI	240	4.59	0.14		CPI	216	4.07	0.27
	MP	239	3.11	0.32		MP	240	3.05	0.37		MP	216	7.59	2.30
	R1D	240	2.27	0.71		R1Y	240	3.03	0.39		R1Y	216	7.49	1.84
	NEER	240	4.63	0.11		NEER	240	4.56	0.07		FX	216	2.22	0.29
	S	240	7.74	0.36		S	240	7.10	0.36		S	216	10.26	0.61

Note: IP (GDP) represents the log of seasonally adjusted industrial production (monthly GDP). CPI is the log of the seasonally adjusted consumer price index. MP refers to domestic policy interest rates (in percent). R represents interest rates (1D: overnight, 3M: 3-month, 1Y: 1-year, and 10Y: 10-year government bond yields, respectively) (in percent). FX is the log of the nominal foreign exchange rate against one unit of the US dollar. NEER is the nominal effective exchange rate, and S is the log of the domestic stock price index.

Table A2. Survey data

Country	Market surveys and descriptions	Data sources
BRA	Expectations for output, inflation, interest rates, and FX rates, based on *Focus Market Readout* forecasts of about 160 banks, asset managers, and other institutions	Central Banco Brazil
CHL	Expectations for inflation and interest rates based on monthly surveys of academics, consultants, and executives or advisors of financial institutions and corporations.	Central Bank of Chile
HUN	Professional forecasts on future inflation, output, FX rates	Consensus Economics
IND	Professional forecasts on future inflation, output	Consensus Economics
IDN	Professional forecasts on future inflation, output, FX rates	Consensus Economics
MEX	Expectations for output, inflation, interest rates, and FX rates based on monthly surveys of private-sector economists	Bank of Mexico
PER	Median expectations for output, inflation, interest rates, and FX rates, based monthly survey of macroeconomic expectations	Central Reserve Bank of Peru
PHL	Consumer expectations surveys on future inflation and output growth	Central Bank of Philippines
POL	Consumer expectations for future Inflation and output growth	National Central Bank of Poland, Central Statistical Office
ROM	Professional forecasts on future inflation and output	Consensus Economics
UKR	Professional forecasts on future inflation, output, FX rates	Consensus Economics
RUS	Monthly inflation expectations for the next year	Central Bank of the Russian Federation
TUR	Monthly survey of expectations for future output, inflation, interest rates, and FX rates,	Central Reserve Bank of Turkey
THA	Professional forecasts on future inflation and output	Consensus Economics
ZAF	Bureau of Economic Research Inflation expectations for current and next years South African Chamber of Commerce and Industry Business Confidence Index	Bureau of Economic Research, South African Chamber of Commerce and Industry
KOR	Monthly consumer survey index of inflation expectations	Bank of Korea
SWE	Monthly consumer trend survey of the general economic situation and inflation	National Institute of Economic Research

Table A3. Literature on the price puzzle

Rationales for the puzzle	Empirical solutions	Main references
1. Omitted variables—commodity prices, output gap, global variables	Control for commodity prices or output gaps in the VAR; A factor-augmented VAR (FAVAR)	Sims (1992); Giordani (2004); Bernanke et al. (2005)
2. Misspecification	Alternative identification of MP shocks Sign-restricted VAR	Canova and De Nicolo (2002); Uhlig (2005)
3. Monetary policy regime—weak interest rate response to inflation	Sub-sample analysis; Impose the long rurestrictions in the cointegrated structural VAR	Borys et al. (2009); Kim and Lim (2018)
4. Central banks setting monetary policy in a forward-looking way, using information beyond that contained in the VAR	Include inflation and GDP forecasts	Romer and Romer (2004); Champagne and Sekkel (2020)
5. Cost-pushing-including firms costs and exchange rates (depreciation)	Including the variables for cost-pushing channels; Sign-restricted VAR	Castelnuovo (2012); Henzel et al. (2009); Grilli and Roubini (1996)

Appendix II. Literature review: Sources of price puzzle

The literature offers diverse perspectives on the positive relationship between monetary policy rates and prices observed in the empirical model. Here, we summarize them into four categories: i) misspecification, ii) cost-pushing channel, iii) exchange rate depreciation, and iv) indeterminacy, as is also summarized in Table A3.

