Exchange Rate Uncertainty and Business Cycle Fluctuations

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Abstract

What is the impact of heightened exchange rate uncertainty on business cycle dynamics? This question is particularly important for emerging economies where exchange rate uncertainty is substantially higher and time-varying. Using data from emerging countries, we show that exchange rate uncertainty is essential for business cycle fluctuations. We find that heightened exchange rate uncertainty yields a drop in economic activity, an increase in prices, and an exchange rate depreciation. We rationalize our empirical findings in a small open economy model augmented with time-varying volatility of exchange rate shocks. In the structural model, the main ingredient of the transmission mechanism is the households' precautionary behavior. We also show that no other shocks, often featured in the literature, can produce the reported co-movement pattern among the macro variables.

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1 Introduction

The volatility of the nominal exchange rates has significantly increased after the fall of the Bretton Woods agreements. As a result, exchange rate risk has become an important concern for policymakers and academics. The matter is particularly relevant for emerging market economies as they are prone to higher exchange rate uncertainty.[1]

This work aims to study the effects of exchange rate uncertainty on business cycle dynamics in a group of emerging countries. In particular, we consider the following four large emerging economies: Brazil, Russia, Argentina, and Turkey. The first part of the paper presents an empirical assessment of the effects of exchange rate uncertainty on the economy. We begin the analysis by identifying exchange rate uncertainty shocks in the data. We model exchange rate uncertainty as variations in the volatility of uncovered interest parity (UIP) shocks. The latter directly enter the UIP condition and are found to be the key driver behind most of the variations in the nominal exchange rate.[2] To assure the robustness of our analysis, we follow two distinct strategies. Our first approach involves sampling the uncertainty shocks from a UIP equation with time-varying standard deviations. Alternatively, we employ a two-step procedure to sample the uncertainty shocks from initially constructed exchange rate shocks (first-order shocks).

We uncover large movements in the volatility of exchange rate shocks, which match with either global events (for example, the financial crisis of 2008-2009) or regional events (for example, Russian - Ukrainian conflict of 2014 and the Brazilian currency crisis of 1998-1999). These measures of exchange rate uncertainty are further used to evaluate the role of uncertainty shocks in short-run fluctuations.[3] Overall, we find that exchange rate uncertainty is an essential source of business cycle fluctuations in the

[1] Throughout the text, "uncertainty," "volatility," and "risk" will be used interchangeably.

[2] See, e.g., Itskhoki and Mukhin (2021).

[3] Using estimated volatility shocks from the first stage in the further analysis may give rise to the "generated regressor" problem. However, as Pagan (1984) shows, the standard errors on the generated regressors are asymptotically valid under the null hypothesis that the coefficient is zero.

selected economies. An increase in the exchange rate volatility leads to a significant drop in output and its components. Moreover, the impact of heightened exchange rate volatility is stagflationary, i.e., the shock triggers a negative conditional comovement between output and prices. We also document a significant depreciation of the nominal exchange rate after a unit increase in the exchange rate volatility. These findings are robust across the different uncertainty measures employed in the analysis.

To rationalize the empirical findings, we next introduce an otherwise standard small open economy model that allows for time variation in the volatility of exchange rate shocks. The model qualitatively matches the empirical impulse response functions. An elevated exchange rate volatility causes a contraction in economic activity and an increase in prices. The main ingredient of the transmission mechanism is the households' precautionary behavior. Faced with higher uncertainty about the exchange rate, the household cuts consumption and investment and builds up a buffer stock. The latter is reflected in a decrease in the foreign debt and is accompanied by an exchange rate depreciation. Interestingly, no other shock in our model (and arguably in other models of this type) can produce the above co-movement pattern among the variables.

This paper is related to different strands of literature. Born and Pfeifer (2014), Ferandez-Villaverde et al. (2015), Basu and Bundick (2015), Mumtaz and Zanetti (2013), Cesa-Bianchi and Fernandez-Corugedo (2018), Alessandri and Mumtaz (2019), Castelnuovo and Pellegrino (2018), among others, consider the effects of aggregate uncertainty on economic fluctuations. From a methodological perspective, our work bears similarities with these studies. Nevertheless, unlike our research, the exchange rate risk is not a subject examined in these and other papers. Ghironi and Ozhan (2020) study the implications of using domestic interest rate uncertainty as a policy tool to affect the composition of capital inflows between FDI and short-term assets. One of the quantitative simulations considers the case where the business cycle is driven by exchange rate volatility shocks (second-order UIP shocks). Still, their study crucially differs from ours in the focus of analysis. Finally, Fernandez-Villaverde et al. (2011) consider the macroeconomic effects of volatility of the real interest rate at which emerging economies borrow. The transmission mechanism of exchange rate volatility shocks in the current paper shares similarities with the one of interest rate volatility shocks documented in Fernandez-Villaverde et al. (2011). In both models, heightened future uncertainty leads to a contraction in economic activity. However, the model in the current paper features nominal rigidities; therefore, unlike Fernandez-Villaverde et al. (2011), we also analyze the behavior of nominal variables in response to a change in volatility.

This study also contributes to the literature on business cycles in developing economies. Prominent examples include, among others, Mendoza (1991), Neumeyer and Perri (2005), Uribe and Yue (2006), Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010), Chang and Fernandez (2013), and Fernandez and Gulan (2015). Our paper differs from these studies in several respects. First, in our analysis, nominal frictions play a crucial role in explaining short-run fluctuations in emerging economies. Second, unlike these studies, we identify the stochastic volatility shocks as drivers of the business cycle.

This paper is also related to the literature on exchange rate determination. Among others, Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021) identify the shock to the international asset demand (which is isomorphic to a UIP shock) to be the main driver behind exchange rate fluctuations. Benigno et al. (2012) and Chen et al. (2020) examine the effects of time-varying volatility of nominal and real shocks on exchange rate dynamics. We contribute to this literature by identifying an essential source of exchange rate fluctuations, the volatility of UIP shocks.[4]

All together, this paper adds to the existing literature from an empirical and a theoretical perspective. Our empirical analysis provides new evidence that exchange rate uncertainty is an important factor in driving real economic fluctuations. Importantly, we

[4] Yet our work does not aim to address the international macroeconomic puzzles associated with nominal exchange rates.

show that the effects of heightened exchange rate uncertainty are stagflationary. Last but not least, we find that exchange rate volatility shocks matter for the dynamics of exchange rates and that the exchange rate significantly depreciates in response to an increase in uncertainty. From a theoretical perspective, we develop a fairly simple model which can replicate the empirical results. The theoretical analysis finds that no other shock in the structural model can produce the reported co-movement pattern among the macro variables.

The rest of the paper is organized as follows. We present the empirical strategy and report the main empirical findings in Section 2. Section 3 describes the small open economy structural model used in quantitative simulations. We discuss the main theoretical results in Section 4. Finally, we summarize the paper in Section 5.

2 Empirical Evidence

This section studies the role of exchange rate uncertainty in economic fluctuations. We follow two distinct empirical strategies. The first approach (Section 2.1) involves sampling the uncertainty shocks from a UIP equation with time-varying standard deviations. Alternatively, we employ a two-step procedure (Section 2.2) to sample the uncertainty shocks from initially constructed exchange rate shocks (first-order shocks). In both approaches, the Sequential Importance Resampling filter (Gordon et al. (1993)) is used to construct the likelihood of the exchange rate volatility processes. We use the median smoothed volatility series to measure exchange rate uncertainty.[5] Details on the data sources are in Appendix 1.

[5] See Born and Pfeifer (2014) for further details.

