Policy Uncertainty and Current Account Dynamics*

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Abstract

What is the response of the current account to heightened monetary policy uncertainty? This question is particularly important for developing countries where policy uncertainty is substantially higher and time-varying. Estimation using Russian and Brazilian data shows that the current account improves by up to 0.2 percent of GDP following a one standard deviation increase in policy uncertainty. I present an open economy New-Keynesian model that can replicate this finding. In the model, an increase in policy volatility leads to an improvement in the current account, a decline in output, and an increase in inflation. The overall improvement in the current account is due to households' precautionary asset accumulation and a rise in the trade balance. In sticky-price DSGE models, policy volatility shocks often generate a comovement problem: output and inflation move in the opposite direction. For developed countries, the countercyclical movement of prices after uncertainty shocks is hard to reconcile with empirical observations. This paper shows that for developing countries this does not seem to be an issue. In Russia and Brazil, output and inflation move in the opposite direction after an increase in policy uncertainty.

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1. Introduction

The central contribution of the current study is to show that monetary policy uncertainty has a statistically significant impact on external accounts, specifically on current account dynamics. This issue is particularly relevant for developing economies as they are prone to higher policy uncertainty.

The analysis is carried out for two developing countries, Russia and Brazil. In the first part of the paper I assess the effects of monetary policy uncertainty by employing a SVAR model with stochastic volatility. I find that the current account improves by up to 0.2 percent of GDP following a one standard deviation increase in policy volatility. As a robustness exercise, I also estimate a conventional SVAR model using Economic Policy Uncertainty indexes (Baker et al. (2016)). The results of the two empirical models are in broad agreement: heightened policy uncertainty is associated with an improvement in the current account.

I next introduce an open economy New-Keynesian model with time-varying policy volatility and show that it can reproduce the observed empirical findings. There are two channels through which uncertainty shocks affect the economy. First, households accumulate precautionary savings in response to the increase in the policy uncertainty. These savings are invested abroad. Second, precautionary pricing behavior of the firms leads to an improvement in the terms of trade. An improvement in the terms of trade generally entails two opposing effects. It either generates a positive wealth effect through higher purchasing power of exports or a substitution effect shifting the demand towards imported goods. With the benchmark calibration, the wealth effect in equilibrium is much stronger, therefore the model generates a positive (conditional) correlation between the terms of trade and the trade balance. This improvement in the trade balance further amplifies the initial rise in the current account.

Three additional results come out of the analysis. In the empirical part of the paper, I find that policy uncertainty shocks are stagflationary in developing economies. By contrast, Born and Pfeifer (2017) show that in the US data price markups fall after uncertainty shocks. Likewise, Mumtaz and Surico (2013) and Mumtaz and Zanetti (2013) establish that an increase in the volatility of the monetary policy shock generates a drop in inflation and output. It is widely known that a standard RBC model is not capable of generating a contraction in output and its components after uncertainty shocks. Basu and Bundick (2017) show that the comovement problem can be solved with countercyclical markups through sticky prices. However, this countercyclical movement of prices driven by uncertainty shocks is hard to reconcile with empirical observations. The recent literature has suggested different approaches to circumvent this problem. For example, Fernandez-Villaverde et al. (2015) deal with this issue by slightly modifying the Taylor rule. Born and Pfeifer (2017) suggest that DSGE models that are used to examine the effects of uncertainty shocks should mainly rely on sticky wages (countercyclical wage markups). They find that unlike price markups, wage markups do increase after uncertainty shocks. By contrast, this paper shows that for developing countries there does not seem to be a comovement problem and a general equilibrium model with sticky prices can successfully generate this negative comovement between output and prices.

In the empirical part, I also show that the exchange rate depreciates following an increase in policy volatility. This is in stark contrast with Benigno et al. (2011) who report the opposite outcome for a group of advanced countries. Finally, in the theoretical part of the paper, I find that the precautionary pricing channel is further amplified when the Central Bank targets a higher inflation rate, a feature shared by many developing countries.

To the best of my knowledge, this is the first paper that explores the effects of policy uncertainty shocks in *developing countries*. This research is related to different strands of literature. The first strand looks at the impact of policy uncertainty shocks on macroeconomic behavior. Recent contributions include, among others, Fernandez-Villaverde et al. (2015), Johannsen (2014), Born and Pfeifer (2014), (2017), Benigno et al. (2011), Mumtaz and Surico (2013) and Mumtaz and Zanetti (2013). The second strand links external imbalances with macroeconomic volatility. Among others, Fogli and Perri (2015), Gete and Melkadze

(2016), Hoffmann et al. (2014), Sandri (2011) and Ghosh and Ostry (1997) examine this topic for advanced and developing economies. The difference from these studies is that the current paper focuses on the effects of policy uncertainty shocks.

From an empirical perspective, I provide new evidence that policy uncertainty significantly affects the current account. Importantly, I show that there are considerable differences in the transmission of uncertainty shocks in advanced and emerging economies. From a theoretical perspective, I develop a fairly standard and simple model which can successfully replicate the empirical results. In the theoretical part of the paper, I also emphasize the effects of nonzero trend inflation on the transmission of uncertainty shocks.

The rest of the paper is organized as follows. The second section estimates SVAR models and reports the main empirical results. The third section describes the general equilibrium model. The fourth section studies the effects of policy uncertainty shocks in the model. The last section summarizes and concludes.

2. Empirical Evidence

This section studies the potential effects of policy uncertainty on macro variables by using SVAR models. The empirical analysis consists of two parts. First, I estimate a Stochastic Volatility SVAR model (Mumtaz and Zanetti (2013)), which allows for a direct impact of recovered policy volatility shocks on various economic aggregates.[1] Second, I estimate a conventional SVAR model, where I employ the policy uncertainty indexes proposed by Baker et al. (2016) (EPU indexes) to proxy the policy volatility shock. The estimation is carried out for the Brazilian economy and the Russian economy. I use quarterly observations on five macroeconomic variables: real GDP growth rate, current account (relative to GDP), change in nominal effective exchange rate (an increase means appreciation of the domestic currency), CPI inflation and nominal short term interest rate. The dataset for Russia covers the period 1998Q1-2015Q2. For Brazil, the sample period is 1997Q2-2014Q4. The data is obtained

[1] A detailed description of the model can be found in Appendix A.

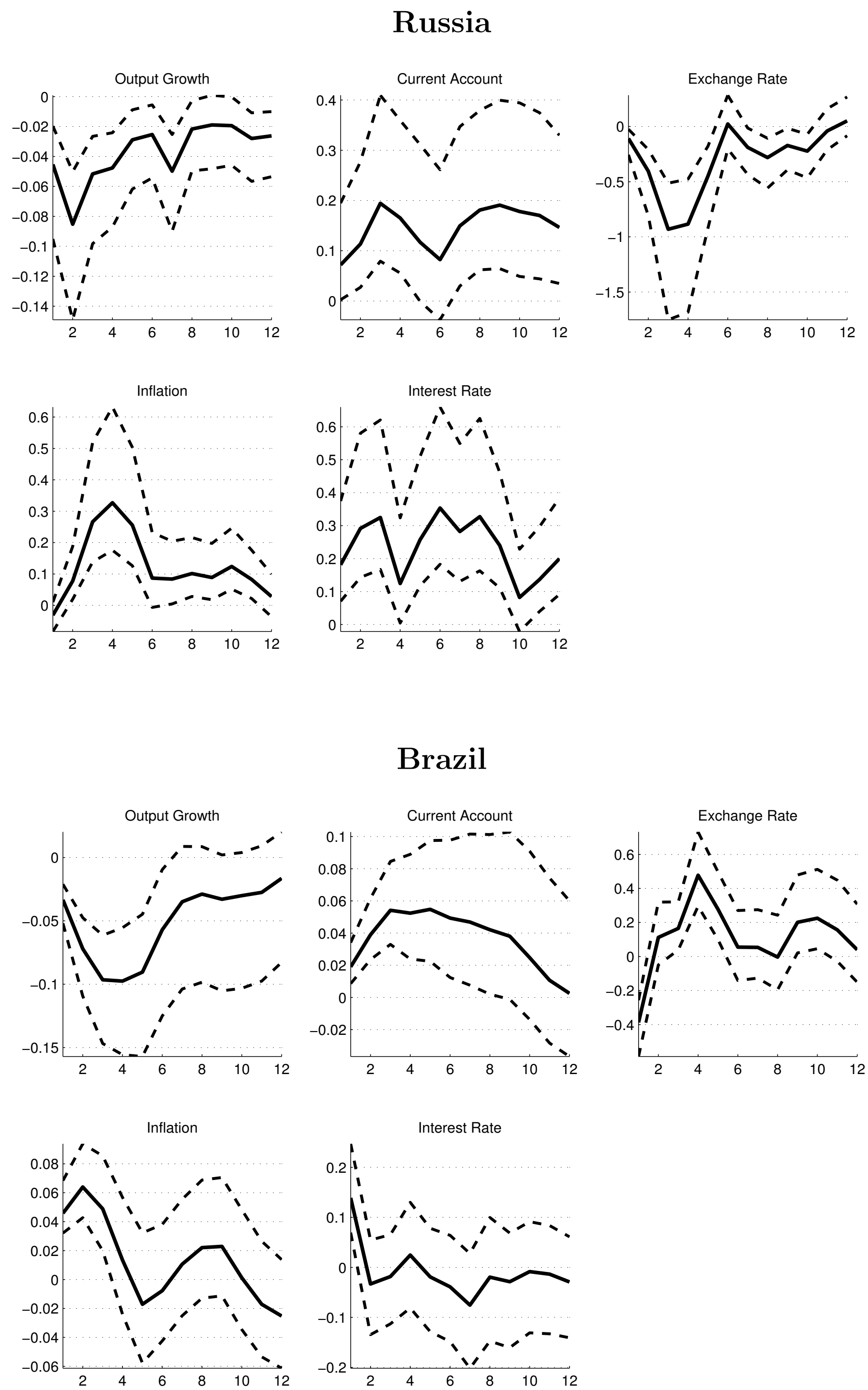
from the statistical offices of the two countries, the Bank for International Settlements and the Federal Reserve Bank of St. Louis's FRED database.