AII.1. Misspecification: omitted variables

A significant body of research claims that the forward-looking component of monetary policy shocks might have been misidentified, and incorporating variables that are expected to help forecast future inflation into the model can resolve the puzzle. This perspective posits that central bank policymakers consider additional variables beyond those typically included in academic studies, which aids in predicting inflation.

Comparing the theoretical models (1)-(3) outlined in Section II with standard monetary VAR models reveals two distinct endogenous variables that are often overlooked by the VAR framework: inflation expectations and output gap expectations. In empirical VAR models, it is commonly assumed that variables such as lagged output and prices, as well as other financial indicators including interest rates (bond yields), stock prices, and foreign exchange rates—reflecting future economic and financial developments—serve as proxies for inflation and output expectations.

However, if the central bank considers a broader information set than what is represented in VAR models, particularly inflation expectations, policy shocks encompass both a genuine policy shock and some endogenous policy reactions to future expectations. Consequently, the econometrician might misinterpret a policy tightening in anticipation of future inflation as a policy shock. Furthermore, if monetary policy only partially offsets inflationary pressures, the VAR may capture a spurious correlation between policy tightening and a rise in inflation, known as the price puzzle. In this context, including a commodity price index in the model has been proposed as a conventional solution to address this issue since Sims (1992), expecting that commodity prices to be useful for inflation forecasting.

However, other scholars argue against the effectiveness of including a commodity price index in resolving the price puzzle, proposing alternative approaches. For instance, Giordani (2004) emphasizes the importance of incorporating the output gap to address the puzzle, suggesting that commodity prices may mitigate the puzzle only because they are correlated with the U.S. business cycle. Hanson (2004) attributes the price puzzle to changes in monetary policy rules during the periods covered by estimated VAR models.[37] Dias and Duarte (2022) propose that the price puzzle may stem from the shelter share in the consumer price index in the case of the United States (approximately 30 percent), arguing that a contractionary policy shock can reduce house prices but increase rents.[38] Cochrane (2016), reviewing various monetary models and empirical studies indicating the price puzzle, discusses the possibility of positive inflation responses to interest rate hikes under certain conditions, particularly in the context of the zero lower bound on nominal interest rates in some developed economies after the 2007-08 financial crisis.

[37] They find that the price puzzle disappears if periods with different monetary policy rules are removed in their analyses.

[38] They find that the price puzzle diminishes significantly if inflation measures excluding the shelter component are used in their estimated models.

While VAR models extended to include more variables in an attempt to capture the information set of policymakers, they are often constrained to around ten variables due to challenges in estimation. Due to this limitation, the model may still capture only a fraction of the information available to policymakers. Factor-augmented VARs (FAVARs) offer a solution to this constraint by combining factor analysis with VAR models. In a FAVAR framework, a small number of factors summarizes information extracted from a large number of time series (Bernanke et al. 2005). Despite these efforts, there is yet no conclusive answer to what can truly give rise to the price puzzle in a cross-country perspective.[39] In some cases, the variables that forecast inflation do not always resolve the puzzle. Alternatively, inflation expectations are also used as an explanatory factor, claiming that it is when expected inflation is omitted from the VAR that accounts for the puzzling response of the price to a monetary policy shock. [40]

AII.2. Cost-pushing channel of monetary policy transmission

Another strand of the literature contends that the price puzzle does not stem from methodological issues in empirical models but from a theoretical basis—supply-driven or cost-pushing channel—underlying the empirical puzzle (Blinder 1987; Fuerst 1992; Christiano and Eichenbaum 1992; Barth and Ramey 2002; Ravenna and Walsh 2006; Chowdhury et al. 2006; Kapinos 2011). According to this perspective, prices tend to increase following a monetary policy tightening because higher interest rates lead to higher production costs, reflected in higher inflation rates. These studies suggest that the cost channel in the transmission of monetary policy was more pronounced during the 1960s and 1970s, but declined during the subsequent decades in the U.S. economy.