2.1 Uncertainty Estimates from a UIP equation

We extend an otherwise standard UIP equation to allow for time variation in the volatility of residuals:

$$\Delta s_{t+1} = \mu^s (i_t - i_t^*) + \sigma_t^s \varepsilon_t^s, \qquad \varepsilon_t^s \sim N(0,1) \tag{1}$$

$$\sigma_t^s = (1 - \rho_{\sigma^s})\bar{\sigma}^s + \rho_{\sigma^s}\sigma_{t-1}^s + \eta^{\sigma^s}\varepsilon_t^{\sigma_s}, \qquad \varepsilon_t^{\sigma_s} \sim N(0,1) \tag{2}$$

Δs_t is the log difference of the nominal exchange rate, and $(i_t - i_t^*)$ is the difference between the domestic and the foreign interest rates. We demean the data before the estimation. Thus, (1) does not contain a constant term. Note also that we do not restrict μ^s to be 1 but rather allow the data to determine its value. σ_t^s is the time-varying volatility of the exchange rate shock. ρ_{σ^s} and $\bar{\sigma}^s$ are the persistence and the unconditional mean of the volatility process. η^{σ^s} is the standard deviation of the volatility shock. Table 1 reports the estimation results. We can observe that the measures of exchange rate uncertainty have considerable persistence. Also, the estimated values of standard deviations show substantial evidence of exchange rate uncertainty for all countries.

Figure 1 displays the median smoothed volatilities along with 68% posterior density intervals. The figure shows that the historical variances for the selected economies have common patterns. For example, in all countries, the exchange rate uncertainty increases during the crisis of 2008-2009. At the same time, we observe individual uncertainty peaks; for example, in Russia, the exchange rate uncertainty jumps at the onset of the conflict with Ukraine in 2014.

The Effects of exchange rate uncertainty shocks: To evaluate the role of exchange rate uncertainty shocks, we employ a local projection regression of a set of economic activity variables on the identified exchange rate volatility shocks. Similar to Jordà (2005), we estimate:

$$x_{t+h} = c_h + \beta_h t + \gamma_h \sigma_t^s + \sum_{j=1}^{p} \alpha_{h,j} Z_{t-j} + u_{t,h}, \quad h = 0,1,2... \tag{3}$$

Here, γ_h denotes the response of x_{t+h} at horizon h to a change in volatility shock at time t, σ_t^s. x_t denotes the outcome variable, in particular, log of GDP, consumption, investment and price level, the nominal interest rate, or the log of exchange rate. The latter are included in the vector of control variables, Z_t. Z_t also includes the US nominal interest rate and log of GDP. Furthermore, we include the log of oil prices in the set of exogenous variables for the Russian economy, given the significant dependence of Russia on oil exports. c_h is a constant and $\beta_h t$ is a linear time trend. The error term, $u_{t,h}$ is assumed to have a zero mean and positive variance. We set the lag length to four, a common choice for quarterly models. Figures 2a - 2d plot the impulse response functions to a positive one percent innovation to an exchange rate uncertainty shock. We can observe that the effect of uncertainty shocks on the selected variables is significant. In Brazil, the drop in GDP can be observed just after one quarter following the shock. In Russia, on the other hand, the impact is more delayed. The response of output is the strongest in Russia, about 0.08 percent. In Brazil and Turkey, by contrast, output declines by only 0.03 percent. These seemingly moderate values imply a significant effect of exchange rate uncertainty on the business cycle dynamics. For example, during the financial crisis of 2008-2009, in Brazil and Turkey, the exchange rate volatility increased by about 60 and 45 percent, respectively. The latter entails a 1.8 and 1.4 percent drop in output only due to heightened exchange rate uncertainty.

In all economies, the contraction in GDP is associated with a sharp drop in domestic absorption. We report the most significant decrease in investment in Russia, more than 0.15 percent. The largest drop in consumption is observed in Argentina, about 0.05 percent following a one percent increase in the exchange rate uncertainty. Next, we note that heightened exchange rate uncertainty implies a significant depreciation in the nominal exchange rate. The exchange rate response is the strongest in Argentina, 0.15 percent. This can partially explain the pronounced responses of inflation and interest rate. The behavior of the last two variables implies that in the selected economies, the impact of exchange rate uncertainty shocks is stagflationary, i.e., the shocks generate negative conditional covariance between the economic activity and prices. The behavior of the last two variables is quite different from what can be found in the literature on the effects of macroeconomic uncertainty. Unlike in Cesa-Bianchi and Fernandez-Corugedo (2018), Fernandez-Villaverde et al. (2015), Leduc and Liu (2015) and Mumtaz and Surico (2013), the uncertainty shocks in the considered emerging economies appear to be inflationary.

We run a series of exercises changing the lag length and the set of control variables in (3). We find that the baseline results are robust to considered alternative model specifications.[6]

2.2 Uncertainty estimates: A two-step procedure

The starting point is the identification of exchange shocks (level shocks). To that end, we use a sign-restricted VARX model for each country separately.[7] The model includes the following endogenous variables: the changes in the log of GDP, price level, exchange rate, as well as the nominal interest rate. The exogenous variables include the US nominal interest rate and the change in the log of GDP. We also include the log of oil prices in the set of exogenous variables for the Russian economy. We assume that a unit increase in the exchange rate shock leads to a contemporaneous fall in inflation and the interest rate. It also causes an appreciation in the exchange rate, by definition. These assumptions are consistent with the structural model presented in the next section. Also,

[6]The results of these exercises are available upon request.

[7]Adopting a recursive identification strategy for the construction of the exchange rate shocks delivers similar final results. These results are available upon request.

they are common in the literature and are robust across a great variety of models.[8] The lag length is set to four. The procedure of estimating the model includes the following steps:

- Randomly factorize (via the QR decomposition) the covariance matrix of reduced-form residuals to get a particular structural shock impact matrix (in fact, a particular structural VAR).
- Check whether the response function satisfies the assumed sign restrictions.
- Stop the procedure if the number of accepted responses (models) equals the pre-specified value. The latter is set to 100000.

We save the constructed exchange rate shocks from each estimated 100000 model and use the averages of these. An alternative procedure of reporting median-based estimates delivers similar final results. We next assume that the standard deviations of exchange rate shocks follow a standard stochastic volatility process:

$$e_{s,t} = \sigma_t^s \varepsilon_t^s, \qquad \varepsilon_t^s \sim N(0,1) \tag{4}$$

$$\sigma_t^s = (1-\rho_{\sigma^s})\bar{\sigma}^s + \rho_{\sigma^s}\sigma_{t-1}^s + \eta^{\sigma^s}\varepsilon_t^{\sigma_s}, \qquad \varepsilon_t^{\sigma_s} \sim N(0,1) \tag{5}$$

where $e_{s,t}$ is the constructed exchange rate shock[9]. The smoothed estimates of the historical variances of the identified exchange rate shocks are depicted in Figure 3, along with the ones obtained from the UIP equation with time-varying standard deviations (Section 2.1). We observe that the two measures of exchange rate uncertainty exhibit similar patterns. This is interesting given the different estimating methodologies of exchange rate uncertainty measures.

[8] See, among others, Adolfson et al (2007), Gali and Monacelli (2005), Justiniano and Preston(2010), Bergin (2006) and Forbes et al (2018).

[9] Note that, similar to (1) and (2) we do not allow for serial correlation in the exchange rate shock process. This is a reasonable assumption as we extract the structural innovations from a sign-restricted VAR model, where the residuals are free from serial correlation.

The Effects of exchange rate uncertainty shocks: As before, we use the smoothed volatility series of the exchange rate shocks to evaluate the role of exchange rate uncertainty in the business cycle fluctuations. To that end, we employ the local projection model of Section (2.1). Figures 4a - 4d plot the corresponding impulse response functions. As one can observe, the responses are generally similar to those of Section 2.1, although the magnitudes are somewhat different.

The main conclusion from the empirical analysis is that there is a statistically and, more importantly, economically significant relationship between exchange rate uncertainty and macroeconomic variables in the observed countries. In both cases, following an increase in uncertainty shock, economic activity drops, prices increase, and the exchange rate depreciates. The following section studies these links through the lens of a conventional small open economy model.