2.1. Stochastic Volatility SVAR estimation

The analysis starts with the Stochastic Volatility SVAR model. The starting point in the estimation procedure is the identification of monetary policy shocks (level shocks). I use an identification strategy based on the recursiveness assumption, according to which monetary policy responds to contemporaneous values of the remaining variables, but these variables respond to the policy instrument only with a lag. These restrictions are implemented by taking the Cholesky decomposition of the variance covariance matrix in a system, where the interest rate is ordered last. The lag length for the endogenous variables is set to four which is reasonable for quarterly models. The model also contains a constant. In the model, the endogenous variables are affected by the current and lagged values of the time-varying volatility.[2] Consistent with the general equilibrium model, I assume that the time-varying volatility of the policy shock follows an AR(1) process. I also assume that the volatility shock and the level shock are orthogonal.

Figure 1 plots the median (solid lines), the 16th percentiles (lower dashed lines) and the 84th percentile (upper dashed lines) of the distribution of the impulse responses to a one standard deviation uncertainty shock. A one standard deviation uncertainty shock is a 30 and 65 percent increase in policy volatility in Russia and Brazil, respectively. The results suggest that after an increase in policy volatility, the current account improves in both countries. The response of the current account is much stronger in Russia, about 0.2 percent of GDP, even though the relative magnitude of the shock is larger in Brazil.

[2]The reason is that in the SVAR model the level shocks contain no autocorrelation.



Solid line: median responses. Dashed lines: 16th and 84th percentiles.
X-axis: Quarters, Y-axis: Values in percent

Figure 1. Uncertainty shocks in the SV-SVAR model

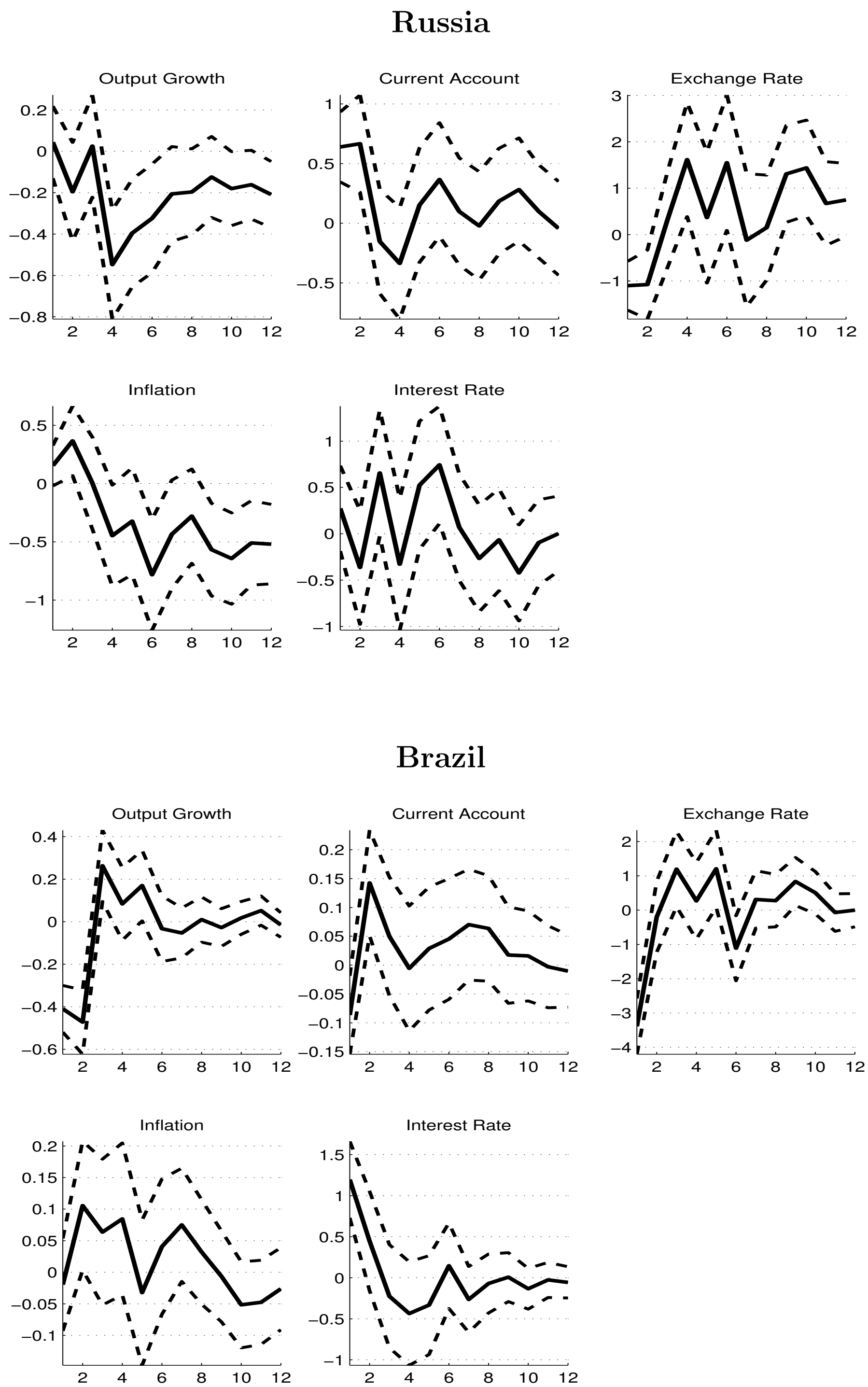
In Russia, the peak increase in the current account occurs in the third quarter. The peak drop of the output growth also occurs quite early, after two quarters. We also observe that in Russia, changes in policy uncertainty strongly impact the exchange rate. This could be the reason behind the pronounced responses of inflation and the interest rate.

In Brazil, the peak impact of a policy volatility shock on the current account happens about five quarters after the shock. A similar observation can be made for GDP growth. An increase in policy volatility causes an immediate depreciation of the exchange rate and a moderate rise in inflation and in the interest rate. We next observe that the response of the exchange rate in Brazil is weaker than in Russia. Both in Russia and Brazil, the behavior of inflation and the interest rate is quite different from what can be found in the literature for developed countries so far. Unlike in developed countries, the uncertainty shocks in Brazil and Russia appear to be inflationary.

I next assess the robustness of the results to different perturbations. In particular, I consider alternative identification schemes which also impose a recursive structure on the contemporary relationships of the variables. I find that my results are robust with respect to the ordering of the interest rate in the SV-SVAR model. The corresponding impulse response functions can be found in Appendix B.

2.2. SVAR estimation: employing EPU indexes

In the second part of the analysis, I study the effects of policy uncertainty on aggregate outcomes by estimating a conventional SVAR model. I use EPU indexes for Russia and Brazil instead of the recovered monetary volatility shock. Following Baker et al. (2016), I identify the policy uncertainty shocks recursively by placing the EPU measures before the main macro variables in the previous analysis. The model specification includes four lags of macro variables, as in the previous case. The model also contains a constant term.



Solid line: median responses. Dashed lines: 16th and 84th percentiles.
X-axis: Quarters, Y-axis: Values in percent

Figure 2. Uncertainty shocks in the SVAR model

The impulse response functions are displayed in Figure 2. It shows the median (solid lines), the 16th percentile (lower dashed lines) and the 84th percentile (upper dashed lines) of the distribution of impulse responses to a one standard deviation uncertainty shock. A one standard deviation uncertainty shock is approximately a 30 basis point increase in the uncertainty index relative to the average value in both countries. The responses are similar to those of the SV-SVAR model, but the magnitudes are different. An increase in the EPU index has a much stronger effect. This is not surprising given that the employed index measures overall economic policy uncertainty, whereas the volatility shock identified in the previous model only captures monetary uncertainty. As before, I consider different orderings of the EPU measure in the model. The corresponding impulse response functions can be found in Appendix C. For alternative orderings some of the results change, while this was not the case in the SV-SVAR model.

The main conclusions of this section are as follows. Estimating the SV-SVAR model, I find that the current account improves after an increase in policy uncertainty. I also find that policy uncertainty shocks are stagflationary. Furthermore, following the approach by Baker et al. (2016), I obtain the same findings in the SVAR model. The next section studies whether a conventional open economy New-Keynesian model can replicate these results.

3. Model

In the current section, I present a small open economy New-Keynesian model to study the effects of policy volatility shocks. The model economy consists of a representative household, a production sector that includes a continuum of monopolistically competitive firms, a fiscal authority, a monetary authority and a foreign sector. The basic structure is similar to Gali and Monacelli (2005) with some features of developing countries. Similar to Sutherland (1996) and Benigno (2009), the domestic financial market is imperfectly integrated into the international market. Also, the monetary authority responds to real exchange rate misalignment. The foreign sector is unaffected by the domestic economy, therefore I do not explicitly model the behavior of the foreign variables. These are fixed at constant values.

3.1. The Representative Household

The representative household has an additively separable utility function over consumption and labor:

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

σ is the coefficient of relative risk aversion, ϕ is the inverse of the Frisch elasticity of labor supply and β is the time discount factor. E_0 is the expectation operator, N_t denotes labour supply and C_t is a composite consumption index defined by:

$$C_t = \left[(1-\alpha)^{\frac{1}{\eta}} C_{H,t}^{1-\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{IM,t}^{1-\frac{1}{\eta}} \right]^{\frac{1}{1-\frac{1}{\eta}}} \tag{3.1}$$

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

$$C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.2}$$

$$C_{IM,t} = \left(\int_0^1 C_{IM,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{3.3}$$

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. α measures openness of the economy.