Specifically, the cost channel of monetary policy transmission is integrated into a theoretical framework by incorporating interest rates into a firm's marginal cost function. Within this framework, monetary policy can directly influence the firm's marginal cost, thereby generating supply-side effects of monetary policy. For example, a monetary tightening raises firms' borrowing costs, thus contributing to an increase in marginal costs. This rise in marginal costs leads to higher prices by constraining supply in the short run. However, over time, prices may decrease as aggregate demand also declines due to higher interest rates. Compared with the econometric framework summarized in Section II, this introduces an additional connection between monetary policy changes and aggregate inflation dynamics. If the inflationary effect triggered by monetary policy adjustments through the supply channel outweighs that operating through the standard "demand channel," a positive inflation response to monetary policy tightening can occur.

AII.3. Exchange rate pass-through

Another way in which monetary policy affects inflation, closely related to the cost-push channel of monetary policy transmission, is via exchange rates. This is regarded as a particularly critical transmission channel in EMEs. In theory, when there is an increase in interest rates, investment in domestic currency-denominated bonds becomes more attractive, leading to an increase in capital inflows. Under a flexible exchange rate regime, this results in an exchange rate appreciation, which then leads to an eventual reduction in overall prices.

[39] Ramey (2016) offers an extensive review of studies investigating the effects of monetary policy on prices, highlighting the persistence of the price puzzle in some specifications over the years.

[40] Castelnuovo and Surico (2010) highlight the role of inflation expectations. In their study, they conduct a battery of four-variable VAR models for the United States, incorporating a linear combination of expected inflation and expected output gap as an additional regressor. Their findings indicate that the combination most effective in mitigating the price puzzle assigns a weight of one to expected inflation and a weight of zero to the expected output gap.

Many earlier studies, however, point out that the conditional movements of foreign exchange rates exhibit puzzling deviations from the theoretical predictions (Clarida et al. 2001; Eichenbaum and Evans 1995; Scholl and Uhlig 2008; among others). For instance, with a positive domestic monetary shock, the currency either depreciates, exhibiting the so-called foreign exchange rate puzzle, or appreciates only gradually over prolonged periods, a phenomenon known as delayed overshooting.[41]

The evidence of the FX puzzle persists in more recent literature. While there is mixed evidence concerning advanced economies, the puzzle is more prevalent in the case of EMEs (Obstfeld et al. 2019; Kohlscheen 2014; Kim and Lim 2018). Based on a meta-analysis, Hnatkovska et al. (2012; 2016) summarize that the exchange rate depreciates due to positive shocks to the interest rate differential in 37 out of 49 developing countries.

In a study of Brazil, Mexico, and Chile, Kohlscheen (2014) finds that even when focusing on 1-day exchange rate changes following policy events—which reduces the potential for reverse causality considerably—there is no support for the view that associates unexpected interest rate hikes with immediate appreciations. Brandao-Marques et al. (2020) similarly find that the effects on prices of a contractionary monetary policy shock are more muted and only significant when accounting for the exchange-rate channel. The authors argue that the behavior of the exchange rate could be a main reason behind countries' heterogeneous responses to monetary policy shocks (e.g., also shown in Ehrmann et al. 2011; Kim and Roubini 2000), potentially accounting for the price puzzle. The transmission of a monetary policy shock to output and prices is statistically different from estimates obtained when excluding the amplification mechanism through exchange rates.

Existing studies attribute the exchange rate puzzle in EMEs to various underlying factors—including concerns over debt financing, habit persistence of exchange rates, disconnection between bond and currency markets, and the response of liquidity problems following monetary policy shocks. The latter, often referred to as "UIP premium puzzle," has been considered one of the most compelling reasons for the disconnection between interest rates and exchange rates. Kohlscheen (2014) argues that it is difficult to attribute the exchange rate puzzle solely to fiscal dominance, as unexpected rate increases are not associated with increases in risk premia. Similar results are obtained in the case of Chile—a country with the highest possible short-term credit rating since 1995 and a debt/GDP ratio below 10%. Instead, De Leo et al. (2023) find, by examining quarterly data from the mid-1990s to 2019 across a large set of EMEs, that monetary policies in EMEs tend to adopt Taylor-rule-like approaches but still exhibit a procyclical nature. They argue that one of the primary reasons for this phenomenon is the disconnect between policy rates and short-term market rates in EMEs.