3 Model

In the current section, we present a small open economy model to study the effects of exchange rate uncertainty shocks. The model economy consists of a representative household, a production sector that includes a final good firm and a continuum of monopolistically competitive firms, a monetary authority, and a foreign sector. Following Benigno (2001), Neumeyer and Perri (2005), and Schmitt-Grohe and Uribe(2003), the domestic financial market is imperfectly integrated into the international market. We modify the shock in the UIP condition, allowing the volatility of the shock to be time-varying. The foreign sector is unaffected by the domestic economy; therefore, we do not explicitly model the behavior of the foreign variables. These are fixed at constant values.

3.1 Households

The representative household has the following utility function:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{(C_t - X_t)^{1-\sigma}}{1-\sigma} - \kappa_N \frac{N_t^{1+\phi}}{1+\phi} \right) \right\}$$

σ and φ measure the curvature of the utility function, β is the time discount factor. $X_t = hC_{t-1}$ represents external habits taken exogenous by the household. N_t denotes labour supply and C_t is a composite consumption index defined by:

$$C_t = \left[(1-\gamma)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \gamma^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right] \tag{6}$$

where C_H,t and $C_{F,t}$ are indexes of consumption of domestic and imported goods, respectively. They are defined as:

$$C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{7}$$

$$C_{IM,t} = \left(\int_0^1 C_{IM,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{8}$$

Here $j \in [0,1]$ marks the good variety. ε is the elasticity of substitution between the varieties (demand elasticity) and η is the elasticity of substitution between domestic and imported goods. γ measures openness of the economy.

The household owns the capital stock that accumulates according to:

$$K_{t+1} = (1 - \Omega(I_t))I_t + (1-\delta)K_t \tag{9}$$

Investment at t is denoted by I_t and δ is the depreciation rate. Similar to Christiano et al. (2005), $\Omega(I_t) = \frac{\kappa_I}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$ measures investment adjustment costs.

The household invests in two types of assets, domestic and international risk free bonds, B_t and B_t^*, respectively. $(1+i_t)$ and $(1+i_t^*)$ are the nominal gross interest rates on domestic and foreign bond holdings. The former is controlled by the Central Bank, while the latter is an exogenous variable determined outside the model. The household faces interest rate, which is increasing in the aggregate level of foreign debt. This assumption ensures stationarity of the foreign debt level in an approximation to the model.[10]

The representative household faces the following period by period budget constraint:

$$C_t + I_t + \frac{B_t}{P_t} + \frac{S_t B_t^*}{P_t} = w_t N_t + r_t^k K_t + (1+i_{t-1})\frac{B_{t-1}}{P_t} + (1+i_{t-1}^*)\frac{S_t B_{t-1}^*}{P_t}\phi_t(A_t) + \Xi_t \tag{10}$$

where S_t is the nominal exchange rate defined as the home currency per unit of foreign currency, w_t is the real wage rate and r_t^k is the return to capital. P_t is the consumer price index and Ξ_t are dividends of firms owned by the households. The function $\phi_t(\cdot)$ is a premium on foreign bond holdings, which depends on the real aggregate net foreign asset position of domestic economy, defined as

$$\phi_t = e^{(-\chi A_t + \sigma_t^s \varepsilon_t^s)} \tag{11}$$

$$A_t = \frac{S_{t-1} B_{t-1}^*}{\bar{Y} P_{t-1}} \tag{12}$$

where σ_t^s allows for time-varying volatility. The latter evolves as follows:

$$\sigma_t^s = (1-\rho_{\sigma^s})\bar{\sigma}^s + \rho_{\sigma^s}\sigma_{t-1}^s + \eta^{\sigma^s}\varepsilon_t^{\sigma_s} \tag{13}$$

[10]See Schmitt-Grohe and Uribe (2003) for further details and alternatives

3.2 Firms

The aggregate output in the economy is produced by a representative, competitive final-good firm. The latter bundles intermediate goods into a single product by the following technology:

$$Y_{H,t} = \left(\int_0^1 Y_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}} \tag{14}$$

ε is the elasticity of substitution between different varieties. The representative firm chooses intermediate good quantities, $Y_{H,t}(j)$ to maximize profits. The usual demand schedule is given by:

$$Y_{H,t}(j) = (\frac{P_{H,t}(j)}{P_{H,t}})^{-\varepsilon} Y_{H,t} \tag{15}$$

The zero-profit condition of the representative firm yields the following relation for the price level of domestically produced goods:

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}} \tag{16}$$

A continuum of competitive monopolists produce differentiated goods using labor and capital according to the following production function:

$$Y_{H,t}(j) = K_t(j)^{\alpha} N_t(j)^{1-\alpha} \tag{17}$$

The good intermediate firms are subject to nominal rigidities, as in Rotemberg (1982). The profit maximization problem of the generic firm j, expressed in terms of the consumer price index, is given by:

$$\max_{P_{H,t+s}(j),N_{t+s}(j),K_{t+s}(j),Y_{H,t+s}(j)} E\sum_{s=0}^{\infty}\beta^s\frac{\lambda_{t+s}}{\lambda_t}(\frac{P_{H,t+s}(j)}{P_{t+s}}Y_{H,t+s}(j)-w_tN_{t+s}(j)-r_t^KK_{t+s}(j)-\frac{AC_{t+s}(j)}{P_t})$$

$$s.t.\quad Y_{H,t}(j)=(\frac{P_{H,t}(j)}{P_{H,t}})^{-\varepsilon}Y_{H,t}$$

$$AC_t(j)=\frac{\kappa_p}{2}(\frac{P_{H,t}(j)}{P_{H,t-1}(j)}-\pi)^2P_{H,t}Y_{H,t}$$

$$Y_{H,t}(j)=K_t(j)^{\alpha}N_t(j)^{1-\alpha}$$

The solution to the maximization problem results in the inflation equation for domestically produced goods:

$$\pi_{H,t}(\pi_{H,t}-\pi_H)=\beta E_t\frac{\lambda_{t+1}}{\lambda_t}\pi_{H,t+1}(\pi_{H,t+1}-\pi_H)\frac{p_{H,t+1}y_{t+1}}{p_{H,t}y_t}+\frac{\varepsilon}{\kappa_p}(\frac{mc_t}{p_{H,t}}-\frac{\varepsilon}{\varepsilon-1}) \quad (18)$$

3.3 Monetary Policy

The monetary authority follows the following Taylor rule:

$$i_t=(1-\rho_i)i+\rho_i i_{t-1}+(1-\rho_i)(\phi_\pi(\pi_t-\pi)+\phi_Y(\ln Y_t-\ln Y)) \quad (19)$$

ρ_i describes interest-rate smoothing. ϕ_π and ϕ_Y control the responses to inflation and output. The letters without a time subscript mark corresponding steady-state values.

3.4 Calibration and Model Solution

We calibrate the model with standard parameter values often used in the literature. Table 2 summarizes the baseline calibration.

We solve the model by third-order approximation, where the innovations to the volatility play a role by themselves (Fernandez-Villaverde et al. (2011)). The simulations are centered around the stochastic fixed point of the model. The latter is computed in the following way: starting from the deterministic steady-state, the model is simulated for several periods setting the variance of all current-period shocks to zero. This is the rest point of the approximated decision rules where the current shocks are zero, but future shocks have nonzero variance. To compute impulse responses, we first simulate the model without any shock realization given the stochastic fixed point of the model. This set of samples are called control simulations. Next, we implement the same simulations adding an appropriate policy volatility impulse. Finally, we subtract control simulations from the series with impulse. An alternative simulation-based procedure commonly used in literature is based on the generalized impulse response of Koop et al. (1996). Instead of being centered around the stochastic fixed point, these impulse responses are computed in deviations from the ergodic mean of the variables. When doing simulations, we find that both procedures deliver similar results.