The household invests in two types of assets, domestic and international risk free bonds ($B_{H,t}$ and $B_{F,t}$ respectively). $R_{H,t}$ and $R_{F,t}$ 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 convex costs of holding foreign assets in quantities different from the respective steady-state level, b_F.[3] This assumption ensures stationarity of the model dynamics.[4] The household's flow budget constraint in period t is given by:

$$\int_0^1 \left(P_{H,t}(j)C_{H,t}(j) + P_{IM,t}(j)C_{IM,t}(j)\right) dj + B_{H,t} + B_{F,t}S_t$$
$$= W_tN_t + B_{H,t-1}R_{H,t-1} + B_{F,t-1}R_{F,t-1}S_t + D_t - \frac{\varphi}{2}\left(\frac{B_{F,t}S_t}{P_t} - b_F\right)^2 P_t + T_t \quad (3.4)$$

$P_{H,t}(j)$ and $P_{IM,t}(j)$ denote the prices of home-produced and foreign good j, respectively. W_t is the nominal wage rate. D_t denotes the dividends from holding shares in the equity of domestic firms, T_t is the lump-sum transfer paid by the government and S_t is the nominal exchange rate (an increase means depreciation of the local currency).

The optimal allocation of expenditure within each category of goods yields the following demand functions:

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} C_{H,t} \quad (3.5)$$

$$C_{IM,t}(j) = \left(\frac{P_{IM,t}(j)}{P_{IM,t}}\right)^{-\epsilon} C_{IM,t} \quad (3.6)$$

Price indexes are given by:

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\epsilon} dj\right)^{1-\epsilon} \quad (3.7)$$

$$P_{IM,t} = \left(\int_0^1 P_{IM,t}(j)^{1-\epsilon} dj\right)^{1-\epsilon} \quad (3.8)$$

$P_{H,t}$ and $P_{IM,t}$ are price indexes in period t for domestic and imported goods, respectively.

Furthermore, the optimal allocation of expenditures between domestic and imported

[3] In the paper, I assume that $b_F = 0$. This is not a strong assumption given the main research question of the paper. Moreover, I solved the model with a positive level of steady-state asset/debt position and found that the results were broadly unchanged.

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

goods implies:

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t \tag{3.9}$$

$$C_{IM,t} = \alpha\left(\frac{P_{IM,t}}{P_t}\right)^{-\eta} C_t \tag{3.10}$$

P_t is the aggregate price index:

$$P_t = \left[(1-\alpha)P_{H,t}^{1-\eta} + \alpha P_{IM,t}^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{3.11}$$

3.2. Firms

A continuum of competitive monopolists in the domestic economy operates under a linear production technology:

$$Y_t(j) = N_t(j) \tag{3.12}$$

$Y_t(j)$ is output and $N_t(j)$ is labor input of firm j. The standard cost minimization problem implies that the real marginal cost is common across the firms:

$$MC_t = \frac{w_t}{\hat{P}_{H,t}} \tag{3.13}$$

Here $\hat{P}_{H,t} = \frac{P_{H,t}}{P_t}$. w_t is the real wage rate. The firms maximize profits and set prices as in Calvo (1983). In each period, a firm faces a constant probability, $1-\theta$, of being able to adjust its nominal price. The ability to adjust prices is independent across firms and time. I also assume that a firm which cannot adjust its price sets $P_t(j)$ according to: $P_t(j) = P_{t-1}(j)$. Thus, each firm j solves:

$$\max_{P_{H,t}(j)} \quad E_t\left\{\sum_{l=0}^{\infty} \theta^l Q_{t,t+l} Y_{t+l}(j)\left(P_{H,t}(j) - P_{H,t+l} MC_{t+l}\right)\right\}$$

$$\text{s.t.} \qquad Y_{t+l}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t+l}}\right)^{-\epsilon} Y_{t+l}$$

Y_t is the "aggregate" output in period t, $Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}}$ and $Q_{t,t+l}$ is the stochastic discount factor. Inflation dynamics of the domestically produced goods is given by:

$$X_{1,t} = \frac{\epsilon}{\epsilon - 1}\lambda_t Y_t MC_t + \beta\theta E_t \pi^{\epsilon}_{H,t+1} X_{1,t+1} \tag{3.14}$$

$$X_{2,t} = \lambda_t Y_t + \beta\theta E_t \pi^{\epsilon-1}_{H,t+1} X_{2,t+1} \tag{3.15}$$

$$(1-\theta)\left(\frac{X_{1,t}}{X_{2,t}}\right)^{1-\epsilon} + \theta\pi^{\epsilon-1}_{H,t} = 1 \tag{3.16}$$

$\pi_{H,t}$ is the inflation rate for domestically produced goods and λ_t is the marginal utility of consumption. In this economy, the law of one price in import goods prices holds, thus after some algebra I get:

$$[(1-\alpha)\hat{P}^{1-\eta}_{H,t} + \alpha RER^{1-\eta}_t = 1 \tag{3.17}$$

RER_t stands for the real exchange rate. Using the definition of $\hat{P}_{H,t}$, I finally get the dynamics of the aggregate inflation rate:

$$\pi_t = \frac{\hat{P}_{H,t-1}}{\hat{P}_H}\pi_{H,t} \tag{3.18}$$

3.3. Monetary and fiscal policy

The fiscal authority's flow budget constraint is given by:

$$B_{g,H,t-1}R_{H,t-1} + G_t = T_t + B_{g,H,t} \tag{3.19}$$

Any debt issued by the government, $B_{g,H,t}$ is held only by the domestic household. I also assume that in equilibrium, the government expenditures are zero, $G_t = 0$. In the model, monetary policy is active and fiscal policy is passive in the sense of Leeper (1991).

The Central Bank sets the nominal interest rate according to the Taylor rule:

$$R_{H,t} = R_{H,t-1}^{\rho_R} R_H^{1-\rho_R} [\left(\frac{\pi_t}{\pi}\right)^{\mu_\pi} \left(\frac{Y_t}{Y}\right)^{\mu_Y} \left(\frac{RER_t}{RER}\right)^{\mu_{RER}}]^{1-\rho_R} e^{\zeta_t} \tag{3.20}$$

ρ_R describes interest-rate smoothing. μ_π, μ_Y and μ_{RER} control the responses to inflation, output and real exchange rate. Here the letters without a time subscript mark corresponding steady-state values. Apart from responding to inflation and the output, the Central Bank also takes into account the real exchange rate misalignment. Real exchange rate has an important role in the formulation of optimal monetary policy in emerging markets. As Aghion et al. (2009) demonstrate, countries with relatively less developed financial systems are more prone to output losses caused by exchange rate volatility. Thus, central banks in these countries are more likely to follow a policy rule that responds to real exchange rate fluctuations.

ζ_t is the monetary policy shock. It follows an AR(1) process of the following form:

$$\zeta_t = \rho_\zeta \zeta_{t-1} + e^{\sigma_{\zeta,t}} \omega_\zeta \varepsilon_{\zeta,t}, \qquad \varepsilon_{\zeta,t} \sim N(0,1) \tag{3.21}$$

ρ_ζ describes the persistence of the policy shock and $\sigma_{\zeta,t}$ is the time-varying standard deviation of the policy shock with ω_ζ as the homoskedastic part:

$$\sigma_{\zeta,t} = \rho_\sigma \sigma_{\zeta,t-1} + \omega_\sigma \varepsilon_{\sigma,t}, \qquad \varepsilon_{\sigma,t} \sim N(0,1) \tag{3.22}$$

ω_σ and ρ_σ denote the unconditional standard deviation and persistence of the policy volatility shock, respectively.

3.4. Market Clearing and Equilibrium

In equilibrium, the markets for goods, domestic bonds and labor clear. Goods market clearing condition implies:

$$Y_t = C_{H,t} + C^*_{H,t} \tag{3.23}$$

$C^*_{H,t}$ is the foreign demand for the domestically produced goods in period t. Using the already familiar demand functions, the goods market equilibrium condition can be modified as: [5]

$$Y_t = (1-\alpha)\hat{P}_{H,t}^{-\eta} C_t + \alpha \left(\frac{\hat{P}_{H,t}}{RER_t} \right)^{-\eta} C^*_t \tag{3.24}$$

C^*_t is the foreign consumption in period t. Market clearing conditions for labor and domestic bonds are:

$$\int_0^1 N_t(j)dj = N_t \tag{3.25}$$

$$B_{g,H,t} = B_{H,t} \tag{3.26}$$

Real dividends received by the household are given by:

$$\frac{D_t}{P_t} = \hat{P}_{H,t} Y_t - w_t N_t \tag{3.27}$$

Using the household's budget constraint and the above conditions, one finally gets:

$$\hat{P}_{H,t} Y_t - \frac{\varphi}{2} \left(\frac{B_{F,t} S_t}{P_t} - b_F \right)^2 = C_t + \frac{B_{F,t} S_t}{P_t} - \frac{B_{F,t-1} S_t R_{F,t-1}}{P_t} \tag{3.28}$$

Appendix D contains the full set of equilibrium conditions.

[5] The elasticity of substitution between domestic and foreign goods is the same in home and foreign economies. This is not a restrictive assumption given that the paper does not examine the transmission mechanism of external shocks to the domestic economy.

3.5. *Calibration and model solution*

I start the current subsection with the baseline calibration of the model. Consistent with the empirical analysis, it is calibrated on a quarterly basis. Following Garcia-Cicco et al. (2010), I set the risk aversion parameter $\sigma = 2$, the parameter governing bond adjustment costs $\varphi = 0.001$ and the Frisch elasticity of labor supply $\frac{1}{\phi} = 1.6$.

The elasticity of substitution between different varieties, ϵ is set to 8 which is close to the value used in Medina and Soto (2005). The value of the demand elasticity implies that the average markup is about 14 percent. Next, I set the price stickiness parameter, $\theta = 0.45$, i.e. prices stay unchanged for a little less than two quarters on average. This is in the range of values estimated by Semko (2013).

The country openness parameter α is set to 0.3 and the elasticity of substitution between imported and domestic goods is set to 0.6, close to the values in Drygalla (2017) and de Menezes Linardi (2016). The annual steady-state inflation rate is 6 percent which is approximately the average inflation rate observed in developing countries starting from the early 2000s. The discount factor, β is set to 0.98, which implies an average real interest rate of about 8 percent per annum. This is empirically plausible for emerging markets (see Garcia-Cicco et al. (2010)).