Blanchard (2004) argues that if an increase in the real interest rate also raises the likelihood of default on debt, it may diminish the attractiveness of domestic government debt, resulting in a real depreciation. This scenario is more likely with higher initial debt levels, a larger proportion of foreign-currency-denominated debt, and heightened risk premiums. In such a context, inflation targeting can yield counterintuitive effects: a rise in the real interest driven by monetary policy responding to higher inflation leads to a real depreciation, subsequently exacerbating inflation. In

[41] In the case of EMEs, earlier studies based on event studies with *daily* data show that the currency response to monetary policy is low or nonexistent (Aktas et al. 2005; Duran et al. 2012; Pennings et al. 2015).

this scenario, fiscal policy, rather than monetary policy, becomes the appropriate instrument for curbing inflation.

Mojon and Peersman (2001) claim that the “exchange rate puzzle” may arise in monetary policy responses to foreign monetary policy, advocating for the inclusion of the foreign interest rate as a direct component of the vector of endogenous variables to capture the strong interconnection between domestic and foreign economies. According to this view, the domestic interest rate adjusts to changes in the foreign rate without directly impacting the exchange rate. Consequently, overlooking the foreign interest rate in the model can result in both price and exchange rate puzzles due to the failure to account for increases in the domestic interest rate in response to increases in the foreign rate.

AII.4. Indeterminacy: violation of the Taylor principle

There is a body of research suggesting that the prize puzzle arises due to indeterminacy in monetary policies, specifically the violation of the Taylor principle, in the context of the United States. Woodford (2003) demonstrates that the solution of the system of equations (1)-(3) outlined in Section II is influenced by the level of systematic policy activism adopted by monetary authorities. Notably, the uniqueness of the solution depends on whether the "Taylor principle" is met—in this case ($\emptyset > 1$). If the Taylor principle is satisfied, the dynamics of the economy rely solely on fundamentals, allowing the output, inflation, and interest rate equations to be written as a function of the structural shocks (ε_t). Conversely, under indeterminacy, the transmission of structural shocks is altered, leading to the augmentation of the system with a latent variable not present in the unique rational expectations equilibrium. Additionally, sunspot shocks may impact expectations and consequently affect the equilibrium of the economic system.

Lubik and Schorfheide (2004) similarly illustrate that the evolution of endogenous variables can be characterized as a combination of structural shocks and a sunspot shock affecting the variables of interest in passive monetary policy scenarios. This sunspot shock may influence inflation expectations, thereby impacting current inflation. Auray and Feve (2008) demonstrate that the price puzzle can arise due to indeterminacy in a model without sticky prices, where monetary policy follows a money supply rule. Castelnuovo and Surico (2010) argue that the price puzzle may result from a spurious correlation induced by the omission of a variable capturing the persistence of expected inflation in VAR models, particularly under a passive monetary policy regime where the nominal interest rate is adjusted less than proportionally in response to inflation movements. They find that the omitted variable problem quantitatively explains the puzzling inflation response to policy shocks observed in data.[42]

Outside the United States, Champagne and Sekkel (2018) employ narrative evidence alongside a unique database of real-time data and forecasts from the Bank of Canada s staff economic projections from 1974 to 2015. They show that failing to account for the shift in the conduct of monetary policy that occurred following the announcement of inflation targeting in 1991 resulted in a price puzzle in Canada.

[42] Clarida et al (1999) also show that his coefficient was less than 1 in the pre-1980 subsample, which is consistent with the results of Castelnuovo and Surico (2010).

AII.5. Price puzzles in EMEs and other small open economies

The prevalence of the price puzzle is widespread across many EMEs and small open advanced economies.