4 Model Results

Here we analyze the effects of an increase in exchange rate uncertainty. Figure 5 plots the impulse responses for one standard deviation exchange rate uncertainty shock. We can observe that an increase in the exchange rate volatility leads to a drop in output and its components, an increase in inflation, and an increase in the interest rate. We also observe a significant depreciation in the nominal exchange rate. In fact, the structural model can match the empirical observations qualitatively.

The contractionary effect of the shock is due to two effects embedded in the model. The first effect is due to the household's precautionary behavior. Faced with higher uncertainty, the household tends to cut consumption and supply more labor. With sticky prices, the latter decreases the marginal costs of production of the intermediate goods firms implying a rise in markups. In a demand-driven economy, this increase in markups also lowers investment in capital stock. In sum, these effects together produce a significant drop in output and its components.[11] In an open economy, the household's precautionary behavior is accompanied by a gradual decrease in the foreign debt (accumulation of foreign assets). Alternatively, holding foreign debt becomes riskier following an increase in exchange rate uncertainty. Therefore, the household reduces its exposure to this risk by lowering its outstanding debt. The decline in foreign debt is achieved by reducing consumption and investment (domestic absorption). Finally, this decrease in the foreign debt is accompanied by an exchange rate depreciation. We can also explain the behavior of the exchange rate following the intuition of Benigno et al. (2012). Uncertainty related to the exchange rate worsens the domestic currency's hedging performance, leading to a decrease in its demand and thereby a depreciation. The reason for the latter is the positive co-variation between the marginal utility of consumption and the exchange rate conditional on UIP shocks.

Similar to households, firms also face increased uncertainty about future demand conditions. In the presence of nominal rigidities and a Dixit-Stiglitz consumption aggregator, firms' marginal profit function is convex. Therefore, heightened future uncertainty leads the firms to set higher prices and higher markups over marginal costs (Kimball (1989)). This increase in markups amplifies the contractionary effects arising from an exchange rate volatility shock.

Do we need the second mechanism to match the empirical results qualitatively? To resolve the question, we repeat the experiment of Fernandez-Villaverde et al. (2015) and eliminate the precautionary pricing channel. To that end, we compute the impulse response functions assuming that inflation evolves according to the linearized version of the Phillips curve:

$$\pi_{H,t} - \pi_H = \beta E_t(\pi_{H,t+1} - \pi_H) + \frac{\varepsilon}{\kappa_p}\left(\frac{mc_t}{p_{H,t}} - \frac{\varepsilon}{\varepsilon - 1}\right) \tag{20}$$

[11] Basu and Bundick (2017) provide a thorough discussion on this mechanism.

Figure 6 illustrates the results. The black line plots the impulse responses for the baseline economy, while the blue line corresponds to the one with linear pricing equations. We observe that there are minor differences between the responses. As a matter of fact, the precautionary pricing channel only marginally amplifies the responses of the selected variables to an increase in exchange rate uncertainty. Thereby, the household's precautionary behavior is the key ingredient driving our results.

4.1 Further Results

Before concluding the analysis, we conduct an additional exercise to compare the transmission mechanism of exchange rate volatility shocks with that of other shocks commonly featured in the literature. From a wide variety of options, we consider first-order supply-side shocks (neutral productivity and price markup shocks) and second-order volatility shocks (productivity volatility, monetary policy volatility, and demand/preference volatility shocks). We embed these shocks into the structure of our baseline model.[12]

Figure 7 compares the responses of the model economy to a one standard deviation increase in the macroeconomic shocks. Consider the transmission mechanism of the first order supply-side shocks. We can observe that while the shocks imply a negative conditional co-variance between the economic activity and prices, the behavior of the other variables (exchange rate and the foreign assets/debt) is not consistent with the one implied by exchange rate uncertainty shocks. Next, consider the effects of monetary policy volatility shocks. The crucial difference between exchange rate volatility and monetary policy volatility shocks is that the latter implies a decline in prices and interest rates. This is due to a significant exchange rate appreciation. The exchange rate behavior under monetary policy uncertainty shocks is consistent with the one in Benigno et al.

[12] All first order shocks have the same persistence and standard deviation, 0.8 and 0.01, respectively. For volatility shocks, we employ the same values as in the case of exchange rate volatility shocks.

(2012). Finally, unlike exchange rate volatility shocks, productivity volatility shocks and demand/preference volatility shocks generate a decline in the foreign assets (foreign debt accumulation) accompanied by an exchange rate appreciation. In sum, no shocks considered in the analysis and often featured in the literature can produce the reported co-movement pattern among the macro variables.

5 Conclusion

We study the impact of exchange rate volatility on the economy both empirically and theoretically. We find that exchange rate volatility is essential in driving real economic fluctuations. We further show that the effects of heightened exchange rate uncertainty are stagflationary. Finally, we find that exchange rate volatility shocks matter for the exchange rate dynamics.

We next construct a small open economy model to rationalize the empirical findings. The model replicates the empirical findings qualitatively. The main ingredient in the transmission mechanism is the precautionary saving channel. We also find that no other shock in the structural model can produce the reported co-movement pattern among the macro variables.

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Table 1: **Parameter estimates of the UIP equation with stochastic volatility**

	Argentina	Brazil	Russia	Turkey
μ_s	0.61 [0.45, 0.74]	0.16 [-0.04, 0.34]	0.60 [0.37, 0.79]	0.27 [0.05, 0.49]
ρ_{σ^s}	0.89 [0.75, 0.99]	0.85 [0.65, 0.99]	0.97 [0.94, 0.99]	0.90 [0.75, 0.99]
η^{σ^s}	0.054 [0.043, 0.066]	0.038 [0.031, 0.045]	0.025 [0.02, 0.031]	0.045 [0.036, 0.055]
$\bar{\sigma}$	0.02 [0, 0.07]	0.03 [0, 0.07]	0.01 [0, 0.02]	0.03 [0, 0.07]

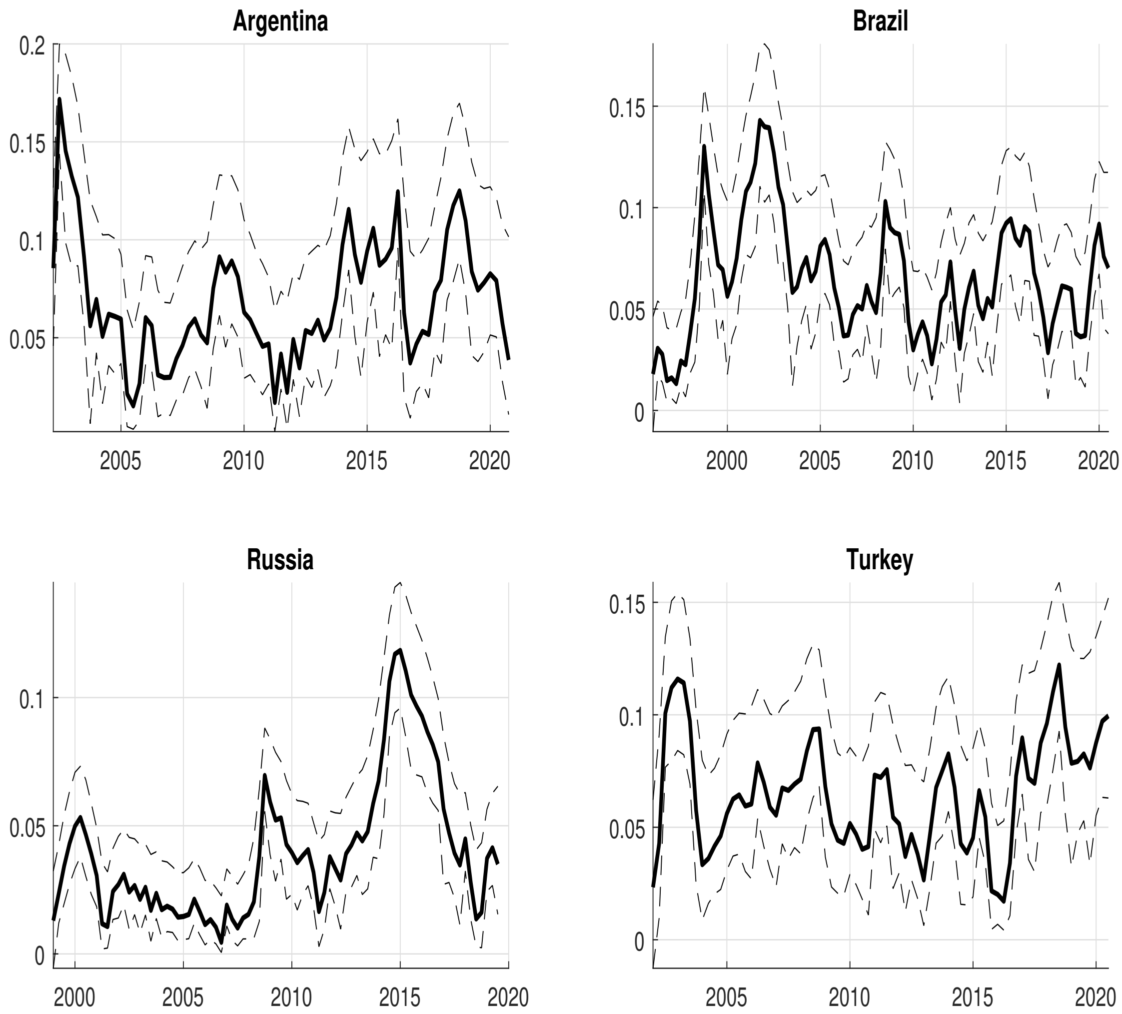
Note: For each parameter, we report the posterior mean and, in brackets, a 68% probability interval.