Regarding the Taylor rule parameters, I set the following values: ρ_{R_H}=0.8, $\mu_\pi = 1.5$ and μ_Y=μ_{RER}=0.3. I set the persistence of the monetary policy shock $\rho_\zeta = 0.1$. The homoskedastic part of the standard deviation, ω_ζ is calibrated at 0.015 consistent with the existing literature (de Carvalho et al. (2014) and Malakhovskaya and Minabutdinov (2013)). I set the standard deviation and the persistence of the volatility shock to 0.55 and 0.8. These are in the range of values estimated in the SV-SVAR model in Section 2.[6] Table 1 summarizes the baseline calibration.

[6]The corresponding values for Russia and Brazil are 0.45, 0.5 and 0.86, 0.95, respectively.

Table 1. Baseline Parametrization

Parameter	Description	Value
σ	Relative risk aversion	2
$\frac{1}{\phi}$	Frisch elasticity of labor supply	1.6
ϵ	Demand elasticity	8
η	Elasticity of substitution: home and foreign goods	0.6
θ	Price stickiness	0.45
α	"Openness"	0.3
β	Time discount factor	0.98
ρ_R	Interest rate smoothing	0.8
μ_π	Response to inflation	1.5
μ_Y	Response to output	0.3
μ_{RER}	Response to exchange rate	0.3
π	Inflation target	1.015
ρ_ζ	Policy shock persistence	0.1
ω_ζ	Policy shock standard deviation	0.015
ρ_σ	Volatility shock persistence	0.8
ω_σ	Volatility shock standard deviation	0.55

The model is solved by third-order approximation, where the innovations to the volatility play a role by themselves (Fernandez-Villaverde et al. (2011)). I use the nonlinear moving average representation of the policy function proposed by Meyer-Gohde and Lan (2012). Following Dynare language, the equilibrium conditions of the model can be presented as:

$$E_t F(y_{t+1}, y_t, y_{t-1}, x_t) = 0 \tag{3.29}$$

Here y_t is the vector of endogenous variables, x_t is the vector of innovations and $F(.)$ is a continuously differentiable function. The solution of the model is a system of policy functions of the following form:

$$y_t = y(\varrho, x_t, x_{t-1}, x_{t-2}, ...) \tag{3.30}$$

The parameter ϱ scales the aggregate risk in the model. With the assumption of normally distributed shocks, I can write the third-order Taylor approximation of the policy function as:

$$y_t = y_{ss} + \frac{1}{2} y_{\varrho^2} \varrho^2 + \sum_{i=0}^{\infty} [y_i + \frac{1}{2} y_{\varrho^2,i}] x_{t-i} + \frac{1}{2} \sum_{j=0}^{\infty} \sum_{i=0}^{\infty} [y_{j,i}(x_{t-j} \otimes x_{t-i})] + \frac{1}{6} \sum_{l=0}^{\infty} \sum_{j=0}^{\infty} \sum_{i=0}^{\infty} [y_{l,j,i}(x_{t-l} \otimes x_{t-j} \otimes x_{t-i})] \tag{3.31}$$

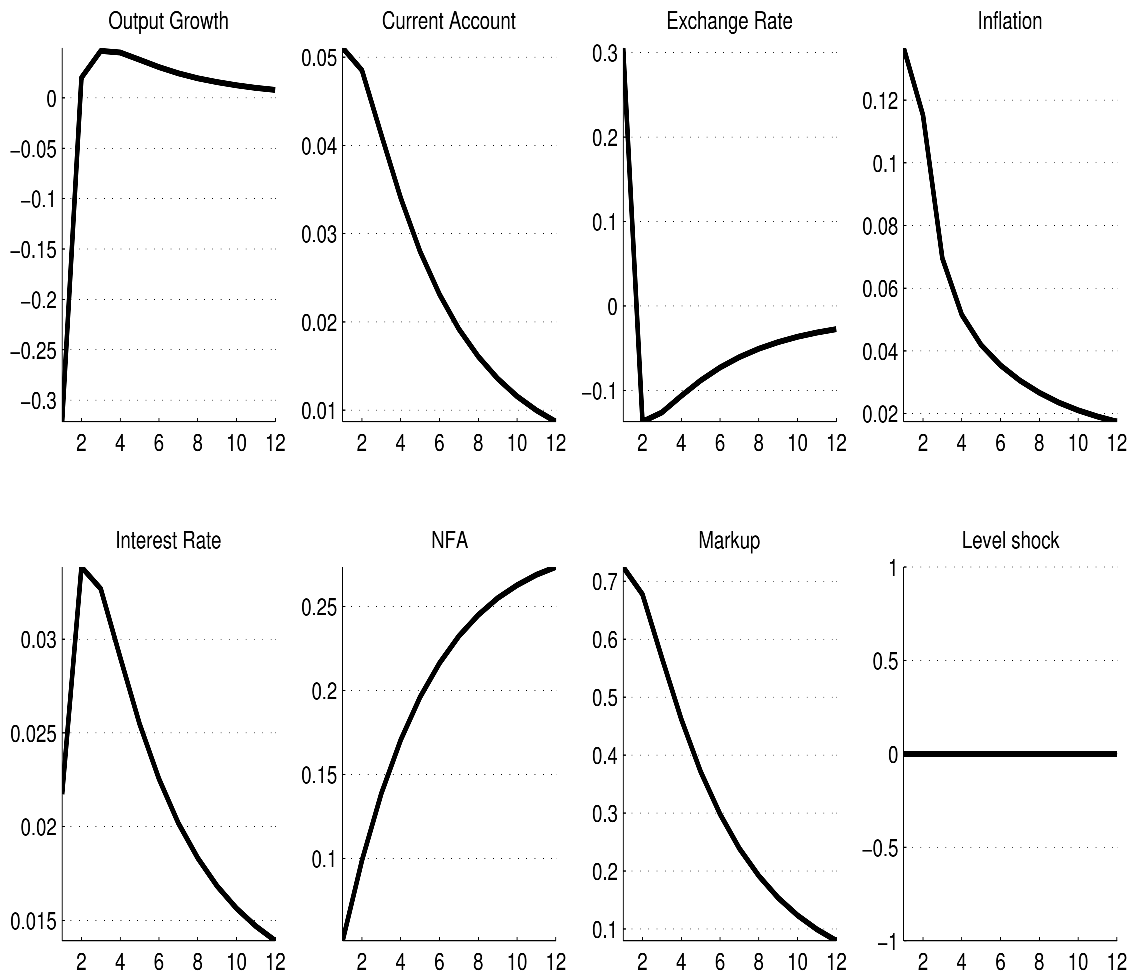
$\otimes$ denotes the Kronecker product. y_{ss} is the policy function computed at the deterministic steady-state. The partial derivatives, y_i, $y_{j,i}$, $y_{k,j,i}$, y_{ϱ^2} and $y_{\varrho^2,i}$ are also evaluated at the deterministic steady-state of the model. In the above specification, y_{ϱ^2} presents a constant adjustment for uncertainty and $y_{\varrho^2,i}$ captures the effect of policy volatility shocks on the model dynamics.

4. Results

In this section, I use the calibrated model to examine the effects of policy volatility shocks on macroeconomic aggregates. First, I study the transmission of volatility shocks. Second, I conduct sensitivity analysis to assess the robustness of the baseline results. Third, I analyze the role of trend inflation in the transmission of volatility shocks.

4.1. The Effects of Policy Volatility Shocks

Before the main analysis, I first look at the effects of volatility shocks in a version of the model where the Central Bank does not respond to real exchange rate fluctuations. Impulse responses for a one standard deviation policy volatility shock are plotted in Figure 3. In the figure, NFA stands for net foreign asset position.[7] The impulse response functions here and in the following figures are in percentage terms. The interest rate is in annual terms. I discuss the transmission of the uncertainty shock in detail below. Here I want to point



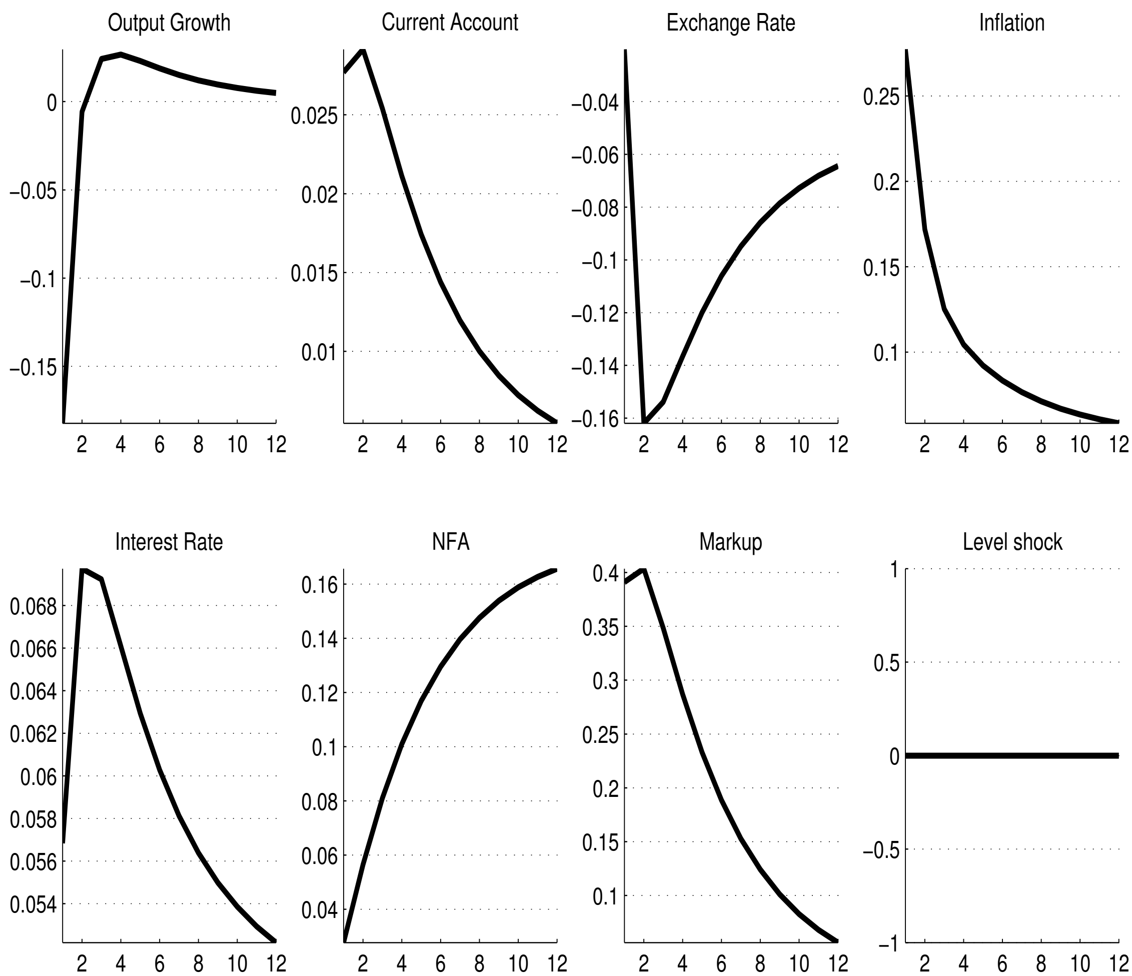
X-axis: Quarters. Y-axis: Values in percent.