Previous studies on Brazil have shown that while monetary policy has the anticipated impact on economic activity, its effect on inflation is less conclusive, with many studies indicating the presence of a price puzzle to a certain degree (Costa Filho 2017). For example, Minella (2003) reports that a contractionary monetary policy shock does not induce a fall in the inflation rate in the short run. Similarly, Cysne (2004; 2005) find evidence of a small and temporary price puzzle lasting for one to three quarters. Luporini (2008) also find evidence of the price puzzle, suggesting that the inclusion of a commodity price index in the model did not solve the price puzzle for Brazil. On the other hand, Céspedes et al. (2008) argue that there is no evidence of the price puzzle because they observe that a contractionary monetary policy shock indeed reduces the price level, although it takes a long time to be effective and statistical significance is less pronounced. Carvalho and Rossi Júnior (2009) also argue against the existence of a price puzzle, but their confidence intervals for the price response to a monetary shock encompass zero.

For Chile, the presence of the price puzzle has been documented by Pedersen (2017) examining the period from 2002 to 2016. While the empirical results are not statistically significant over the full sample period, the study reveals that inflation increases in response to an unexpected monetary policy shock in the pre-crisis period. However, after the crisis, inflation decreases following a contractionary monetary policy shock.

Chowdhury et al. (2006) examine three economies (Chile, the Czech Republic, and India) and demonstrate that inflation rises for several months before falling in response to monetary tightening, suggesting the price puzzle. Héricourt (2005) argues that despite numerous proposed solutions, the price puzzle remains unresolved in the case of Czech Republic. The inclusion of a broad commodity price index has been insufficient to resolve the puzzle. Additionally, Giordani's (2004) proposition of simultaneous inclusion of output and output gap in the VAR to mimic IS and Philips curves has not resulted in any change in price behavior.

Javid and Munir (2010) attribute the currency depreciations as a source of price puzzle, citing cases where exchange rate depreciation follows monetary tightening. Creel and Levasseur (2005) rationalize this exchange rate puzzle in terms of market expectations regarding the sustainability of sovereign debt and the probability of default, particularly with high levels of government debt and deficits. Beckers (2020) finds evidence of the price puzzle in Australia data, even when controlling for the systemic response of the cash rate to the Reserve Bank's own inflation forecasts. This is attributed to an additional but omitted systematic response of the cash rate to credit market shocks, leading to a positive correlation between cash rate changes and future inflation.

Appendix III. Evidence on U.S. Monetary Policy Transmission

In this section, we focus on the effects of U.S. monetary policy shocks on the financial markets and macroeconomic variables in EMEs. Our empirical framework enables us to investigate the transmission of U.S. monetary policy shocks as U.S. monetary policy instruments and the VIX index are incorporated as control variables. We use shadow short-rate point estimates, constructed by Wu and Xia (2016), to address zero lower bounds (ZLB) and unconventional monetary policies implemented during the period after the global financial crisis. However, since these rates encompass both endogenous (anticipated) and exogenous (unanticipated) components of monetary policies, we also implement the analysis using the pure monetary policy surprises estimated by Jarocinsky and Karadi (2020). Additionally, we present the responses of the variables following an increase in VIX as a proxy for global financial uncertainty for the purpose of comparison. We then compare the responses of domestic variables to U.S. monetary policy shocks to those induced by domestic monetary policy shocks.[43]

Figure A11 presents the impulse responses of domestic macroeconomic and financial variables in EMEs to U.S. monetary policy rates ("SHADOW"), U.S. monetary policy surprises ("CJKMP"), and the VIX index ("VIX").

Foreign exchange rates. We first discuss the dynamics of foreign exchange rates per US dollar, a primary channel for international monetary spillovers. Initially, following a contractionary U.S. monetary policy shock, the domestic currencies of these economies experience immediate depreciation, followed by a gradual appreciation over several months. This pattern aligns with the predictions of the overshooting theory by Dornbusch (1976). Interestingly, there is no evidence supporting the delayed overshooting or foreign exchange rate puzzle proposed in previous studies, corroborating recent findings (Rogers et al. 2018; Bjørnland 2009).