Table 2: Model calibration

	Description	Value/Target	Comments
β	Discount factor	0.99	Conventional value
φ	Inverse of the Frisch elasticity	1.5	Justiniano and Preston (2010)
σ	Relative risk aversion	2	Conventional value
κ_N	Scaling parameter on labor supply	$N = \frac{1}{3}$	Conventional value
h	Habit persistence	0.3	Justiniano and Preston (2010)
γ	Share of imported goods	0.3	Conventional value
ε_H	The Demand elasticity for domestic goods	11	Devereux et al. (2006)
κ_I	Investment adjustment cost	2.5	Christiano et al. (2005)
δ	Quarterly rate of depreciation	0.025	Conventional value
η	Elasticity of substitution: home and foreign goods	1.3	Conventional value[13]
χ	Risk premium elasticity	0.000742	Schmitt - Grohé, Uribe (2003)
α	Share of Capital in Production	0.33	Conventional value
κ_H	Price adjustment	116	Conventional value
ρ_r	Persistence coefficient of interest rate	0.8	Justiniano and Preston (2010)
π_h	Inflation rate	0	Conventional value
μ_π	Response to inflation	1.8	Justiniano and Preston (2010)
μ_y	Response to output	0.1	Justiniano and Preston (2010)
ρ_σ	Volatility shock persistence	0.90	Authors' calculations
η_σ	Volatility shock standard deviation	0.05	Authors' calculations
$\bar{\sigma}$	Mean volatility	0.03	Authors' calculations

This table reports the values of calibrated parameters in the structural model.

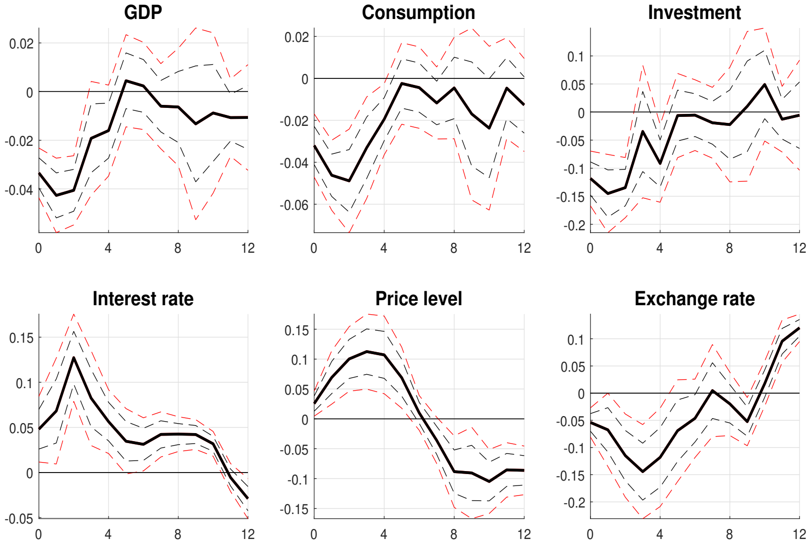
Figure 1: Exchange rate volatility estimates from the UIP equation



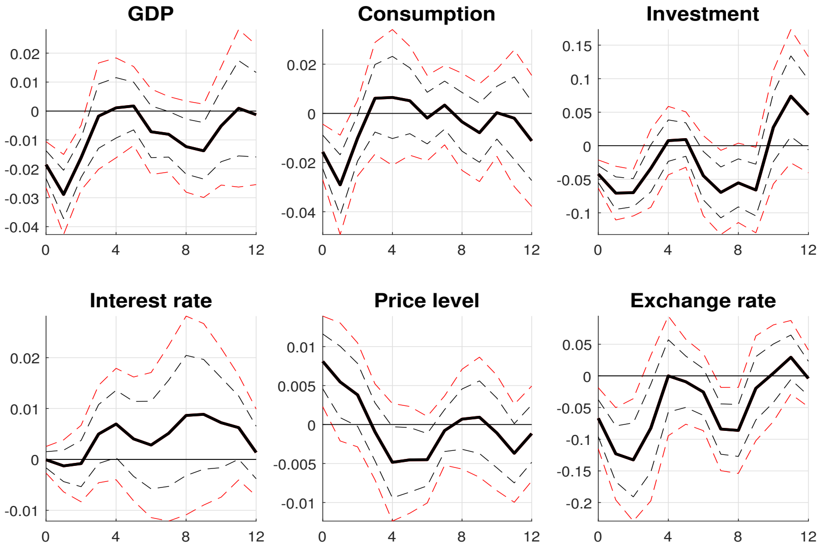
The solid lines plot the median smoothed exchange rate volatility series. The dashed lines mark 68 percent credible intervals.