Figure 3. Monetary policy uncertainty shock: Conventional policy rule

out the fact that the model with a conventional monetary policy reaction function fails to replicate the exchange rate depreciation documented in Section 2.

[7] In Section 2, the exchange rate is expressed in terms of domestic currency per a foreign currency. Therefore, in Figure 3 and in the following figures, the response of the exchange rate is flipped down to have consistency with the empirical results in Section 2. Thus, an increase of the exchange rate means appreciation of the local currency.

I next examine the model dynamics with the baseline monetary policy reaction function. Figure 4 plots the impulse response functions to a one standard deviation policy volatility shock. We can observe that an increase in policy volatility leads to a rise in the current



X-axis: Quarters. Y-axis: Values in percent.

Figure 4. Monetary policy uncertainty shock: Baseline policy rule

account, a drop in the output growth, an increase in inflation and an increase in the interest rate. We also observe that with the baseline monetary policy rule, the exchange rate depreciates after an increase in policy volatility. Therefore, the model replicates the empirical results documented in Section 2.

In the model, there are two mechanisms through which policy volatility shocks affect the current account. The first effect is the household's precautionary savings behaviour. Faced with higher uncertainty, the household cuts consumption and supplies more labor, building up a buffer stock. These savings are channeled abroad, increasing the holdings of foreign assets. We can observe this gradual accumulation of external assets in Figure 4. The second effect is the precautionary pricing behaviour of the firms. In the presence of nominal rigidities and a Dixit-Stiglitz consumption aggregator, firms' marginal profit function is convex. Therefore, increased policy volatility leads the firms to set higher prices and higher markups over marginal costs.[8] As a result, the terms of trade (ratio of export prices to import prices expressed in the domestic currency) improves. With the baseline parameterization, this rise in the terms of trade yields an improvement in the trade balance and the current account. The conditional comovement between the terms of trade and the trade balance generally depends on the substitutability of domestic and imported goods. In the sensitivity analysis, I consider this question in detail in the context of the presented model.

Does the model need both mechanisms to replicate the documented empirical findings? To resolve the question, I repeat the experiment of Fernandez-Villaverde et al. (2015) and eliminate the precautionary pricing channel. To that end, I replace the nonlinear pricing equations with linearized ones:[9]

$$\bar{\pi}_{H,t} = \beta E_t \bar{\pi}_{H,t+1} + \Lambda \left(\bar{M}C_t + \frac{(1-\pi_H)}{1-\theta\beta\pi_H^{\epsilon}} (\bar{Y}_t + \sigma \bar{C}_t) \right) + \frac{\Lambda(\pi_H - 1)}{1-\theta\beta\pi_H^{\epsilon}} \bar{f}_t \tag{4.1}$$

$$\bar{f}_t = (1-\theta\beta\pi_H^{\epsilon-1})(\bar{Y}_t - \sigma\bar{C}_t + \bar{M}C_t) + \theta\beta\pi_H^{\epsilon} E_t(\epsilon\bar{\pi}_{H,t+1} + \bar{f}_{t+1}) \tag{4.2}$$

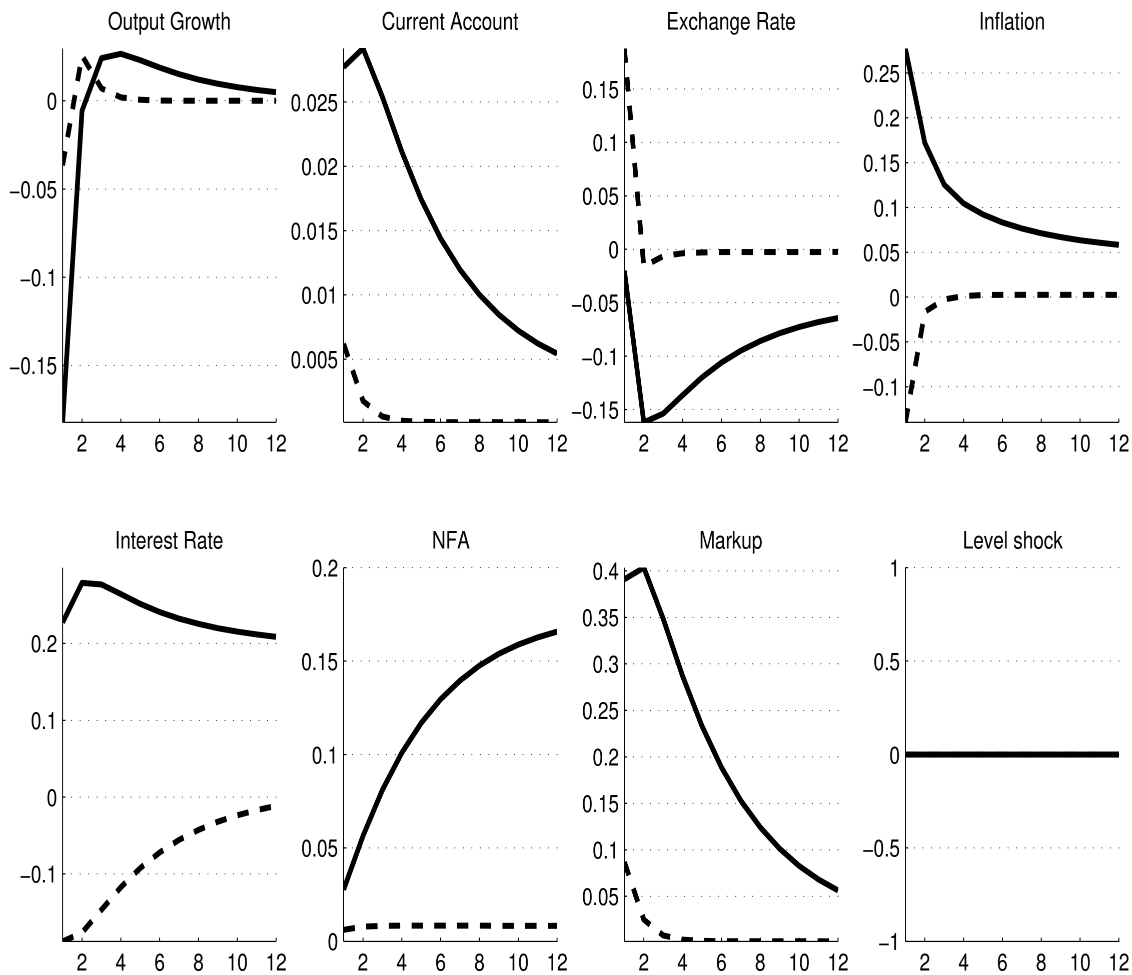
$$\Lambda = (1-\theta\pi_H^{\epsilon-1}) \frac{1-\theta\beta\pi_H^{\epsilon}}{\theta\pi_H^{\epsilon}}$$

The variables above are in log-deviations from corresponding steady-state values. Figure

[8] See Kimball (1989) for further details.

[9] The derivation of the Phillips curve under non-zero trend inflation in an open economy setup is similar to that of a closed economy. For the latter case, see Ascari and Ropele (2009).

5 displays the impulse responses for a one standard deviation policy volatility shock. The solid line plots the results for the baseline model. The dashed line shows the responses for the model with linear pricing equations. We observe that the current account improves,



Solid line: Baseline economy. Dashed line: Economy with linear pricing equations. X-axis: Quarters. Y-axis: Values in percent.

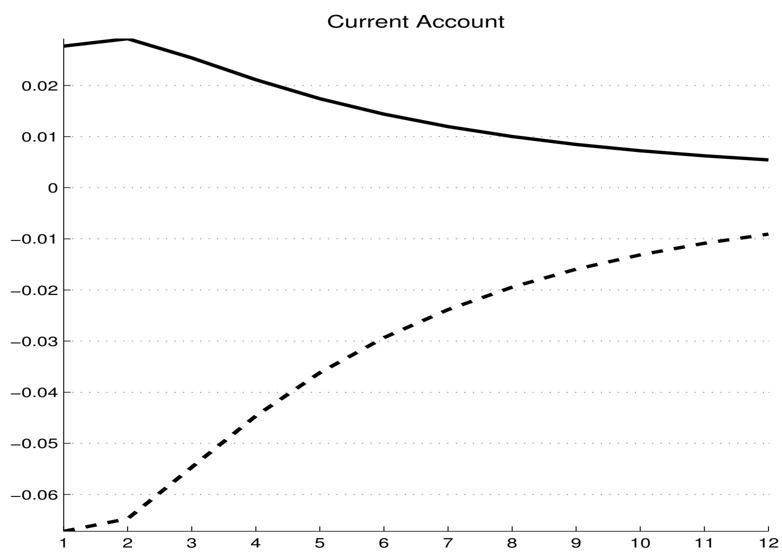
Figure 5. Monetary policy uncertainty shock: Linear versus nonlinear pricing

for the precautionary savings channel is still present. We also observe that price markups rise, even though the precautionary pricing behaviour of the firms is absent from the model. The intuition for this result goes as follows. An increase in policy uncertainty induces precautionary labor supply by the household. On the production side, the firms' marginal costs decrease. This decrease in the marginal cost, coupled with slowly-adjusting prices, cause a rise in price markups.