Equity prices. Following a contractionary U.S. monetary policy shock, equity prices in the EMEs spontaneously decrease by 5–20 percent, and these impacts last for at least a few months. Notably, the response of EME equity prices differs depending on the nature of U.S. monetary policy shocks. In Chile, Mexico, and India, equity prices exhibit positive response following an increase in U.S. shadow interest rates. However, when tested with the pure monetary policy shocks, equity prices decline significantly in all EMEs. These contrasting results suggest that the positive response of equity prices following the shadow rate increase was mainly driven by the endogenous reactions of the Federal Reserve to future demand or supply shocks or central bank information shocks that led to a rise in U.S. monetary policy instruments.

Interest rates. The short-term interest rates display similar reactions across the EMEs. Initially, on impact, the yields respond positively to the shock, but these effects gradually diminish over approximately a year.[44] However, following pure monetary policy shocks, interest rates decline over time in most EMEs. This decline may reflect the reductions in aggregate demand due to U.S. monetary tightening or alternatively, the subsequent response of monetary policies in EMEs as reflected in the responses of policy rates in these economies.

[43] When U.S. monetary policy rates are included as an endogenous variable, the empirical results do not differ much.

[44] These estimates are comparable to findings of studies on advanced economies. For example, Bluedorn and Bowdler (2011) utilized US monetary policy shocks sourced from Romer and Romer (2004) and showed that the short-term interest rates in Canada and the UK respond by up to 0.5–1.0 percentage point following a one percentage point increase in the Federal Funds Rate.

Policy rates. Policy rates in these open economies show significant responses to US monetary policy shocks, with variations in magnitude and persistence across countries, even when the SVAR system explicitly controls for the impact of local monetary policy shocks. The results may reflect high business-cycle correlations between the countries and the United States. Alternatively, it is possible that central banks in these economies align their policy actions with US monetary actions to mitigate the impact of a dramatic change in exchange rates or other financial asset prices that affect cross-border monetary transmission. One extreme interpretation of this synchronization of policy actions could involve monetary policy coordination between the United States and other open economies, where the shock reflects the policy stance of the country it passes through as monetary transmission from the United States occurs.

Macroeconomic variables. The effects of U.S. monetary tightening on macroeconomic variables (output and inflation) in EMEs could be either contractionary or expansionary. If the negative impacts of U.S. monetary shocks on financial conditions and domestic demands (financial channel and aggregate demand channel) outweigh the positive impacts on net exports through exchange rate depreciation (trade channel), then output and price levels in the economies would decline after U.S. monetary policy tightening (Iacoviello and Navarro 2019). On the other hand, if the trade channel is more effectively than the financial and aggregate demand channels, the macroeconomic consequences of U.S. monetary tightening would be expansionary, consistent with empirical results in Rey (2016) and Miranda-Agrippino and Rey (2020) (for the global economy), and the predictions by Jones et al. (2021), where industrial production and price levels in open economies significantly increased following contractionary U.S. monetary policy shocks. We observe that following an increase in shadow rates, both output and price levels in Brazil unambiguously decline, whereas output in other EMEs shows mixed results. On the other hand, in response to an increase in pure monetary policy surprises, output declines in all EMEs except for Chile, where the response was insignificant.[45]

Comparison with domestic monetary policy transmission. Since the models estimate simultaneously the impulse responses of domestic variables to both local and U.S. monetary policy shocks, we can compare those responses. We observe that U.S. monetary policy shocks appear to exert a stronger and more persistent influence on each asset class in EMEs. In the case of foreign exchange rates, while the variables show puzzling movements of appreciation following domestic monetary tightening, they did not exhibit such puzzles U.S. monetary policy shocks. Concerning equity prices, the influence of U.S. shocks seems quite dominant, displaying much greater impacts than those of domestic monetary shocks. Despite the reactions in foreign exchange rates, U.S. monetary shocks propagate strongly to domestic financial markets in other countries, possibly reflecting correlated term and risk premiums across countries. In terms of interest rates, domestic monetary policies seem to have greater impacts than U.S. monetary shocks, partly reflecting the control of central banks over domestic policy or short-term interest rates as a toll for monetary policies. Nonetheless, the significant response of domestic interest rates following foreign monetary policy shocks poses a critical challenge for domestic central banking.

[45] When tested with monetary policy shocks constructed by Bu et al. (2021), the output response was significantly negative.

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