Figure 2: The impact of exchange rate uncertainty shocks: One-step procedure

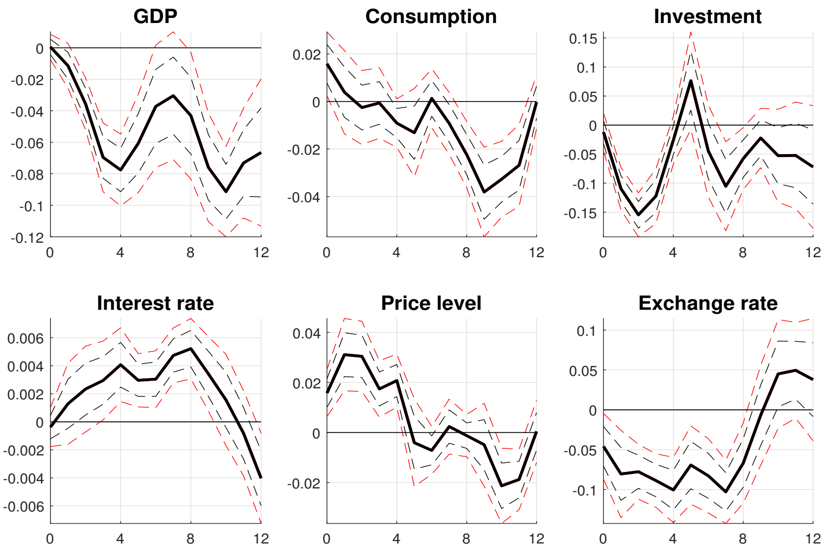
a. Argentina



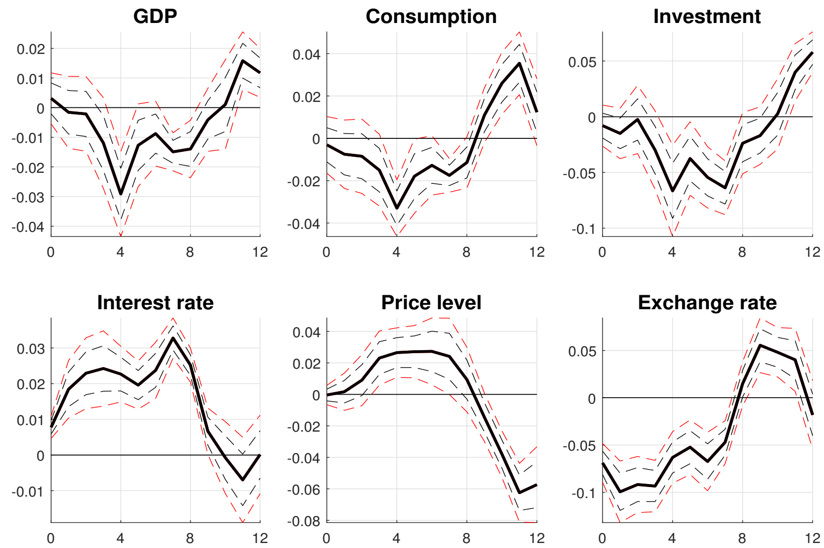
b. Brazil



c. Russia

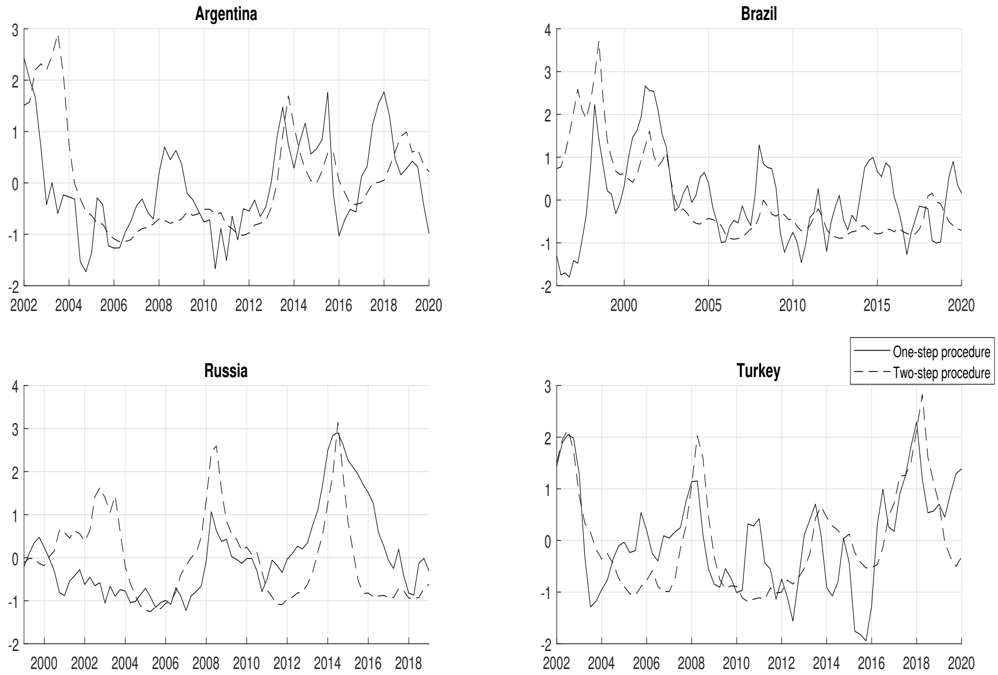


d. Turkey



The solid lines plot the responses to an exchange rate volatility shock sampled from the UIP equation with time-varying volatilities. The dashed black and red lines show 68 and 90 percent confidence bands, constructed using Newey and West (1987) standard errors. The entries are in percentage points. The interest rate is in annualized percentage points.

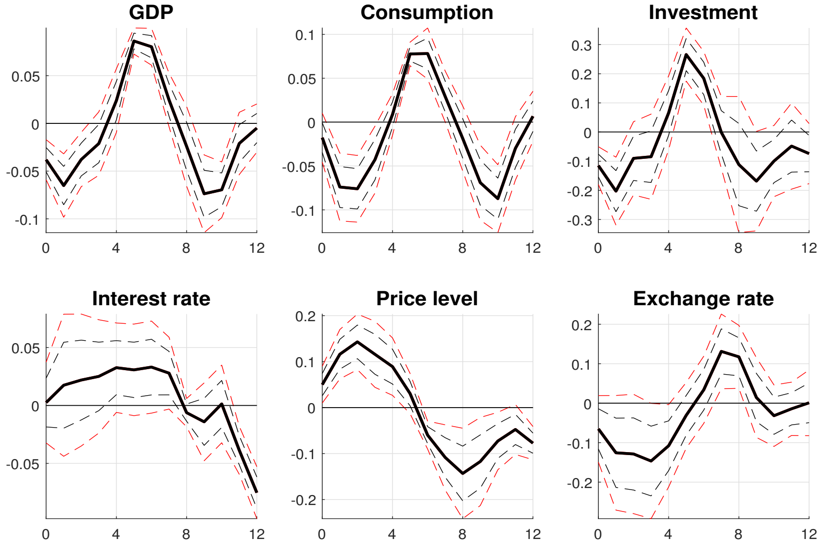
Figure 3: Comparing the exchange rate volatility measures



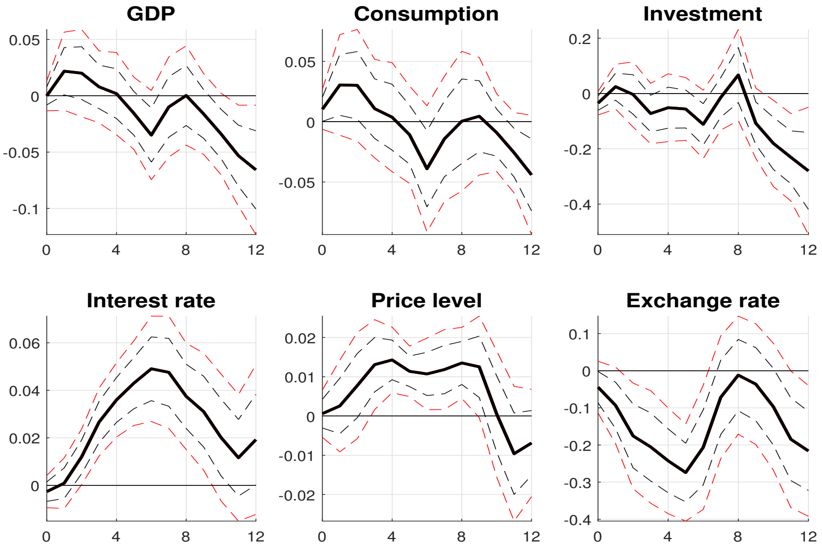
The solid lines plot the exchange rate volatility shocks sampled from the UIP equation with time-varying volatilities. The dashed lines plot the exchange rate volatility measure obtained with the two-step procedure. The series are normalized to have zero mean and unit variance.