Finally, Figure 5 shows that the model with linear pricing equations fails to replicate the behaviour of several variables, like the interest rate, inflation and the exchange rate. Therefore, I conclude that the producers' precautionary pricing behavior is a crucial feature of the model.

4.2. Sensitivity analysis

In this subsection, I consider how robust the results of the model are to changes in the baseline calibration. I solve the model with different parameter values and find that for a broad range of constellations the results are broadly unchanged. However, I also find that

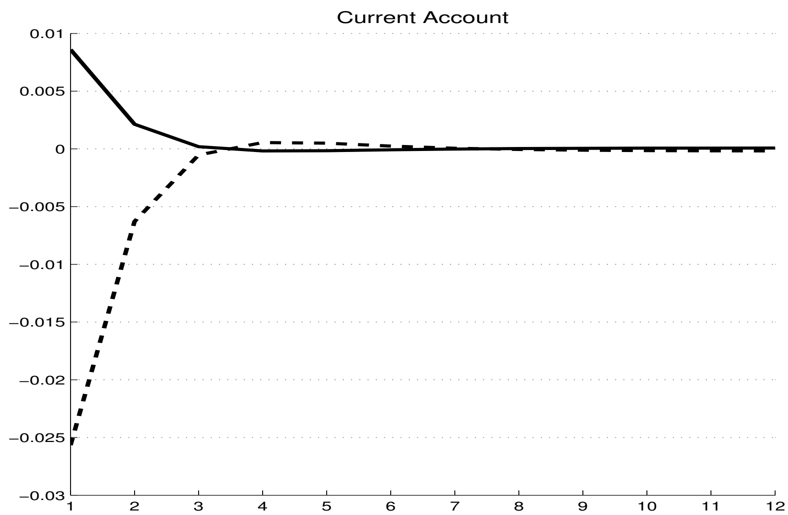


Solid line: Low elasticity of substitution. Dashed line: High elasticity of substitution. X-axis: Quarters. Y-axis: Values in percent.

Figure 6. Current account response to uncertainty shocks: High versus low elasticity of substitution

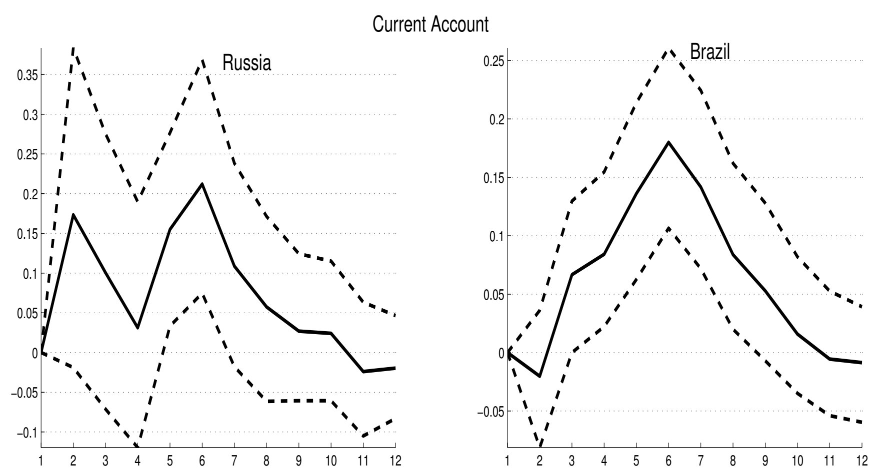
the response of the current account to increased policy volatility is sensitive to changes in the value of the elasticity of substitution between domestic and imported goods, η: for values of η larger than 1, the response of the current account is actually reversed. Figure 6 illustrates this fact. It shows the behaviour of the current account for the baseline calibration and for a one with higher elasticity of substitution where, as an example, I choose $\eta = 1.1$. As discussed in Tille (2001), the elasticity of substitution between home-produced and imported goods captures the sensitivity of the consumption allocation between domestic and foreign goods with respect to the terms of trade. It determines whether the increase in the revenues of domestic firms following a rise in the terms of trade is large enough to compensate for the consumption switching towards imported goods. If $\eta < 1$, domestic and imported goods are complements and a rise in the terms of trade increases the firms' revenues due to the growth in the purchasing power of the exports. As a result, the trade balance and the current account improve. If $\eta > 1$, domestic and imported goods are substitutes and a rise in the terms of trade worsens the current account. Therefore, the low substitutability between domestic and foreign goods is the key in generating the improvement in the current account documented in Section 2.

In the model, the value of η also determines the sign of the relationship between the terms of trade and the current account conditional on a monetary policy shock (level shock). When $\eta < 1$, a contractionary policy shock leads to a rise in the terms of trade and an improvement in the current account, while $\eta > 1$ implies a current account deterioration after a policy shock. Figure 7 displays this fact. It plots the response of the current account to a one standard deviation monetary policy shock for the baseline calibration and for a one with $\eta = 1.1$. This feature of the model is an additional guidance for choosing a value for η. For this purpose, I employ a SVAR model with the dataset from Section 2 to estimate the response of the current account to monetary policy shocks. As before, I use a recursive identification strategy placing the interest rate after the remaining macroeconomic aggregates. The SVAR model includes four lags and contains a constant term similar to the specification in Section 2. Figure 8 shows the response of the current account to a one



Solid line: Low elasticity of substitution. Dashed line: High elasticity of substitution. X-axis: Quarters. Y-axis: Values in percent.

Figure 7. Current account response to monetary policy shocks: High versus low elasticity of substitution



Solid line: median responses. Dashed lines: 16th and 84th percentiles. X-axis: Quarters, Y-axis: Values in percent.

Figure 8. Current account response to monetary policy shocks: SVAR model

standard deviation monetary policy shock for the Russian economy and Brazilian economy. We observe that in both countries, the current account improves following a contractionary monetary policy shock.[10] In sum, I find that under the benchmark calibration, both monetary policy shocks and volatility shocks induce an empirically sensible current account dynamics. This result confirms the plausibility of the baseline calibration of η.

4.3. Further results: the role of trend inflation

Having established the importance of the precautionary pricing channel, I further show that the latter is amplified with higher rates of trend inflation. To that end, I solve the model setting the steady-state inflation rate to zero. Figure 9 displays the corresponding impulse responses. As before, the solid line presents the baseline calibration. The dashed line shows the responses when the steady-state inflation rate is zero percent. We observe that the impact of policy volatility shocks is much weaker when the Central Bank targets a lower inflation rate. A simple example, which follows Born and Pfeifer (2014), explains the intuition for this result.

Consider the following partial equilibrium model. The firm seeks to maximize expected profits. It sets the price one period in advance facing uncertainty about the aggregate price level. The period profit function of the firm j is given by:

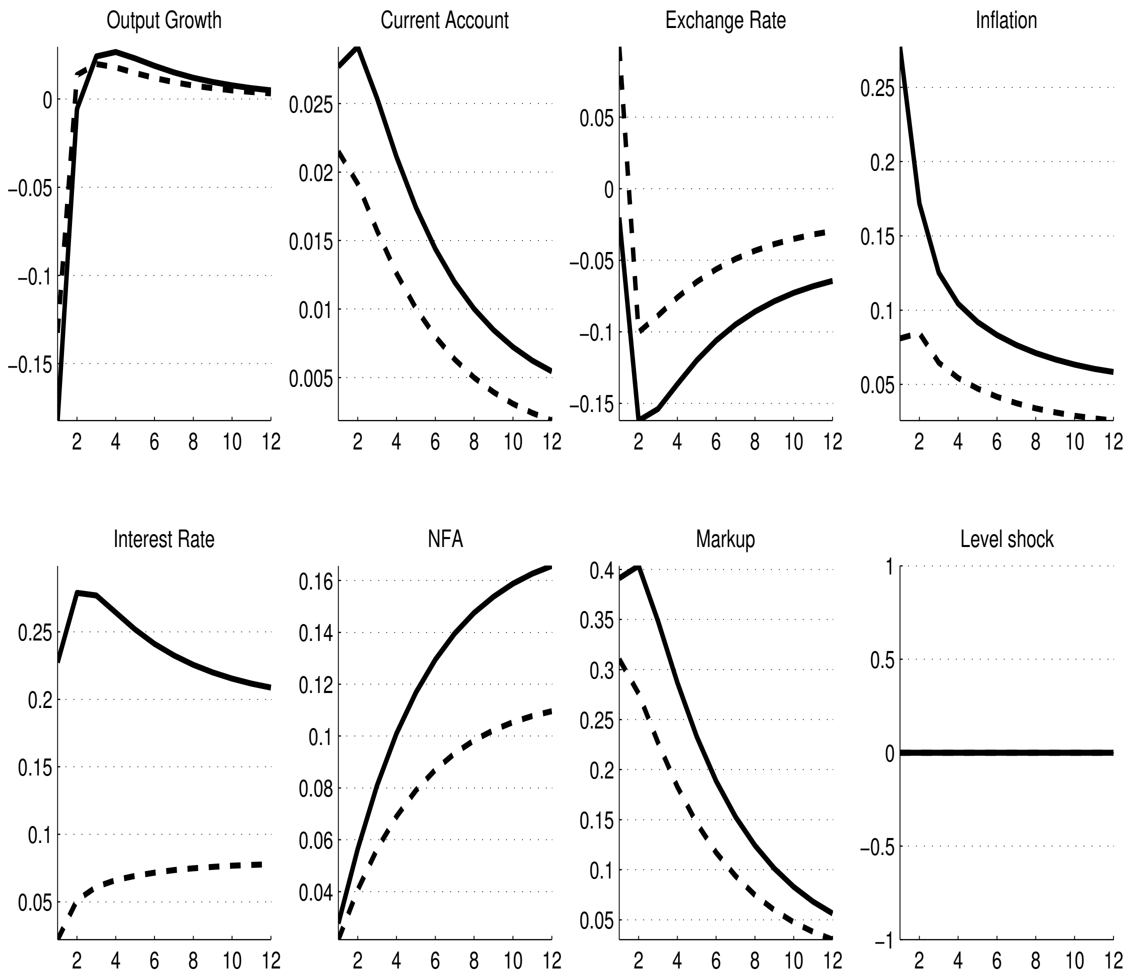
$$\Pi(j) = [\frac{P(j)}{P} - \mu](\frac{P(j)}{P})^{-\epsilon}Y \tag{4.3}$$

$$P = \pi P_{-1} + Z \tag{4.4}$$

Here Z is a simple discrete random variable which captures the uncertainty about the price level:

$$Z = \begin{cases} 0.1 & \text{with probability } 0.5 \\ -0.1 & \text{with probability } 0.5 \end{cases}$$