Figure 4: The impact of exchange rate uncertainty shocks: Two-step procedure

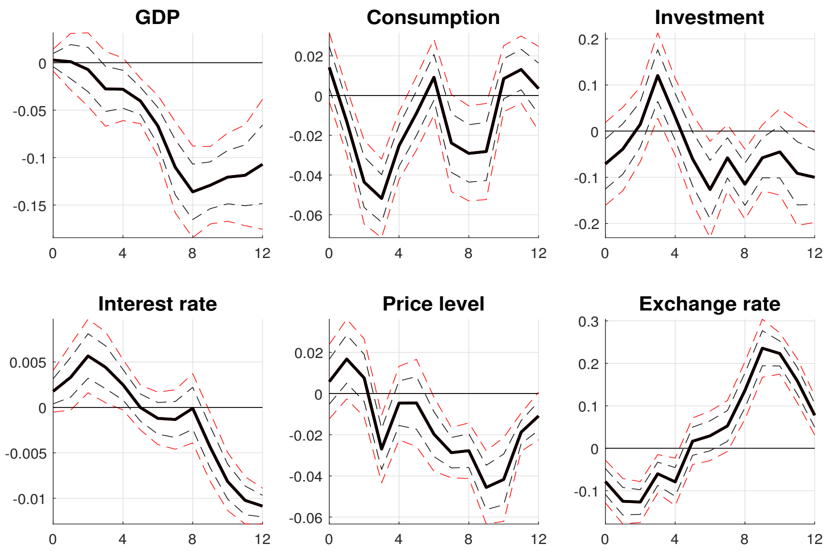
a. Argentina



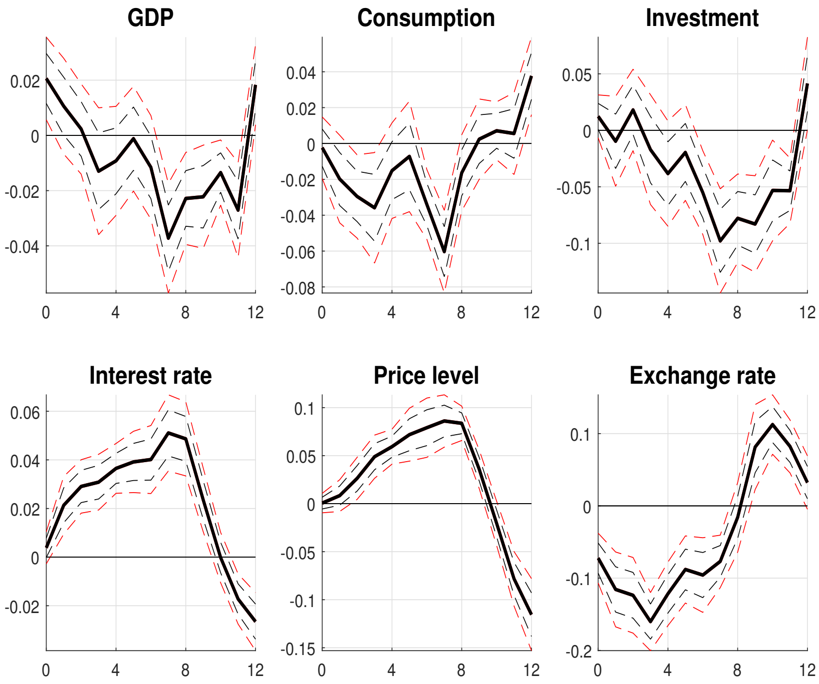
b. Brazil



c. Russia

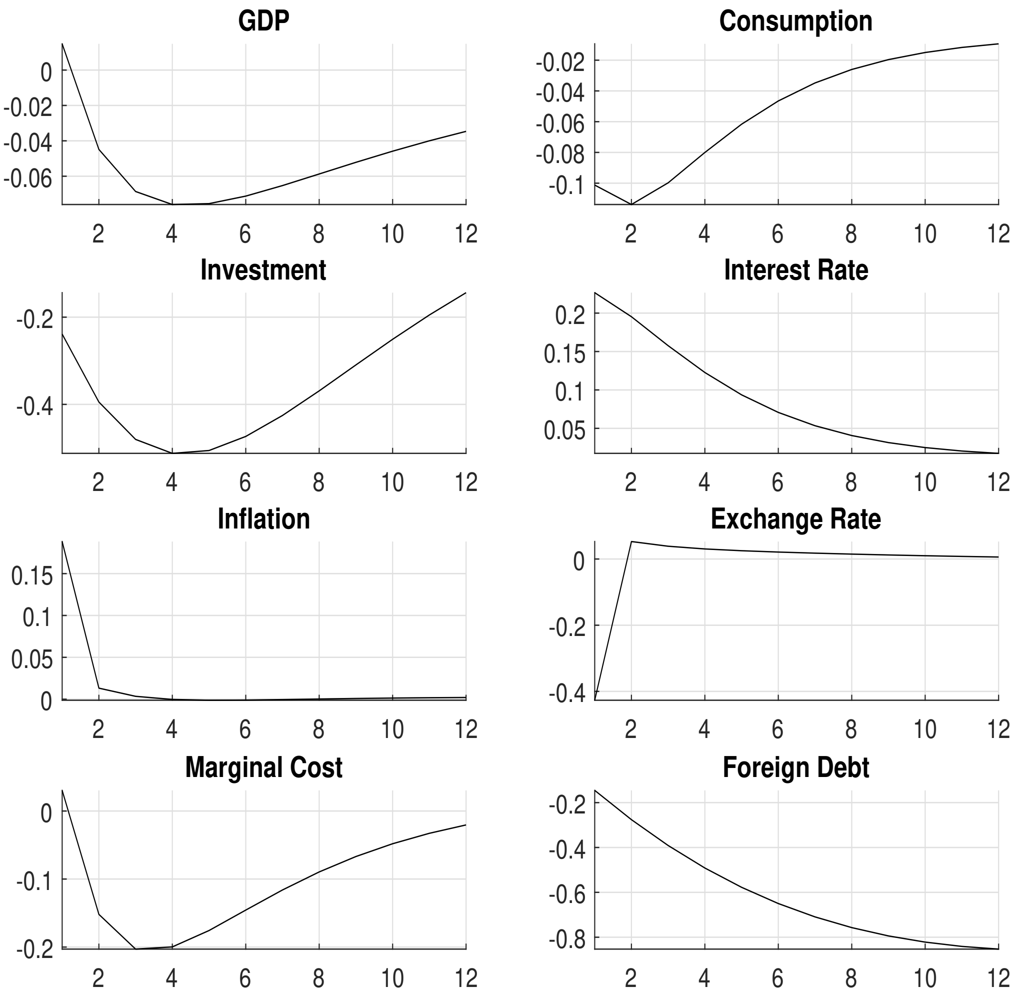

GDP
0
-0.05
-0.1
-0.15
0
4
8
12
Consumption
0.02
0
-0.02
-0.04
-0.06
0
4
8
12
Investment
0.2
0.1
0
-0.1
-0.2
0
4
8
12
Interest rate
0.005
0
-0.005
-0.01
0
4
8
12
Price level
0.02
0
-0.02
-0.04
-0.06
0
4
8
12
Exchange rate
0.3
0.2
0.1
0
-0.1
0
4
8
12

d. Turkey



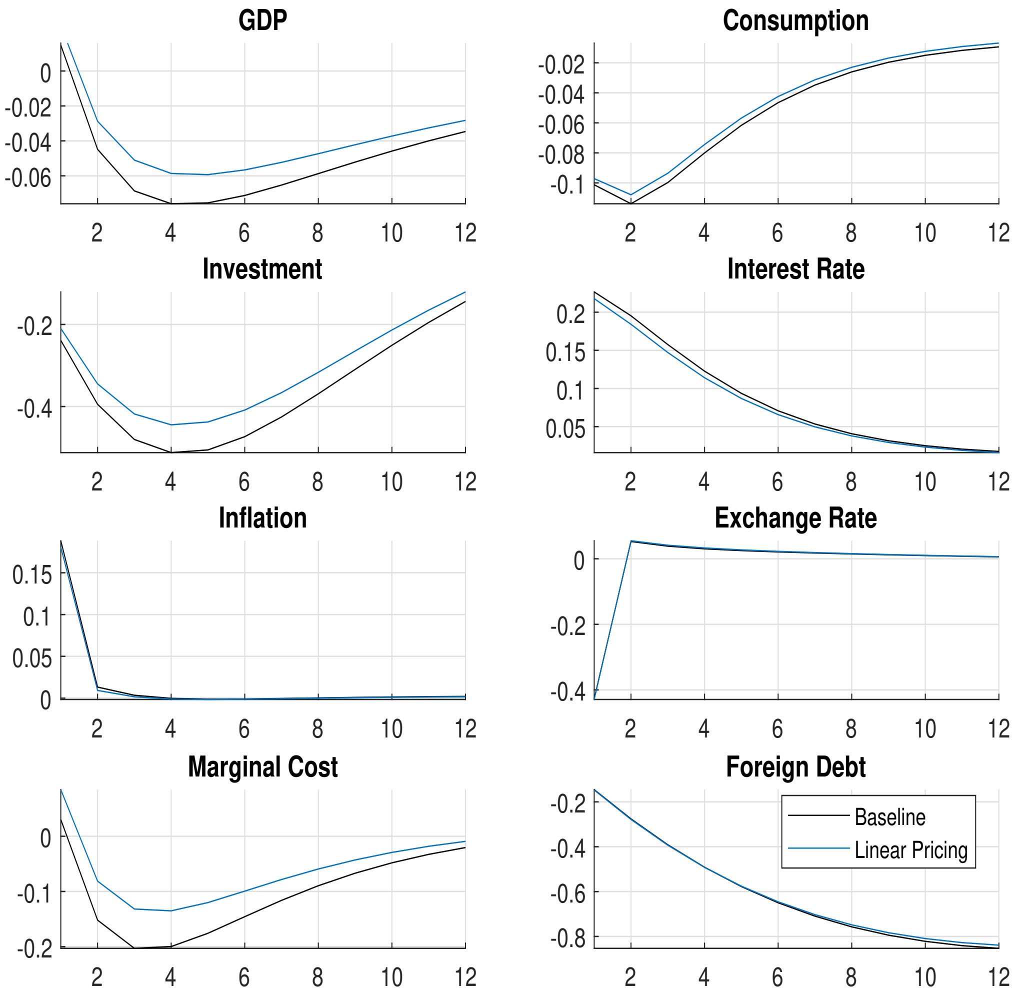
The solid lines plot the responses to an exchange rate volatility shock sampled from the UIP equation with time-varying volatilities. The dashed black and red lines show 68 and 90 percent confidence bands, constructed using Newey and West (1987) standard errors. The entries are in percentage points. The interest rate is in annualized percentage points.

Figure 5: Exchange rate uncertainty shocks in the structural model



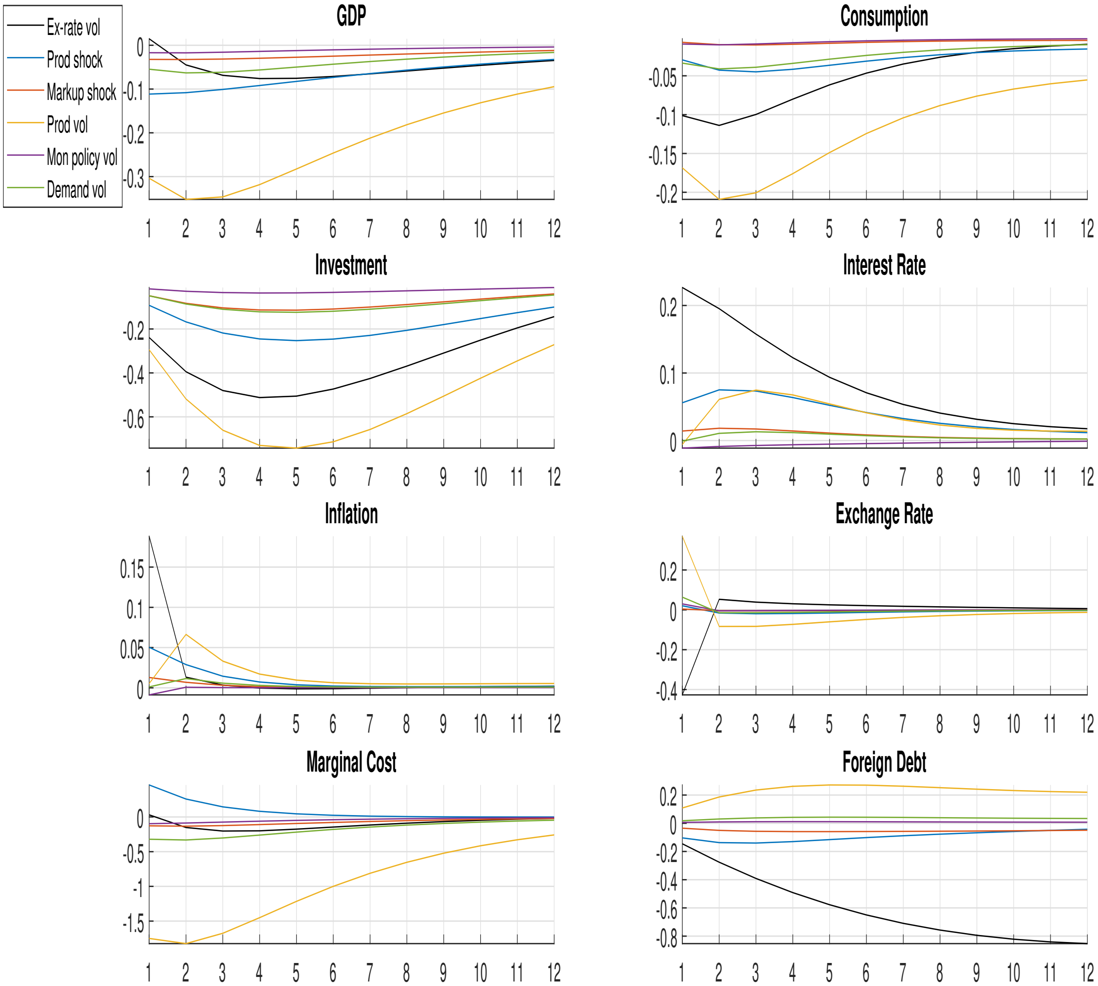
The entries are in percentage terms. The interest rate is in annualized percentage points.

Figure 6: Exchange rate uncertainty shocks: The role of precautionary pricing channel



The black lines plot the results for the baseline model. The blue lines show the responses for the model with linear pricing equations. The entries are in percentage terms. The interest rate is in annualized percentage points.

Figure 7: The response of the economy to macroeconomic shocks



The figure plots the response of the economy to first-order supply-side shocks (neutral productivity and price markup shocks) and second-order volatility shocks (exchange rate volatility, productivity volatility, monetary policy volatility, and demand/preference volatility shocks). The entries are in percentage terms. The interest rate is in annualized percentage points.

Appendix 1: Data

We draw the data from the International Financial Statistics (IFS) service of the International Monetary Fund, the FRED database and the Bank for International Settlements. The sample size for each country depends on data availability, except for Turkey, which had pegged exchange rate regime before 2001. The data coverage is as follows: Argentina 2002Q1 - 2020Q3; Brazil 1996Q2 - 2020Q4; Russia 1999Q2-2019Q4; Turkey 2002Q1 -2020Q3. Consumption is the household expenditure on goods and services. Investment is the sum of gross fixed capital formation and changes in inventories. Price level is the CPI index. The exchange rate is the nominal effective exchange rate. As for the interest rate, it is Central Bank policy rate for Argentina and Turkey, savings rate for Brazil and money market rate for Russia. Finally, exogenous variables include the U.S. data. [14] Real variables were obtained by dividing nominal ones by either the GDP deflator or the CPI index. All variables were seasonally adjusted using the U.S. Census Bureauís X-12 program.

[14]We also include oil prices in the set of exogenous variables for the Russian economy.