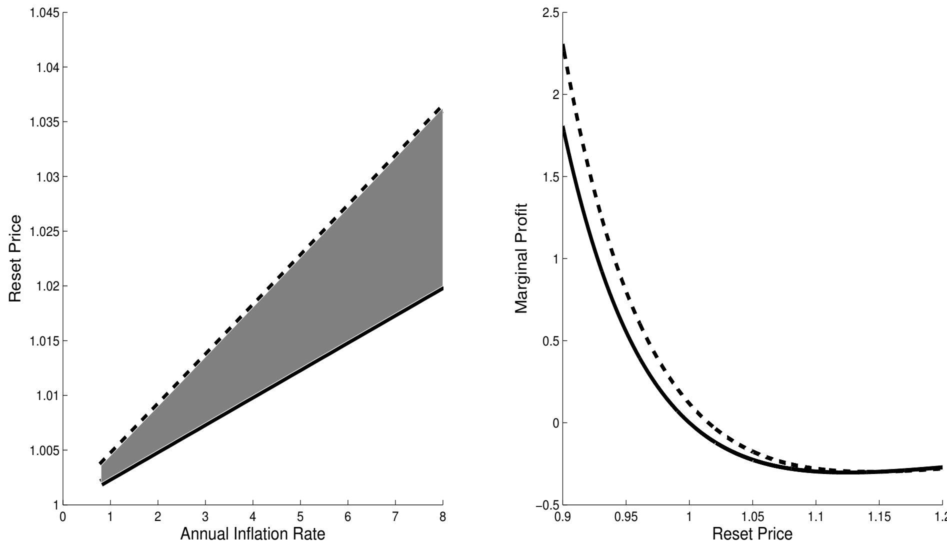
[10] I find that this result is robust with respect to the ordering of the interest rate in the model.



Solid line: Baseline economy. Dashed line: Economy with zero trend inflation. X-axis: Quarters, Y-axis: Values in percent.

Figure 9. Policy uncertainty shock: zero versus nonzero trend inflation

I assume that the price level has an average growth rate of π. The parameter μ is the inverse of the steady-state markup. The output Y is given exogenously. I use the baseline parameter values to solve the firm's problem. The left panel of Figure 10 shows, that the reset price is an increasing function of the inflation rate. The dashed line displays the



Left panel: Reset prices. Right panel: Marginal profit function

Figure 10. Price setting under uncertainty

reset price when the firm faces uncertainty about the future economic conditions. The solid line shows the optimal reset price without uncertainty. It has an upward sloping shape, as the firm front-loads the expected inflation into the currently reset price: in the absence of uncertainty the firm sets its price, $P_j = P$. Therefore, the shaded area between the lines shows the precautionary pricing behaviour of the firm. This behaviour stems from increased convexity of the marginal profit function. We can observe this fact in the right panel of Figure 10. The solid line plots the marginal profit function when the inflation rate is zero and the dashed line corresponds to the case of six percent inflation.

The overall impact of volatility shocks is much stronger in the baseline model, as the duration of price contracts is uncertain and on average longer than one period (quarter). The fact that higher rates of trend inflation amplify the precautionary pricing behavior of firms can partially rationalize the contrasting effects of uncertainty shocks on inflation in developed and emerging countries.

5. Conclusion

This paper shows that, in developing economies, increased monetary policy uncertainty leads to an improvement in the current account. Using data from Russia and Brazil, I estimate a SVAR model with stochastic volatility which allows to capture dynamic interactions between the endogenous variables and the time-varying policy volatility. In both countries, policy uncertainty shocks have statistically significant effects. The results are robust to various identification schemes that have been proposed in the model. I also estimate a SVAR model in which I use the EPU indexes. The baseline results are in agreement with the ones in the SV-SVAR model.

I also show that a standard open economy New-Keynesian model can replicate these results. The important features of the model are the inclusion of the exchange rate in the monetary policy reaction function and non-zero trend inflation. The specified policy rule ensures that the impulse responses produced by the model after a volatility shock match those estimated in the data. Non-zero trend inflation amplifies the effects of volatility shocks. Both features are common to many emerging countries.

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Appendix A. SV-SVAR Model

The SV-SVAR model is given by:

$$Y_t = A_0 + A_1 Y_{t-1} + ... + A_p Y_{t-p} + B_0 ln(M_t) + B_1 ln(M_{t-1}) + ... + B_q ln(M_{t-q}) + \epsilon_t \quad \text{(A1)}$$

$$\epsilon_t = V_t^{\frac{1}{2}} e_t \quad \text{(A2)}$$

$$V_t = C^{-1} M_t C^{-1'} \quad \text{(A3)}$$

Y_t is an $n \times 1$ vector of observed endogenous variables. $A_i,\ i = 0, ..., p$ and $B_j,\ j = 0, ..., q$ are $n \times n$ matrices of coefficients. ϵ_t are heteroskedastic unobservable shocks with variance covariance matrix V_t and e_t is a standard normal vector. C is a lower triangular matrix capturing contemporaneous relations among the reduced form shocks (level shocks):

$$C = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ c_{2,1} & 1 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ c_{n,1} & c_{n,2} & \cdots & 1 \end{pmatrix}$$

M_t is a diagonal matrix containing volatility of the shocks:

$$M_t = \begin{pmatrix} m_{1,t} & 0 & \cdots & 0 \\ 0 & m_{2,t} & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & m_{n,t} \end{pmatrix}$$

It evolves as follows:

$$ln(M_t) = F ln(M_{t-1}) + E^{\frac{1}{2}} u_t \quad \text{(A4)}$$

u_t is an $n \times 1$ standard normal vector. F and E are $n \times n$ diagonal matrices. The volatility of structural shocks follows an AR(1) process. Note, that the assumption on the structure of E allows us to interpret a change in an element of M_t as a shock to the volatility of a particular structural (level) shock.

This framework has several advantages. After identifying underlying structural shocks (through imposing restrictions on the matrix C), it allows the volatility of a structural shock to directly affects the endogenous variables. Therefore, the setup provides results directly comparable to those of a general equilibrium model with time-varying volatility of structural shocks.

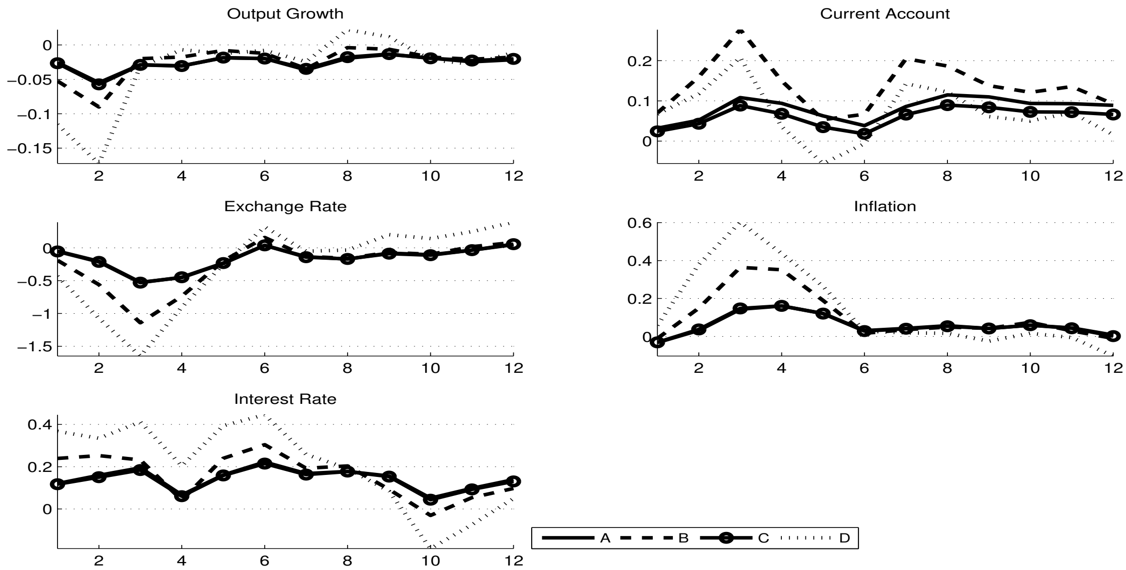
The model is estimated using a Gibbs sampling algorithm. It consists of the following steps:

1. Conditional on a draw for M_t and C, draw from the conditional distribution of $[A_i \; B_j]$ using the multi-move algorithm proposed in Carter and Kohn (1994).
2. Conditional on a draw for M_t and $[A_i \; B_i]$, simulate the elements of the matrix C. Next, conditional on a draw for M_t, F and E can be simulated using familiar results for linear regressions.
3. Conditional on $[A_i \; B_j]$, C, F and E, simulate the stochastic volatilities by applying the univariate algorithm of Jacquier et al. (1994) to each element of e_t.

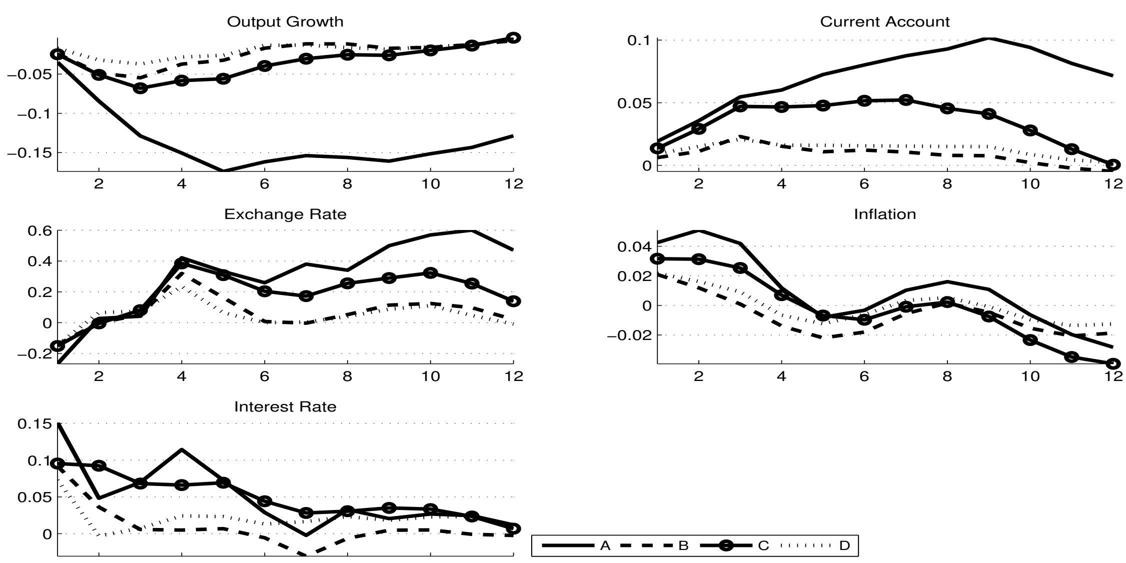
I run the above Gibbs sampler for 250000 replications, with 200000 burn-in replications discarded and 50000 replications retained.

Appendix B. Robustness analysis: SV-SVAR model

Russia



Brazil

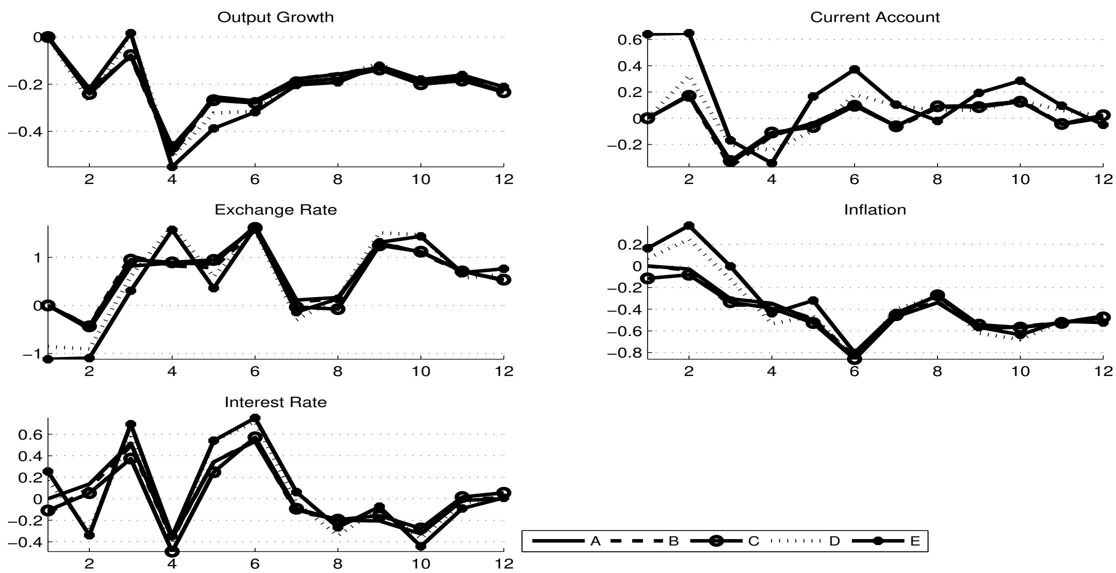


A,B,C and D are the median responses when the interest rate runs from the fourth to the first position, respectively

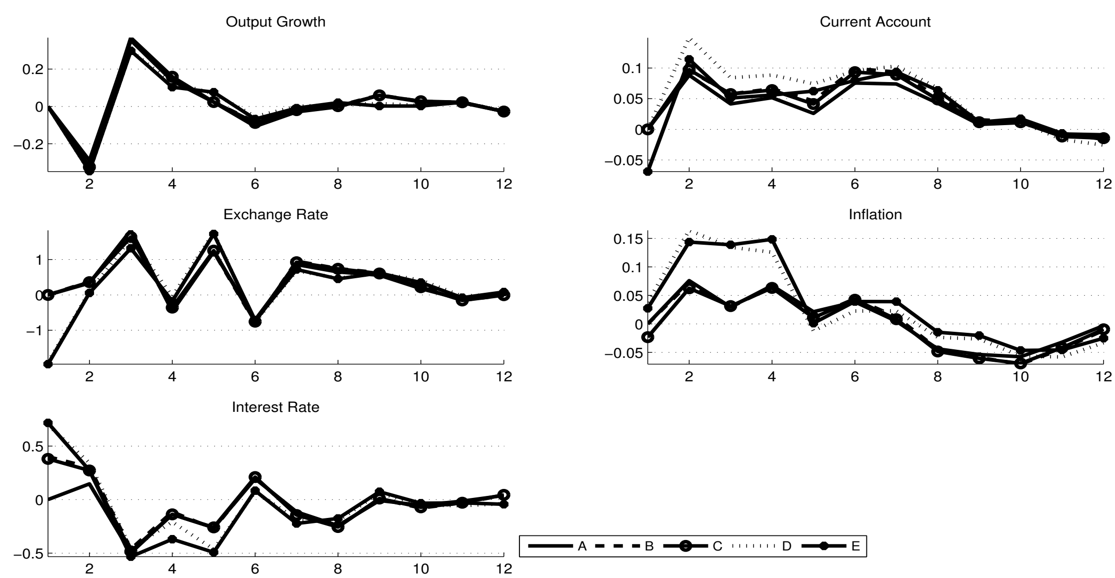
Figure 11. Alternative Cholesky orderings in the SV-SVAR model

Appendix C. Robustness analysis: SVAR model

Russia



Brazil



A,B,C,D and E are the median responses when the EPU index runs from the fifth to the first position, respectively

Figure 12. Alternative Cholesky orderings in the SVAR model

Appendix D. Equilibrium Conditions

Households

$$\lambda_t = \beta E_t \lambda_{t+1} \frac{R_{H,t}}{\pi_{t+1}} \tag{D1}$$

$$\lambda_t(1 + \varphi(b_{F,t} - b_F)) = \beta E_t \lambda_{t+1} \frac{R_{F,t}\Delta RER_{t+1}}{\pi_{F,t+1}} \tag{D2}$$

$$\lambda_t \nu_t = w_t \tag{D3}$$

ν_t is the marginal disutility of labor, $b_{F,t}$ is the real holdings of foreign bonds, $b_{F,t} = \frac{B_{F,t}S_t}{P_t}$, ΔRER_{t+1} is the change in real exchange rate, $\pi_{F,t}$ is the foreign inflation rate.

Firms

$$MC_t = \frac{w_t}{\hat{P}_{H,t}} \tag{D4}$$

$$X_{1,t} = \frac{\epsilon}{\epsilon - 1} \lambda_t Y_t MC_t + \beta\theta E_t \pi^{\epsilon}_{H,t+1} X_{1,t+1} \tag{D5}$$

$$X_{2,t} = \lambda_t Y_t + \beta\theta E_t \pi^{\epsilon-1}_{H,t+1} X_{2,t+1} \tag{D6}$$

$$(1-\theta)\left(\frac{X_{1,t}}{X_{2,t}}\right)^{1-\epsilon} + \theta\pi^{\epsilon-1}_{H,t} = 1 \tag{D7}$$

$$\Omega_t = (1-\theta)\left(\frac{X_{1,t}}{X_{2,t}}\right)^{-\epsilon} + \theta\pi^{\epsilon}_{H,t}\Omega_{t-1} \tag{D8}$$

$$(1-\alpha)\hat{P}^{1-\eta}_{H,t} + \alpha RER^{1-\eta}_t = 1 \tag{D9}$$

$$\pi_t = \frac{\hat{P}_{H,t-1}}{\hat{P}_H}\pi_{H,t} \tag{D10}$$

$$\Omega_t = \int_0^1 (\frac{P_{H,t}(j)}{P_{H,t}})^{-\epsilon} dj \tag{D11}$$

Ω_t is the resource cost induced by the inefficient price dispersion (Schmitt-Grohe and Uribe (2005)).

Monetary policy

$$R_{H,t} = R_{H,t-1}^{\rho_R} R_H^{1-\rho_R} [\left(\frac{\pi_t}{\pi}\right)^{\mu_\pi} \left(\frac{Y_t}{Y}\right)^{\mu_Y} \left(\frac{RER_t}{RER}\right)^{\mu_{RER}}]^{1-\rho_R} e^{\zeta_t} \tag{D12}$$

Aggregation and equilibrium

$$Y_t = (1-\alpha)\hat{P}_{H,t}^{-\eta} C_t + \alpha \left(\frac{\hat{P}_{H,t}}{RER_t}\right)^{-\eta} C_{F,t} \tag{D13}$$

$$Y_t \Omega_t = N_t \tag{D14}$$

$$\hat{P}_{H,t} Y_t - \frac{\varphi}{2}\left(\frac{B_{F,t} S_t}{P_t} - b_F\right)^2 = C_t + \frac{B_{F,t} S_t}{P_t} - \frac{B_{F,t-1} S_t R_{F,t-1}}{P_t} \tag{D15}$$

The current account is given by:

$$CA_t = TB_t + (R_{F,t-1} - 1)\frac{b_{F,t-1}\Delta RER_t}{\pi_{F,t}} \tag{D16}$$

$$TB_t = \hat{P}_{H,t} Y_t - C_t - \frac{\varphi}{2}\left(b_{F,t} - b_F\right)^2, \tag{D17}$$

where TB_t is the trade balance

Exogenous processes

$$\zeta_t = \rho_\zeta \zeta_{t-1} + e^{\sigma_{\zeta,t}} \omega_\zeta \varepsilon_{\zeta,t} \tag{D18}$$

$$\sigma_{\zeta,t} = \rho_\sigma \sigma_{\zeta,t} + \omega_\sigma \varepsilon_{\sigma,t} \tag{D19}$$